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TRANSACTIONS.

I.—The Nemertines of Millport and its Vicinity. By J. Stephenson, M.B., D.Sc. (Lond.); Major, Indian Medical Service; Professor of Biology in the Government College, Lahore. *Communicated by* Professor D'Arcy W. Thompson, C.B. (With One Plate.)

(MS. received July 4, 1910. Read November 21, 1910. Issued separately May 16, 1911.)

THE NEMERTINES OF MILLPORT AND ITS VICINITY.

The present communication deals with the Nemertines of Millport and its vicinity, the study of which occupied part of the time I spent at the Millport Biological Station during May and June 1909. The material was not completely worked out during my stay there, and most of the section-cutting was left till after my return to India. I wish to acknowledge here the uniform courtesy and kindness which I received from Mr R. Elmhirst, the Superintendent of the Station, to whom my thanks are due for the readiness with which he placed the resources of the institution at my disposal, and for help in other ways.

The number of species examined was twelve; this list is probably fairly complete as regards the Millport littoral forms, though I have little doubt that other species will be found to occur at greater depths.

The results which I believe have been attained may be summarised as follows:—

(1) Of the forms examined, two—an *Amphiporus* and a *Micrura*—appear to be new; their descriptions are given at length.

(2) Not less interesting has been the working over of certain species already fairly well known. I have not, of course, given full descriptions of these, but have contented myself with drawing attention to variations, which are sometimes marked, between my observations and the accounts of previous writers; and in a few cases I have been able to add facts which have escaped previous record.

(3) It is in a consideration of the variations just alluded to that the chief value of the work may be found to lie. The great variability of the class is evidenced in the first place by my own observations; many of the forms examined are very common, and a large number of specimens passed under my investigation. In the second place,

and even more strikingly, it is brought out by comparisons with the descriptions of those who have worked in other localities.

The authors whose works I have used for the purpose of comparison are MacIntosh (10), Joubin (7, 8), and Bürger (3, 5). MacIntosh's monograph (1873), with its valuable coloured plates, represents the chief attempt at an exhaustive account of the Nemertine fauna of Great Britain; Joubin's works (1890–1894), though without the same wealth of illustration, represent a similar undertaking for the coasts of France; Bürger's great monograph (1895) describes in detail the rich Nemertine fauna of Naples, with the aid of a beautiful series of plates, and more recently (1904) the same author has given in the *Tierreich* a general systematic account of the whole class.

It would, of course, have been better if a larger number of authors could have been used for purposes of comparison, and especially if the original descriptions of the several species could have been utilised for this purpose; but my recent stay in England, and, with it, my access to zoological literature, was unfortunately of short duration. I believe, nevertheless, that, though thus incomplete, the comparisons I have been able to make between the various species, as met with by myself and by previous writers respectively, are not without value and interest.

The variability of Nemertines as a class has long been known as regards colour, and in specific diagnoses the colour, though recognised as one of the principal points requiring description, is usually stated in wide terms.

It seems to me, however, that not only colour, but also other characters commonly used for purposes of specific distinction, are variable in a high degree. Thus this appears to be the case with regard to (*a*) the shape of the head (compare below, under *Lineus longissimus*, *L. ruber*, *Prostoma candidum*); (*b*) the degree in which the head is marked off from the body (*Lineus longissimus*); (*c*) the length of the specimens (the Millport examples of *Prostoma candidum* and *Emplectonema neesii* as compared with MacIntosh's specimens from the East Coast); (*d*) the number and arrangement of the eyes (see the comparison of the several authors' descriptions of *Lineus longissimus*, *Amphiporus pulcher*, and *Emplectonema gracile* given below, and compare the Millport specimens of *Amphiporus lactifloreus* and also, as regards size of eyes, *Prostoma candidum* with Bürger's descriptions); (*e*) the cephalic grooves (compare the descriptions of *Amphiporus lactifloreus* and *A. pulcher* here given with those of Joubin); (*f*) the arrangement of the musculature (Millport and Naples specimens of *Tubulanus annulatus*).

Two variations remain, which seem to demand more than mere mention. The first of these concerns (*g*) the shape of the basis of the stylet. This feature one would naturally be inclined to look on as a definite morphological character, capable, if anything were so, of affording a criterion of specific distinction. Thus Joubin (9) writes concerning it: "Il peut-être plus ou moins long, étroit ou renflé, pourvu d'ailerons latéraux ou presque carré; tous les caractères sont utilisés dans la détermination des espèces." The author who most often describes this structure in species possessing it is Bürger, and it is somewhat surprising to find that in most cases (*Amphiporus lacti-*

floreus, *A. pulcher*, *Prostoma candidum*, *Oerstedia dorsalis*) the Millport specimens show a wide divergence from the Naples forms. It is curious, too, that one particular difference repeats itself in all these cases—the Naples forms show a marked constriction about the middle of the basis, which is scarcely to be observed at all in the same species as found at Millport. In the case of *Amphiporus lactifloreus* the shape varies even among the Millport specimens.

Attention may here be called to the fact that OXNER (12) has also found the shape of the basis to be variable in *Prosorochmus delagei*, a new species described by him. He says: "La forme et les dimensions du socle peuvent subir de nombreuses variations. Cette variation est un trait caracteristique pour *P. delagei.*" The figure shows that the basis may either present a constriction or not, that its posterior end may be either wider or narrower than the anterior end, and that its size may vary, both relatively to the size of the stylet, and also absolutely. He, however, supposes, as we have seen, that this variability is a special feature of this particular form.

The fact that BÜRGER in different works gives two different shapes for the basis of the stylet in *Prostoma flavidum* is presumably also to be explained by the variability of this structure. In the Naples monograph, the figure shows it as somewhat dumbbell-shaped—that is, with rounded ends of equal size, and a constriction in the middle; in the *Tierreich*, however, it is described as "Der kegelförmige, kaum in der mitte eingeschnürte Sockel."

Lastly, (*h*) the number of proboscis nerves furnishes an example of another definite morphological character which might have been supposed to be constant and capable of furnishing a criterion of specific distinction. Yet *Amphiporus pulcher* is stated by BÜRGER in the *Tierreich* to possess ten proboscis nerves, while the Millport specimens examined for this character showed twelve.

The importance of a recognition of the variability of the above-mentioned characters lies in the fact that they are among those which are most frequently used for purposes of diagnosis. With regard to the shape of the head, for example, the details of which are used in many genera as specific distinctions, and in some cases take the chief, or at least a leading part, among the criteria of diagnosis, one constantly meets, combined in various ways, such expressions as spoon-shaped, lancet-shaped, egg-shaped; marked off, or not marked off from the body; wider than, slightly wider than, or not wider than the body.

Consider for a moment such specific diagnoses as these (*Tierreich*)—(i.) *Prostoma vermicularis* (Quatr.): "Vorderende verbreitert, Hinterende etwas verjüngt. Kopf spatelförmig, nicht vom Rumpf abgesetzt. Mit 4 kleinen Augen, die im Rechteck stehen. L. 12–15, Br. kaum 1 mm."*

(ii.) *Prostoma flavidum* (Ehrbg.): "Kopf vorn abgerundet, spatelförmig, nicht vom Rumpf abgesetzt. Rosenfarben, Seitenränder durchscheinend. Mit 4 einfachen, sehr kleinen Augen, die im Rechteck stehen. Angriffsstilett ein wenig länger als der

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* *P. vermicularis* is divided, certainly, into three sub-species, which are distinguished among themselves by various markings or the absence of them. The above, however, constitutes the whole of the specific diagnosis.

kegelförmige, kaum in der mitte eingeschnürte Sockel; beide schlank. Reservestilettaschen mit je 3 Reservestiletten. L. etwa 13, Br. 0·75 mm."

Seeing that no particulars as to the stylet or its basis are given in the case of *P. vermicularis*, when allowance is made for slight variation of the shape of the head, length, etc., does any tangible difference remain?

Or, again—(i.) *Cephalothrix rufifrons* (Johnst.): "Weisslich. Mit 2 kleinen rotblauen Pigmentflecken an der kopfspitze. L. 30–40, Br. 0·5 mm." (ii.) *Cephalothrix bipunctata* (Bürg.): "Ockergelb, Kopf heller. Dicht vor dem Gehirn 2 kleine schwarze, seitliche Pigmentflecke. L. 60–100, Br. 1 mm."

I have considered a similar case at some length below; but again, in such cases as this, when necessary allowances are made, does anything remain?

It will, I think, be agreed that the present observations tend to show the inadequacy of many of the specific characters in use, and the need for new ones. It seems probable that such will have to be sought for in the details of internal anatomy, rather than, as has been the case with most of the old ones, among the external features. That this will make the description and identification of Nemertine species a more difficult matter than has hitherto been the case cannot be doubted. One has only to compare, for example, the laboriousness of the task of description of Enchytræid or Tubificid species, where every identification requires a complete series of sections.

(4) The fourth result which I believe has been reached is the union of two species of *Cephalothrix* into one, as just mentioned. I have considered this particular case in some detail, since I believe that it is typical of what will have to be done in the future in a number of similar cases. I have also, in another place, given reasons which seem to me to go far towards establishing the necessity for a similar treatment of two species of *Prostoma*. My observations also, as stated below, support the unification by JOUBIN and by BÜRGER of the two species *Lineus gesserensis* and *L. sanguineus*, considered by MACINTOSH as distinct. It seems to me to be beyond doubt that further work on similar lines would have similar results in other species also.

(5) Finally, I may mention here the observations on the physiology of the circulation in *Cephalothrix linearis*. In view of the paucity of such physiological observations in this class they appear to be of interest.

The nomenclature adopted throughout is that of the *Tierreich*.

Tubulanus annulatus (*Carinella annulata*) (Montagu).

Specimens are not common at Millport; they were found under stones near low-water mark at Balloch, and were dredged in 15 fathoms off Ascog Bank.

Length 3½–7 inches (85–170 mm.); breadth 1 mm., broadest at the anterior end, tapering gradually to a fine point posteriorly. These figures for the length of this animal are practically those given by BÜRGER in the *Tierreich*; they are larger than those for specimens found at Naples (3) (8–10 cm.), though much less than those given by

MacIntosh (7 - 30 inches) and especially Joubin (7). The latter speaks of specimens measuring 80 cm., and sometimes 1·5 metres, and quotes Quatrefages as giving 2 metres.

The striking *coloration* has been described in detail by previous writers. Briefly, the general colour of the body varies from a rich red to a vandyke brown; there is a white mid-dorsal stripe, a pair of similar lateral stripes, and a number of white transverse stripes which encircle the whole body; the mid-dorsal stripe does not reach the anterior end of the body, but leaves a red "frontal patch" (*Stirnfeld*), undivided at the anterior tip.

Points which have either not received mention by previous observers, or in which my specimens, which were generally of a brilliant brown colour, differ from theirs, are as follow:—

(i.) The frontal patch was always less brilliant, or lighter in tint, than the rest of the coloured surface of the dorsum. This was evidently not the case in Bürger's specimens; the frontal patch is stated to have the same appearance as the general coloured surface of the body, and it is so shown in the plate.

(ii.) The ventral surface was of a lighter brown than the dorsal; it was sometimes white in the greater part of its extent, becoming light brown posteriorly, though here still much paler than the dorsum.

(iii.) The mid-dorsal and lateral white stripes consisted of a dull white ground with a longitudinal stripe of a more intense opaque white down the middle of each; the transverse stripes also had mostly a similar appearance.

(iv.) The genital apertures appeared as a series of whitish spots, dorso-laterally placed, beginning some distance behind the head, at first in a single row on each side, but more numerous posteriorly.

The *cephalic grooves* slightly notch the lateral borders of the head a little in front of the level of the mouth: thence followed inwards on the dorsal surface they have a slightly sinuous course, at first convex forwards, then concave, ending near the median line; on the ventral surface they are continued directly inwards from the lateral notch, almost meeting each other in the middle line.

The *cerebral organs* are present in this genus as mere grooves, not as canals or sacs. MacIntosh, however, in the general account of the cephalic sacs of the Anopla (10), says: "Just in front of the external border of the curved dorsal groove on the snout of *Carinella annulata* is an ovoid body apparently homologous with the foregoing, but I have not yet been able to trace its anatomy, on account of the opacity of the cutaneous tissues in this animal." In his description of this species he says: "There is a curved streak in the bend of each ciliated furrow on the dorsum, perhaps in connection with the cephalic sac." The corresponding figure (10, pl. xvii., fig. 24) shows an ovoid structure of fair size in the bend of the groove on the dorsal surface, near the lateral margin, a little in front of the level of the mouth. Bürger states (5) that in this species, "die cerebral Organe sind kugelige Gebilde."

The true state of affairs appears to be as follows: On the dorsal surface of the head, just in front of the cephalic grooves and in their concavity, there is to be seen a circular area, rather indefinite in its limits, which is of a lighter brown than the surrounding parts; with an ordinary microscope nothing further is to be made out, but with a binocular it appears that this area is slightly depressed below the general surface (figs. 1, 2). It is apparently this area which corresponds to the oval outline in MacIntosh's figure.

Sections show that there is no cerebral organ of the usual type—that is, that there are no canals or sacs; the depressed areas just mentioned are, however, recognisable as areas of the epidermis with cells and ciliation like those of the cephalic grooves; the areas are sunk below the general surface, and, owing probably to contraction in killing and fixing, their margins are much better defined than in life and project inwards towards the centre of the area (fig. 3).

The species, therefore, does not form an exception—at least not such a marked exception as would be inferred from previous descriptions—to the general rule for the genus in regard to the cerebral organs.

A well-developed *inner* (*splanchnic*) *circular muscular layer* is characteristic of the family Tubulanidæ (Carinellidæ); but this particular species is stated to form an exception to the rule. Thus Bürger (5) writes: "Die innere Ringmuskelschicht ist ziemlich schwach entwickelt, nur das dorsale muskelfaserkreuz ist vorhanden." My specimens must differ markedly from those on which this statement is founded; they agree with others of the family in having a well-developed inner circular layer, while, on the other hand, the dorsal crossing of the fibres (as represented, *e.g.*, for *Tubulanus superbus*, 5, p. 3, fig. 1; 1, p. 169, fig. viii.) is not recognisable.

A feature, the description of which I have not met with elsewhere, is the character of the *epithelial lining* in the most *anterior part of the proboscis.* Almost immediately behind the spot where the proboscis becomes free within its sheath the lining epithelium of its dorsal, and somewhat less markedly of its ventral, wall is formed by a compact mass of tall and very narrow cells. This patch, elongated transversely to a semicircle which comprises the dorsal half of the circumference of the proboscis, is narrow antero-posteriorly, so that in a longitudinal section it appears as a cushion-like or fan-like projection (figs. 4, 5). The cells of which it is composed stain deeply, and are of a very different appearance from the much lighter, more loosely arranged, and more ragged-looking cells which succeed them; two layers of nuclei are visible, one near the base, the other at about the middle of the 'cushion.' The appearances are similar, but the cells are not so high, on the ventral wall of the tube (fig. 4).

Cephalothrix linearis (J. Rathke).

Under the name *Cephalothrix linearis*, MacIntosh has united certain forms which other writers have separated under the names *C. linearis* and *C. rufifrons* (or *bioculata*). It is a question how far the Millport specimens bear out this separation.

MacIntosh's description (10) of *C. linearis* gives the length as three to four inches. The colour is stated to be variable; the animals are said to be in general of a pale cream tint, which is sometimes diversified by a yellowish patch on the snout and a yellowish tinge in the œsophageal region; or the pigment—yellowish, orange, or reddish—of the snout may be increased towards its tip, the œsophageal region being also in such cases of a reddish orange colour. There are said to be no eyes; and the red pigment at the anterior end is stated to be of no specific value. In the specimen represented in this author's pl. iv. fig. 5 (the posterior part of the specimen being green), the reddish pigment of the snout is shown as extending farther back laterally than in the middle line. Nothing is said in the text as to the aggregation of the pigment in granules.

Joubin (8) describes separately the forms with red anterior tip as *C. bioculata.* He states that in these the head is red, the red colour increasing in depth towards the tip of the snout; the pigment occurs in the form of minute granules; the two eyes, constituted perhaps by the agglomeration of minute ocelli, are of considerable size, on the extreme margin, and placed among the red pigment grains. The same author (7) speaks of the presence of two "oculiform points," which may or may not be capable of resolution into a number of small eyes, as the feature which distinguishes *C. bioculata* from *C. linearis*; *C. bioculata* is also said to be shorter than *C. linearis.*

Bürger (3), also describing *C. linearis* and *C. bioculata* separately, states that the single specimen of *C. linearis* met with at Naples had no eyes, nor pigment of any kind in the head. *C. bioculata* is said to be three to four cm. long, and to be colourless or whitish with the exception of two very small bright red spots at the end of the head; with weak magnification, there is visible at the anterior border of the head a small black pigment spot, which, however, may not be an eye; and immediately behind this are two larger, sharply defined, round reddish spots in which cœrulean-blue pigment is interspersed. It is difficult to see much of this in the corresponding figure, which, being on a small scale, does not even show the separation of the red areas of the two sides. Bürger compares his specimens of *C. bioculata* with those of MacIntosh's specimens (of *C. linearis*) which possessed the red pigment; he considers the two to be the same form, though he recognises that MacIntosh's specimens showed a more diffuse distribution of the pigment than those found by him at Naples.

In the *Tierreich* (5), Bürger defines *C. linearis* as being white, often with a yellow tinge, as having no pigment spots, and as being 100–150 mm. in length. *C. rufifrons* (= *bioculata*), on the other hand, is whitish, with two small red-blue pigment spots at the end of the head, and is 30–40 mm. in length.

The forms about to be described are common at Millport, and may often be found under stones between tide levels. When extended they are filiform, and from two to three inches (50–75 mm.) in length; the proboscidean apparatus extends about one-third to two-fifths of the length of the animal; the distance between brain and mouth is about three times that between anterior end and brain. Since the union of these forms into one, or their separation into two, species depends mainly on the facts of pigmentation, a full account of this character and its variations will be given.

The general colour of most of my specimens was yellow; in some cases it was a pale orange, deeper in tint in the anterior part of the body. In all cases the anterior tip of the head was brilliantly coloured, either a bright orange or a bright red; this area of colour was not definitely limited, but was smaller in extent than that shown in MacIntosh's pl. iv., fig. 5. The red pigment appeared to be partly diffuse and partly or mostly granular, and the individual grains had a bluish tinge; two larger aggregations, symmetrically placed one on each side, near the anterior end and near, but not at, the margin of the body, resembled two eyes; a somewhat smaller and more anteriorly placed median spot was also sometimes distinguishable; and, by focussing, it was found in one instance that the lateral spots were dorsal, the median spot, however, ventral.

In addition to the above general account, two observations may be given in detail; both the following specimens were obtained from Fairlie, on the mainland.

(*a*) In one of these specimens the pigment in the head consisted of (i.) an orange pigment, diffused (*i.e.* not aggregated into visible granules) over the anterior end of the head, continuous in area, not as two patches; (ii.) a granular pinkish-red, with a slight blue tinge, at the tip of the head, apparently between the epithelium and the deeper layers, much more limited in extent than the orange; (iii.) two large dark spots, of a dusky purple colour, one on each side near the anterior tip, but no median spot.

(*b*) The second specimen contained ripe ova; the whole anterior part of the body was more orange than usual, and this was especially marked over the anterior part of the head and over the œsophageal region. In this case the distinctive pigment at the anterior tip was mainly concentrated into two red patches, with an especially brilliant red spot in each; there were no blue eye-like spots at all. There were also over the general surface of the body, but not of the head, a large number of minute white specks.

It follows from the above descriptions taken together that forms are met with in colour from whitish through cream to yellow and pale orange; that the anterior end of the body is in many specimens more deeply pigmented than the rest; and that in a whole group of forms the extreme tip of the snout has a brilliant red or orange colour.

Again, in the specimens with red tip, the red colour may be more or less extensive and more or less definitely localised. MacIntosh evidently considers it as an intensification of the body-pigment, and shows it as of relatively considerable extent; Joubin also indicates that it is not delimited from the general red colour of the head; my own specimens show a more limited extent of brilliant red than MacIntosh's, but equally with his and Joubin's it is not sharply defined; while Bürger, on the other hand, finds two very small bright red spots.

Further, in these specimens with red tip, the pigment may be in part granular, and the granules may have a bluish tinge. Aggregations of these granules may be distinguishable to the number of two or sometimes three; such aggregations look like eyes, and may appear bluish-red, dusky purple, or even black. MacIntosh apparently did not meet with these forms.

MacIntosh gives the length of his specimens as three to four inches (approximately 75–100 mm.); Joubin gives 600 mm. as the maximum for *C. linearis*, and says that *C. bioculata* is shorter than *C. linearis*; Bürger makes *C. linearis* 100–150 mm., and *C. rufifrons* (= *bioculata*) only 30–40 mm.; my specimens were 50–75 mm., on the whole somewhat shorter than MacIntosh's and intermediate between Bürger's two forms.

If now it is decided to separate these forms into two species, this may conceivably be done either on the basis of the presence or absence of a red tip to the snout, or on the aggregation or otherwise of the bluish granules into eyelike masses. The presence of the first of these characters is the origin of the appellation *rufifrons*, the second of *bioculata*.

The latter of the indicated alternatives is the one chosen by Bürger in the *Tierreich*. The diagnosis of *C. linearis* runs: "Weiss öfters mit gelblichem Anfluge. Ohne Pigmentflecke. L. 100–150 (nach Joubin bis 600); Br. 0·5–1 mm." That of *C. rufifrons* is: "Weisslich. Mit 2 kleinen rot-blauen Pigmentflecken an der Kopfspitze. L. 30–40, Br. 0·5 mm."

On this it may be remarked that the reddish-blue spots are variable features, consisting as they do apparently of closer or looser aggregations of scattered granules. Their size seems to vary, and also their colour, the latter feature probably according to the closeness of the aggregation; their position, too, is not always the same, for while Joubin describes them as on the extreme margin, I have always found them a little distance within the margin; their number also varies—sometimes three, sometimes only two. Again, if this feature be adopted as the criterion, the Millport specimen (*b*) above (which for the rest comes nearest of any of my specimens to Bürger's Naples specimens of *C. bioculata* with two small bright red spots) would have to be excluded from *C. rufifrons* as showing no trace of a blue tinge; while all my others, though with a less concentrated pigmentation, would nevertheless be *C. rufifrons*.

Bürger himself gives us an example of the confusion which results from taking this character as a criterion. As we have seen, he considers his Naples specimens (*C. bioculata*, = *C. rufifrons* of the *Tierreich*) to be the same form as MacIntosh's specimens with red pigmentation. MacIntosh groups all his forms together as *C. linearis*, and accordingly we find in the *Tierreich*, as part of the synonymy of *C. rufifrons*, "*C. linearis* (part.) MacIntosh." It may, however, be inferred with certainty that MacIntosh's specimens had no red-blue pigment spots, since they could not possibly have escaped his observation if present (he states, indeed, that there are no eyes); yet this is the character which to Bürger is distinctive of *C. rufifrons*, under which he subsumes these specimens of MacIntosh's.

If the presence or absence of red-blue pigment spots fails as a criterion of distinction, much the same kind of objections seem to apply to the presence or absence of a red tip to the snout. The extent of pigmentation may be greater (MacIntosh) or less (Millport forms, Naples forms); it may be delimited in two patches (Bürger), or continuous in area and not sharply defined (other authors). MacIntosh's description seems to imply that he had had intermediate forms between the typical *linearis* and *rufifrons* forms before him, and he states that he does not consider the red pigmentation to be of specific import. Both he and Joubin evidently consider it to be an intensification of the general colour of the head.

The impression given by a consideration of all the above descriptions is, I think, that of a continuous series, somewhat as follows. In the first place, we have forms of a pale cream colour without any special pigment in the head; next, there may be a yellowish patch on the snout and a yellowish tinge in the œsophageal region; then the tip of the snout may show special pigmentation—a deeper yellow, orange, or red—but the pigment is here not apparently granular in form. Again, while the general colour of the body is yellow or orange, the whole anterior part may be deeper in tint, the head being red, and the anterior tip most brilliantly coloured of all, but there is no sharp limitation of the red area; the pigment is partly diffuse, but also partly granular. As the next stage in concentration, the red pigment may be mainly visible as two red patches, with, it may be, again a particularly brilliant red spot in each.

This condition may be reached without the appearance of any blue tinge. As a rule, however, a blue tinge makes its appearance already in specimens with a pigmentation more diffused than that last described; it may occur as a mere tinge in the red, or may give rise to the appearance of eye-spots by the aggregation of bluish-red pigment grains. Such spots may have a colour which, like that of the individual granules, may be described as bluish red, or a closer aggregation of the granules may result in a dusky purple or even a black. Of these 'eye-spots' there may be either two or three; if two, they are symmetrical, one on each side; the third, when present, is median and anterior.

The length of the Millport specimens, intermediate between the figures given by Bürger for his two forms *linearis* and *rufifrons*, also tends to obliterate the distinction between them.

For the above reasons, I believe that the names *rufifrons* and *bioculata* ought to disappear as specific appellations, and that the peculiarities to which these names refer constitute merely colour varieties of *C. linearis*.

On the Physiology of the Circulation in Cephalothrix linearis.

My observations on this subject are in the main confirmatory of those of MacIntosh on *Cephalothrix* (quoted below). In view of the little that is known concerning the physiology of the circulation in Nemertines, I may be permitted to call attention again to this form, in which the vascular phenomena appear to be particularly obvious.

Under these circumstances it may perhaps be useful first to bring together, as far as has been possible to me, what has been written on the subject of the circulation of Nemertines. How contradictory, as well as scanty, are the statements concerning the physiology, as distinct from the anatomy, of this system, will appear from the following references.

The most definite accounts are to be found in MacIntosh (**10**). With regard to the

Enopla generally, he says: "The course of the circulation, so far as observed, is as follows. Posteriorly a gentle contraction from behind forward drives the contained fluid along the great central vessel to the front, where it is forced through the anastomotic into the lateral vessels and the cephalic arch. Each lateral trunk swells with the wave, and the fluid then proceeds to the posterior end to enter the median, as before mentioned. In addition to the stream poured into the lateral trunks, another passes into the cephalic arch by the vessel on each side, and the counter-currents must meet and commingle, returning again during the diastole of the central vessel." The contraction of the lateral trunks in *Nemertes carcinophila* is stated to be very vigorous.

With regard to the Anopla, he states that " the current is driven by the contraction of the vessels now backward, now forward, so that it is rather a kind of oscillation. . . . The dorsal generally contracts from behind forward, and drives the corpuscular fluid, not only to the front, but also through the transverse branches into the lateral trunks. The latter propel their contents in both directions." And with regard to *Cephalothrix*, " in the living animal each lateral vessel contracts regularly and swiftly from before backwards, sending a wave of fluid towards its posterior end, at which the contraction ceases. A reversed movement by-and-by takes place, the contents being propelled towards the snout. . . . There appears to be little regularity or rhythm in the movement of the fluid in these vessels, both occasionally contracting from before backwards at the same time. Generally, however, the contractions are alternate."

Oudemans (11), who made a careful study of the circulatory system in a number of forms, seems to have worked entirely with preserved material, by the method of serial sections.

Joubin (8), says : " Les vaisseaux . . . . sont animés de contractions et de battements, mais il n'y a point de cœur distinct. Le sang progresse vers la tête dans les troncs latéraux, vers la queue dans le tronc médian." Speaking of *Tetrastemma flavidum*, he says : " Les vaisseaux sont remplis de sang rouge et font des ondulations colorées, saillantes sous la peau." The same author, in a subsequent work (9), says : "Le sang circule grâce à la contractilité des vaisseaux, car il n'y a aucun organe central de propulsion ; il suit une direction determinée ; vers la tête dans le vaisseau median, vers la région caudale dans les vaisseaux latéraux " (thus agreeing with MacIntosh, and reversing his previous statement). " Le sens contraire est indiqué par Vogt et Yung pour le *Tetrastemma flavidum.* Quand on observe à l'état vivant certaines espèces transparentes, on voit les ondes contractiles progresser lentement sur les vaisseaux à intervalles réguliers."

Bürger (2) says, with regard to the Anopla : "Das Blutgefässsystem wird von mit Muskeln ausgestalteten Stämmen gebildet, welche eine Flüssigkeit, die freie Zellkörper enthält, durch den Körper pulsiren lassen ;" but I cannot find any reference to the Enopla. I find nothing concerning the physiology of the circulation in the same author's great monograph (3), nor in his later contribution to Bronn's series (4) ; though Benham (1) says that, according to Bürger, "the blood, in Metanemertines, flows out of the dorsal, through the circular vessels, into the lateral ones, returning to the dorsal vessel at each end of the worm," which is practically MacIntosh's statement; but he adds that this is very unsatisfactory and uncertain.

Punnett, in his Addenda and Corrigenda to this volume of Lankester's Treatise (13), says that "in spite of what has often been written to the contrary, it is exceedingly probable that in most cases, if not all, the blood vessels are destitute of muscle fibrils; and that the blood is kept in circulation by the waves of contraction passing over the body-wall."

Finally Coe (6), in describing *Carinomella*, states that "shortly behind the nephridial region the lateral vessels acquire muscular walls and are strongly contracted at intervals." He does not describe vascular contractions in any other forms; and in the general section of his work, under "Histological Structure," after describing the muscular coat of the chief vessels, says: "The transverse vessels and many of the lacunæ are without muscular walls, and even where muscles occur, the circulation of the blood is dependent mainly on the movements of the body as a whole, and as a rule passes backward and forward irregularly in any of the vessels."

The circulation in the lateral vessels of *C. linearis* can be seen in specimens compressed under a coverslip. The phenomenon appears as a series of waves, passing along in the situation of the vessels, laterally to the alimentary canal. The walls of the vessels are not themselves visible, and the waves manifest themselves as the rapid passage of a lighter streak or patch along the body of the animal.

The rhythm is irregular. The waves pass in all cases through the greater part of the length of the animal, it may be from the region of the nerve ganglia anteriorly to the extreme posterior end. The passage of the waves was always rapid.

In direction the waves may be either postero-anterior or antero-posterior; and these usually alternate, with, it may be, a second's interval between the arrival of the wave at the head, and the starting thence of a wave in a posterior direction. The waves on the two sides may be almost synchronous; but I have observed a wave on one side only, quite unaccompanied by any indication of a wave on the opposite side.

The specimens were, as a rule, motionless during the observation of the phenomenon.

With regard to *Cephalothrix*, then, it seems allowable to conclude:—

(i.) That there is a definite circulation in the lateral vessels, occasioned by a series of contractile waves alternately postero-anterior and antero-posterior.

(ii.) That this is not due to contractions of the body-wall, nor to movements of the body as a whole.

(iii.) And that it would therefore seem necessary to assume the presence of muscular tissue in the walls of the vessels.

Emplectonema gracile (Johnst.) (= *Nemertes gracilis*).

Near low-water mark, under stones, Balloch. Not uncommon.

Length up to seven inches; proportionally very thin; not markedly pointed at the posterior end.

The general *colour* is brown, with sometimes a greenish tinge, especially towards and on the head; the green colour can sometimes, especially from the ventral surface, be seen to be due to the diverticula of the alimentary canal. In one specimen, the green became a distinct blue on the anterior part of the head. Sections show a blue granular deposit in the walls of the alimentary canal, especially in the anterior part of the body. The ventral surface is lighter in colour; the margins of the body are clearer; a thin stripe of a lighter tint in the middle line of the anterior part of the body is due to the proboscis cavity. The genital products may show as yellowish masses within the lighter margins of the body.

The *head* is somewhat circular in shape, with median anterior notch; it is broader than the succeeding part of the body, and is fairly well marked off. The *eyes* are numerous, and not usually distinctly arranged in two groups on each side. No *grooves* were to be seen in the living animal, though they are apparent in transverse sections of the head.

The *stylet* is very large, with a sabre curve, and is situated very near the anterior end of the body; the *basis* (v. fig. 6) is much elongated, at least twice as long as the stylet, and swollen at its proximal end. There are two reserve sacs; seven stylets were counted in each.

The condition as to *head-glands* and other *gland-cells* in the head, the *cerebral organs*, and position of the *mouth* are as given by Bürger (3, 5). The statement in the *Tierreich*, that "der Blinddarm reicht bis in die Nähe des Gehirns," is a little misleading; it is, as in *E. neesii*, two long anteriorly directed diverticula of the cæcum, one on each side, which nearly reach the brain, and the condition might have been described in terms identical with those used in the definition of the latter form.

The differences between the above description and the accounts of previous observers are, except perhaps with regard to the eyes, not considerable. Green or brownish (greyish, olive-) green appears to be the commonest colour; MacIntosh and Joubin have noted a bluish tinge. MacIntosh's plate does not show the head as being marked off from the body.

The eyes are stated (MacIntosh, Bürger) to be arranged in two or three groups on each side. MacIntosh adds that the middle group on each side is nearer the middle line of the head; his plate, on the other hand, does not show any marked division into groups, nor is the middle group, such as there is, any nearer the middle line than the anterior group—rather the reverse, in fact. Bürger (3) adds that the eyes are in rows in the anterior, massed together in the posterior group.

Emplectonema (*Nemertes*) *neesii* (Örst.).

Common, especially in the byssus of mussels, on the Keppel pier; also between tide levels.

Length two to four feet (considerably greater than the lengths found by previous observers); breadth 4 mm. Slow-moving: placed in a vessel of water, slowly uncoils and extends itself as a long strip round the sides of the vessel at the level of the surface of the water; the tail tends to curl in a corkscrew fashion.

Colour of the dorsal surface brown, with often a tinge of purple; on examination with a lens, the colour appears as a dark brown mottling on a lighter ground. Head slightly lighter in tint; under surface light greyish, with darker bands one on each side of the middle line; the intestine is seen on the ventral surface as a pale yellow line giving off branching diverticula.

Head not expanded, not marked off from the body; tail slightly tapering.

Cephalic grooves small, oblique, on the under surface of the head near the tip, approaching one another at their anterior ends.

Eyes very numerous, small, in two groups on each side, a more numerous anterior and less numerous posterior; on focussing, they appear some distance beneath the surface, and the examination of sections shows them to be beneath the epithelial layer.

The *head glands* are well developed, and there are also, as noted in the specific diagnosis in the *Tierreich*, a large number of subepithelial *gland-cells* in the head. It may be added that gland-cells extend continuously for some distance along the body, aggregated in two rows, one along each side; the masses are very conspicuous to the naked eye in a series of sections, since they stain deeply (with hæmatoxylin), and are of considerable size; they displace the longitudinal muscle layer, and impinge on or even surround the nerve cord. The gland-cells of the head, as they are traced backwards in serial sections, leave first the mid-dorsal area, then the mid-ventral, and so come to be aggregated in the two lateral rows described above.

The *cerebral organs* and the anterior *diverticula of the alimentary canal* agree with previous descriptions. I have not, however, seen any statement as to the number of *proboscis nerves*; there are definitely twelve in one of my specimens; but the number of nervous tracts differentiated in the nervous sheath perhaps varies, since in another specimen the nerves themselves appear to be less definite, and their number seems to be greater (fourteen or sixteen).

With regard to the coloration of this form, there is a general agreement in the descriptions to which I have been able to refer; and to these my specimens also conform. The descriptions of the cephalic grooves by MacIntosh and Joubin differ slightly, and the account given above accords rather with that of MacIntosh. The same may be said with regard to the eyes; Joubin figures them as aggregated on each side into a large group of curious shape, extending farther back than in the Scotch examples, and not separated into two groups on each side. The length of my specimens (2 to 4 feet) is to be compared with the figures given by MacIntosh (4 to 18 inches) and by Bürger in the *Tierreich* (up to 460 mm. = 18 inches), as well as by Joubin (8) (50–60 cm. = 20–25 inches).

Amphiporus lactifloreus (Johnst.).

Fairly common at and near Millport.

Length, $\frac{3}{4}$–5 inches; breadth, average, 1–1$\frac{1}{2}$ mm.; body dorso-ventrally flattened; head slightly expanded, frequently somewhat diamond-shaped with a blunt point anteriorly; the hinder end does not taper to a point.

The animals contract very markedly on interference, and assume a slug-like shape; a specimen an inch and a half long will shorten to a third of an inch. The surface secretes a very sticky mucus. Progression may take place by an equable gliding, or by the passage over the body of a series of contractile waves; or the head may crawl evenly while the tail executes swimming movements.

Two varieties of *colour* were met with; the first includes specimens from a light purple to a delicate French grey; the second includes forms which may be described as cream, yellow, pale orange, or pale flesh colour. The posterior part of the body is often darker than the anterior; there is a white line, due to the proboscis, down the middle of the dorsum, and the margins of the animal are paler or more translucent.

The *cephalic grooves* are in two pairs, an anterior and a posterior. The anterior notch the margin of the head at its widest part, and are continued thence somewhat backwards on the dorsal, obliquely forwards on the ventral surface. The posterior pass obliquely backwards on the dorsal, transversely on the ventral surface, and nearly meet those of the opposite side in the middle line both dorsally and ventrally.

The above description of the grooves agrees in the main with that of MacIntosh, who, however, states that the anterior grooves run forwards on the dorsal surface, not backwards. Joubin (8), on the contrary, shows quite a different form for the posterior grooves, which, in his specimens, had on both dorsal and ventral surfaces something the shape of the letter M.

The *eyes* are usually, not always, in two groups on each side, which are divided by the anterior furrows; I have never seen three groups. The number of the eyes varies very much; the smallest numbers I have noted are three in each anterior, two in each posterior group, or ten in all; but twenty-four, twenty-seven, thirty-four, and thirty-six are met with. The largest eyes are in the posterior group. It may be mentioned that Bürger's Naples specimens possessed a very large number of eyes, twenty in each of four groups.

Another, and a more important, variation between the Naples and the Millport specimens has to do with the shape of the *basis of the stylet.* This is shown by Bürger as being markedly constricted a little posterior to the middle of its length; its thickness is about equal in front of and behind the constriction; since, however, according to the figure, the constriction is nearer the posterior end, the anterior portion of the basis is the bulkier. A similar description ("plumpe Sockel, in der Mitte ringsum eingeschnürt, vorn und hinten fast gleich dick") is repeated in the specific diagnosis given in the *Tierreich.*

The shape of the basis in my specimens is seen in fig. 7. It will be seen that the constriction is very slight, if indeed it exists—if, that is, the appearance of a slight constriction be not merely due to the rather greater width of the posterior rounded end of the basis; the posterior part of the basis is, owing to this greater width, bulkier than the anterior. Fig. 8 represents a different shape, met with on one occasion only; the basis is here much shorter and broader than usual, and resembles a truncated cone. In the two reserve sacs I have found either two or three stylets.

The number of *proboscis nerves* is not given in any account of the species that I have seen. Since it varies in the different species of this genus, and since it is a character that is sometimes used as a specific distinction, it may be worth while stating that the number is fourteen.

The *cæcum* sends off a pair of long and slender prolongations, which reach as far as the brain. These, which are usually described as hollow pouches, are in my preparations solid throughout. As stated by other authors, the *cerebral organs* are large, and situated in front of the brain.

This form appears to be a good example of the variability of the class. JOUBIN's account of the cephalic grooves differs considerably from those of MACINTOSH and myself; BÜRGER's specimens differed from the British forms in being found at some depth, in possessing a much larger number of eyes, in the shape of the basis of the stylet, and in coiling themselves up, not contracting themselves slug-like; the colour also, as in most members of the class, is variable; and even in the Millport forms I found in one instance, as has been noted, a considerable divergence from the rest in the shape of the basis of the stylet.

Amphiporus pulcher (Johnst.).

This species has been the subject of a number of descriptions which vary from each other considerably in certain points, *e.g.* the eyes, the cephalic grooves, and the stylet. A comparison of the forms met with at Millport with those described from other localities may therefore be of interest.

Specimens are rare at Millport; three were dredged in fifteen fathoms off Ascog Bank. This supports JOUBIN's statement (8) that "on ne trouve pas non plus les deux espèces (*i.e. A. pulcher* and *A. lactifloreus*) dans les mêmes localités."

The length was about $1\frac{1}{2}$ inch, the body relatively broad and flat; the tail much flattened; the head not wider than the rest of the body, somewhat rhomboidal in shape, ending anteriorly in a blunt point. The animals are sluggish in habit, contracting readily to a slug-like mass $\frac{1}{3}$ of an inch long; they can swim lazily, ventral side uppermost, at the surface of the water. I have not seen the peculiarity noted by MACINTOSH, that, when irritated, they turn on edge and swim rapidly through the water by swift lateral strokes of the oar-like extremity.

The colour is a light orange-pink, the margins and ventral surface being lighter, of a very light flesh colour. The proboscis, readily extruded, is also of a delicate pink colour. The animals very readily break up, more readily than any other Nemertines met with at Millport.

The *cephalic grooves* are two on each side, an anterior and a posterior; and each groove extends on both dorsal and ventral surfaces (v. figs. 9,10). Dorsally the anterior grooves run transversely, nearly meeting in the middle line, and giving off a number of small secondary grooves which run in an anterior direction at right angles to the main groove; the posterior grooves run very obliquely backwards and meet in the middle line. Ventrally, the anterior grooves are continued transversely, meeting or not in the middle line, with secondary grooves of the same description as those on the dorsal surface, and a dimple nearly half-way between the lateral margin and the median line; the posterior grooves run transversely, with a slight inclination forwards, but do not meet.

The above description corresponds in most points with that of MacIntosh, except that this author neither figures nor describes any extension of the posterior grooves on the ventral surface. Joubin (7) criticises MacIntosh ("la figure donné par MacIntosh est assez défectueuse pour ce qui est des sillons"), and states (8) "je n'ai point vu les sillons secondaires que figure MacIntosh." He describes (8) the anterior dorsal grooves as being together V-shaped, like the posterior, but his figure shows that they run for the most part almost transversely, each, however, bending in a posterior direction near its inner end; the ventral grooves of his specimens seem to have been entirely different from the Scotch forms, and, according to his figure, produce by their bifurcations and reunions the appearance of a number of somewhat rhomboidal or irregular areas on this surface. Bürger (3, 5), as for *A. lactifloreus*, does not mention the grooves. It would seem therefore, on the whole, that both the course of the main grooves and the presence of secondary grooves are liable to very considerable variations.

The *eyes* in my specimens were numerous, and distributed somewhat irregularly near the lateral margins of the head, mostly in front of the anterior groove. In one specimen there were thirty-four on the left side and about as many on the right; in another, there were fifteen on each side. The larger eyes are irregular aggregations of pigment, apparently formed by the fusion of smaller eye-spots.

Other authors give diverse accounts of the eyes. MacIntosh states that they are about twenty-three in all; Joubin (7) that they are thirty-five to forty-five on each side, or, again (8), eighteen to twenty-five on each side. Bürger (3) states that they are "ziemlich regelmässig zweireihig angeordnet," and, in the *Tierreich*, includes this feature in the diagnosis of the species ("mit vielen Augen, die in 2 Reihen angeordnet sind"). From what has been said, however, it would appear that neither the number nor the arrangement of the eyes present sufficient constancy to permit of their being used as a specific distinction.

The *basis of the stylet* is of a regular oval shape, and the stylet itself may project behind it (fig. 11). The distal free portion of the stylet is equal in length to the basis.

There are two reserve sacs, the numbers of reserve stylets found in these were six, seven, eight, or nine.

Here, again, MacIntosh's figure (his pl. xii., fig. 6) shows a close agreement with the above description. Bürger, however, appears to have been dealing with a very different shape of pedestal; compare the latter author's plate (3), and also his statement that the basis "ist kegelförmig und hinten etwas kuglig angeschwollen." A similar statement is made part of the specific description in the *Tierreich.* Students of the Nemertini will for ever be indebted to Bürger's comprehensive and masterly work; but if a criticism may with all respect be ventured, I would suggest that he has relied too much on his own specimens for the construction of specific diagnoses, and has not allowed enough weight to the descriptions of previous authors, nor considered sufficiently the great variability of many species of the class.

With regard to certain other specific characters given in the *Tierreich*, the *cæcum* in my specimens corresponds to what is there stated; the *cerebral organs*, stated to lie behind the brain, I find to be for the most part alongside and almost coextensive anteroposteriorly with the brain, though they extend backwards for some little distance behind it; the number of *proboscis nerves*, however, is different—Bürger giving ten, while I find twelve.

Amphiporus elongatus, n. sp. (fig. 12).

A single specimen; found on Fairlie sands.

Length, 3 inches; filiform, breadth when extended being less than 1 mm.; tapering markedly towards the head, which is flattened; the tail blunter than the head.

Colour bright yellow, becoming an orange yellow when contracted; the margins lighter, the ventral surface of the same colour as the dorsal.

The *head* was flattened, tapering, and not marked off from the body; the ganglia were visible as reddish masses. The *eyes* were five in number (v. fig. 13)—two smaller ones, one on each side near the tip of the snout, and three larger ones, two on one side, and one on the other, over the cerebral organs; there was a considerable interval between the two sets.

The *cephalic grooves* were two on each side (v. fig. 13), the anterior very oblique, leading backwards on the dorsal surface from the lateral margin to the cerebral organ; the posterior also leading obliquely backwards almost parallel to the anterior pair, and nearly meeting in the middle line at the level of the anterior end of the brain. Both sets of grooves were continued round the margins on to the ventral surface in the same direction, *i.e.* running from the lateral margin forwards and inwards towards the middle line.

The *cerebral organs* were large, and situated quite in front of the brain (v. fig. 13).

The *proboscis sheath* was continued to within a very short distance of the hinder end. The *stylet* was rather thick as compared with its length, and shorter than its pedestal; the shape of the latter was roughly cylindrical, with rounded ends, very slightly constricted nearer the proximal (base) than the distal end (v. fig. 14). There were two reserve sacs, containing respectively one and two stylets. The rhynchocœlom had no diverticula.

The *alimentary canal* possessed a large number of lateral diverticula, attached by strands to the body-wall; a diverticulum was sometimes attached by two strands, a slight bifurcation of its extremity being thus produced. When the whole animal was examined under the microscope, the diverticula appeared as a series of leaf-like appendages of the alimentary tract, *i.e.* were flattened from before back.

Examined in spirit several months afterwards, the specimen was about an inch and a half long, a millimetre broad, and of a light brown colour; tapering gradually at one end, more suddenly at the other.

Examination of Sections.—Portions of the animal were sectioned for further investigation of certain characters used in discriminating species of this genus. The following additional features may be noted:—

The ventral *ganglia* of the brain are much thicker than the dorsal. There are no neurochord cells or neurochord. The sections confirm the above statements as to size and position of the *cerebral organs.* The cæca of the *alimentary canal* can be seen, in horizontal sections, sometimes to be bifurcated; the anterior ventral cæcum is of large size, and sends forwards a pair of diverticula, which do not nearly reach the brain. *Testes* are scattered between the alimentary diverticula but not as a regular series alternating with these latter. The (presumably mucous) contents of many of the *epidermal cells* are intensely stained (by Delafield's hæmatoxylin). The *head-glands* are not strongly developed. The *proboscis,* as seen in transverse sections, lies in a spacious rhynchocœlom, but is itself of very small diameter, and the proboscis nerves are not to be made out.

Since this form differs from most species of the genus *Amphiporus*—which are, as a rule, somewhat compact and thickset forms—in being thin, indeed filiform when extended, I have chosen for it the specific name *elongatus.*

I propose the following diagnosis for this form:—*Length* 75 *mm., breadth when extended less than* 1 *mm., filiform. Head tapering, not marked off from body; tail blunter. Colour bright yellow, the same on both dorsal and ventral surfaces; margins whiter. Eyes few in number, in two groups on each side. Stylet shorter than its pedestal; the latter roughly cylindrical, slightly constricted posterior to its middle; two reserve sacs. Head grooves two on each side, directed obliquely backwards and inwards on dorsal surface, continued over margin of head on to ventral surface. Cerebral organ in front of brain.*

Prostoma (*Tetrastemma*) *candidum* (Müll.).

This worm is commonly found at and near Millport, under stones between tide-marks. Previous authorities have differed considerably in the characters which they attribute to the species; the following account may therefore be of interest.

In *length* most specimens were from one-third to two-thirds of an inch, some few longer, some even shorter; they agreed therefore rather with **Bürger**'s Naples specimens (scarcely more than 1 cm.) than with **MacIntosh**'s (1–1½ inches). In breadth they were about 1 mm. They were thus relatively short, and sausage-shaped; the posterior end was narrower and somewhat pointed. The animals are active, can swim freely, and are very hardy and resistent under examination.

Green and yellow are noted by previous authors as being the usual *colours*; **Joubin** (8) adds white and red. In my specimens the range of colour was extensive—yellow, light orange, light greyish yellow, light brownish grey, light brown; one specimen was noted as being between pink and brick-red, the colour being due to the intestine. A green specimen, almost certainly of this species, was given me one evening by Dr A. L. **King**. I was just leaving the laboratory, and deferred a detailed examination; but the animal, which was damaged, had disintegrated before the next day. The head, or the tail, or both, are lighter in tint, and the margins of both head and body are more translucent. The ova may appear as very marked yellow masses in a row on each side of the middle line.

Certain markings on the head deserve notice. **MacIntosh** has described a pale streak in the median line anteriorly; and has noted that in some individuals a few white grains are to be seen between the anterior pair of eyes. **Bürger**, however (3), found no pigment spots or streaks on the head. In the Millport specimens there may be a pale streak in the middle line in front of the eyes; certain specimens, again, show a pair of white splashes, each a collection of minute white specks, between and in front of the anterior pair of eyes; while others show a pair of dark pigmented patches, elongated in shape, broader anteriorly, one on each side of the dorsal surface of the head, stretching from the anterior to the posterior eye; but none of these markings on the head were constant.

The *shape of the head* is much used in this genus as a means of discriminating the various species. **MacIntosh** describes it as being wider than the succeeding part of the body, **Bürger** as being broadened and of an elongated egg shape. I have found it as a rule a somewhat short oval, sometimes rather flattened in front, occasionally shorter and almost circular in shape; it is slightly—sometimes very slightly—broader than the succeeding part of the body, from which it is marked off by a constriction; there is a slight median notch with well-marked cilia in the middle line anteriorly.

The *eyes*, in this genus four in number, are, according to **MacIntosh**, set in a square; according to **Bürger**, they are very small, and are set in a rectangle. In my specimens they were arranged in a rectangle, the side lines of which were as a rule distinctly longer than the front and back; occasionally, in an animal with shorter and more circular head, they formed a square. They were, for the size of the animal, large and conspicuous; and in one specimen the anterior pair were rather larger than the posterior.

The *cephalic grooves* are one pair, which notch the margins of the head in front of the level of the posterior eyes; thence they incline obliquely backwards on the dorsal surface, passing just in front of the eyes and nearly meeting in the middle line; on the ventral surface they are continued obliquely forwards for some distance from the margin.

The *basis of the stylet* is, according to BÜRGER, constricted, the constriction being situated, according to the figure (3), nearer the posterior end; the anterior swelling is as thick as the posterior; the basis is longer than the stylet. I find the basis elongated in shape, rounded and expanded posteriorly (v. fig. 15), and slightly longer than the projecting part of the stylet. There may be an appearance of a slight constriction around the middle of the basis, but this is due to the bulging of the posterior end; and an actual constriction does not exist, or is of the very slightest, the sides of the anterior part of the basis being parallel to each other.

There are two *reserve sacs*, with two, three, or four reserve stylets in each; in one case there was only one reserve stylet on one side, two on the other. BÜRGER, at Naples, found two; in the *Tierreich* he gives two or three as the number.

That this is the form commonly known as *Tetrastemma candidum* there can, I think, be no doubt. The only form with which it could be confused would be the nearly related *Prostoma* (*Tetrastemma*) *flavidum*, but the colours are distinctive—yellow and green for *candidum*, pink for *flavidum*. Again, the head is wider than the body in *candidum*, as generally in my specimens; and the white grains between the anterior eyes, described by MACINTOSH, were also seen in some of the Millport forms.

It may be noticed here, again, how considerably BÜRGER's Naples specimens diverge from the description here given. In the length, in the broadening of the head, and in the position of the cephalic groove on the dorsum, the two correspond; and in colour BÜRGER's specimens—of a light or dark green, with yellow margins and yellow head—agree in a general way with MACINTOSH's description, if not with mine. But, on the other hand, BÜRGER found no pigment spots or streaks on the head, the eyes were "very small," and his description of the basis of the pedestal is quite different from that given above. In the *Tierreich* we find certain of these variations given as parts of the specific diagnosis; thus, the length is limited to 10–12 mm. (though MACINTOSH had previously given 1–1½ inches), the eyes are stated to be very small, the pedestal to be moderately constricted, and the number of reserve stylets is limited to two or three. A revision of the definition would therefore seem to be advisable.

On the Distinction of P. candidum from P. flavidum.

If the descriptions of the above two forms, as given by MACINTOSH, JOUBIN, and BÜRGER in his Naples monograph, as well as the diagnoses of the latter author in the *Tierreich*, be compared, it will be found that a number of characters are given by each author which might serve to distinguish the two forms from each other. But, on a closer examination, it will appear that the points of difference are differently stated by the various authors—that is, that there is no general agreement as to what the points of difference are. It will further appear from the above descriptions, that of the Millport specimens included, that these forms, or at any rate *P. candidum*, are subject to a great amount of variation. And it will be seen also that specimens have come under examination which unite in themselves characters ascribed to the two forms separately.

With regard to the first point, it appears from a tabulation of the characters of the two species, as given by the several authorities, that the only distinguishing character in which all agree is that in *P. candidum* the head is broader than, in *P. flavidum* of the same width as, the succeeding part of the body;* even this is not stated directly by BÜRGER with regard to *flavidum*, but it may perhaps be inferred from the fact that the head of *flavidum* is said to be not marked off from the body.

Thus, with regard to colour, while it is generally agreed that green or yellow, or both, are the characteristic colours of *candidum*, and a pinkish or a rose colour of *flavidum*, JOUBIN finds red specimens of *candidum* also. MACINTOSH alone mentions various markings on the head of both species. JOUBIN states that the head is long in *flavidum*, and the distance between anterior and posterior eyes greater ("leurs ganglions sont très allongés comme la tête en général, dont les yeux sont plus distants que dans aucun autre *Tetrastemma*"); MACINTOSH finds the eyes arranged in a square in *candidum*, while the interval between anterior and posterior eyes is greater in *flavidum*; but BÜRGER makes no distinction between the two forms as regards this feature. MACINTOSH alone notes that *candidum* is of active, *flavidum* of a more sluggish habit. Differences in the relative length of stylet and basis, and in the shape of the basis, have been noted only by BÜRGER.

To the fact that there is no general agreement as to the distinguishing characters of the two forms is to be added the fact that the forms themselves are very variable. This may be illustrated by the different colours and combinations of colours assumed, especially by *P. candidum*; JOUBIN specially notes the variability of this form, and gives for it a greater range of colour than other authors; he mentions white, yellow, green, and red. The length, again, as given by BÜRGER, is in the case of *P. candidum* only one-third of that given by MACINTOSH, and little more in the case of *P. flavidum*. The size of the eyes, according to BÜRGER, is "very small" in both; this is not noted by other authors, and was very distinctly not the case in the Millport specimens. With regard to the shape of the basis of the stylet in *P. candidum*, BÜRGER, as has been seen, gives a description which is quite inapplicable to my specimens; and with regard to *P. flavidum*, while the figure in his Naples monograph shows the basis to be somewhat dumbbell-shaped, with a constriction in the middle and rounded ends of equal size, his description of this structure in the *Tierreich* runs "der kegelförmige, kaum in der Mitte eingeschnürte Sockel." And it has been seen that in my own specimens of *P. candidum*, in addition to well-marked colour differences, the length, the pig-

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* JOUBIN has not given full descriptions of these forms; in points not specified by him he associates himself with MACINTOSH, and accordingly is counted as agreeing with this author in such cases.

mentation of the head, the occurrence of white splashes in front of the eyes, the number of stylets in the reserve sacs, the shape of the head, and the disposition of the eyes, were all found to be variable.

Lastly, the Millport specimens in several cases showed a combination of the characters of *P. candidum* and *P. flavidum*, and seem thus to have been to some extent intermediate between the two. While agreeing on the whole more closely with *P. candidum*, in one case a pinkish colour was found, pink or rose being the characteristic colour of *flavidum*. The arrangement of the eyes in a square (characteristic, according to MacIntosh, of *candidum*) was as a rule replaced by the arrangement in a rectangle (characteristic of *flavidum*). The head of my specimens was as a rule only slightly, sometimes very slightly, broader than the next succeeding part of the body—the condition, that is, was intermediate between those characteristic of *candidum* and *flavidum* respectively. And while the anterior and posterior eyes were as a rule of the same size, in one instance the condition of *P. flavidum* was reproduced, in which form, according to MacIntosh, the anterior pair of eyes are larger than the posterior.

I do not consider that any of my specimens represented the typical form of *P. flavidum*; and it would therefore be unwise in me to pronounce a definite opinion on the following point. But having regard to the want of any general agreement as to the characters by which the above two forms are to be distinguished, and, in addition, to the great variability of the forms themselves, as well as to the fact that forms exist which may be considered as intermediate in character, it seems not improbable that it will be found advisable to unite the two under a common designation.

Oerstedia dorsalis (Abildg.) (= *Tetrastemma dorsale*).

A single specimen was dredged in the channel near the Biological Station.

Length one-third of an inch; comparatively stout, cylindrical or sausage-shaped, of generally stiff appearance; the blunt posterior end tapers very little. The specimen frequently doubled itself up so that its two halves lay apposed side by side. It protruded its proboscis on apparently no provocation; it ultimately broke into two under examination, and the anterior part then vomited and shook off the proboscis.

The general *colour* was yellow to orange, very slightly lighter on the ventral surface; a brownish pigment was also present, with a double arrangement—(i.) in three bands, two lateral and one mid-dorsal, not very definite; (ii.) in transverse bands over the dorsum, which became fairly conspicuous when the animal contracted itself, and which then gave the animal an annulated appearance. Scattered over the body were a number of minute white dots, easily seen with a low power of the binocular microscope; these were specially aggregated to form a mid-dorsal line, superposed on the median dorsal brown-pigmented streak. The animal frequently twisted itself so that the mid-dorsal white line appeared as a spiral round the body.

The *head* was flattened, not broader than the body, not marked off, tapering somewhat towards the front. The *proboscis*, when extruded, was bulky and long. A pair of transverse *grooves*, which indented the lateral margins, were visible one on each side dorsally behind the posterior eyes.

The *eyes* were four in number, large, reddish brown, apparently situated some distance beneath the surface. The distance between anterior and posterior eyes of the same side was considerably greater than that between the two anterior or the two posterior eyes.

The *stylet* was of the same length as its basis; the latter was somewhat conical in form, with rounded end (v. fig. 16). Here, again, I find a considerable difference from BÜRGER's figure (3), which shows a somewhat dumbbell-shaped basis, markedly constricted, with rounded ends of about the same size.

There were two *reserve sacs*, each with four stylets.

Lineus longissimus (Gunn.).

Not uncommon; under stones near low-water mark, Balloch.

No great *lengths* were met with; 10 feet is not uncommon; breadth $\frac{1}{8}$ to $\frac{1}{6}$ inch, large specimens $\frac{1}{3}$ inch.

The animals are sluggish in habit. The general *colour* is from a dark brown to a dark velvety black, with a slight purple iridescence; the ventral surface is a little paler than the dorsal. This general ground colour is varied by a longitudinal striping of a lighter tint; distinct lateral and mid-ventral lighter stripes are always present, but the dorsal stripes are variable—of these latter there may be several, running parallel. All the stripes are most marked in the anterior part of the body; some of the larger specimens had none on the dorsal surface except a mid-dorsal stripe, and that only on the head.

The *shape of the head* would seem to merit a short consideration. MACINTOSH describes the head simply as being wider than the succeeding portion of the body. BÜRGER, however, lays more stress on this character, and writes, in the diagnosis of this form in the *Tierreich*: "Kopf verbreitert, spatelformig, nicht vom Rumpf abgesetzt;" while in his key to the various species of the genus the distinguishing character is "Kopf auffallend stark verbreitert." JOUBIN (8) does not mention a broadening of the head, and his figures show it as slight or absent.

In the Millport specimens the head has whitish margins and is somewhat flattened. When the animals are contracted, it is narrower than the succeeding part of the body; but, when well extended, it is of equal breadth or very slightly broader. It is marked off by distinct though slight notches, and is indented in the middle line anteriorly; I could not distinguish median and lateral papillæ. The situation of the ganglia is marked by a reddish patch about one-sixth of an inch behind the anterior end.

The broadening of the head would seem, therefore, taking all the descriptions into consideration, to be a variable characteristic, and hardly suitable for employment as a specific character, or for use as the diagnostic mark in a key. It will also be noted that, contrary to **Bürger**, the Millport specimens showed a distinct marking off of the head from the body.

The *eyes* appear to be another variable character. **MacIntosh** describes them as constituting a long wedge on each side, with the apex forwards. **Joubin** (8) speaks of "des amas de petits yeux noirs." I have, however, always found them arranged in a single line; they are numerous, situated anteriorly on each side, along the junction of the pale margin of the head with the general brown of the dorsal surface; they extend from near the tip to a point about half-way between this and the situation of the ganglia.

The lateral *grooves* extend from nearly the anterior end of the head backwards to the level of the ganglia. They can be narrowed or closed, but the pit at their posterior end always remains open.

Lineus ruber (Müll.) (= *gesserensis* auct.).

This is the commonest Nemertine of the shore at Millport; it is found abundantly under stones at all tide-levels. I examined specimens from the shore near the Biological Station, from Balloch (1½ miles to the N.), from the islands in Millport harbour, and from Fairlie sands.

Specimens live well in captivity in spite of lack of care in changing the water or in compensating evaporation; they sometimes show a tendency to leave the dish and very often lie along the water-line at the side. A number of individuals commonly coil themselves up together.

Specimens were met with of all *lengths* from 1 to 9 inches; a common length is 2 to 3 inches. The breadth does not vary so much as the length, being from 1 to 2 mm.; ordinary specimens thus appear moderately stout.

The *colour* is remarkably variable. **Joubin** (8) has distinguished five colour varieties, as follows — (α) black and dark blue, (β) dark olive green, (γ) light olive green; these three correspond to *Lineus gesserensis* as described by **MacIntosh**; (δ) green and red, (ϵ) red; these two correspond to *Lineus sanguineus* in **MacIntosh**'s description. **MacIntosh**, for *L. gesserensis*, gives the two colours reddish brown and dull olive. **Bürger** did not meet with this species at Naples.

The specimens met with at Millport fall into three classes, as follows:—

(i.) The commonest is a purple variety. This may be a pure deep purple throughout, though more usually the animal shows, when extended, a brownish tinge; the colour may be mottled with a number of small patches of a lighter tint; and the ventral surface may be somewhat or even much lighter than the dorsal.

(ii.) The next most common is a brown variety. The depth of tint varies, and a purplish tinge may be present, especially in the darker forms, due presumably to the cilia on the surface of the body. The head may be darker than the rest of the body. In a light-brown specimen the ventral surface was quite pale, and the lateral margins of the body were also marked by a narrow lighter stripe.

As will be seen, these two varieties shade into each other, the purple having frequently a brownish, and the brown a purplish tinge.

(iii.) The rarest variety is the green, of which specimens were obtained from an island in the harbour, and also from Fairlie sands. The colour may be a light green throughout; or it may be darker, with a bluish tinge anteriorly; or it may be a light olive, becoming reddish anteriorly (not due to the colour of the ganglia); or, finally, it may be a dark olive green, with a faint appearance of longitudinal striping. One specimen showed a white constriction at about the middle of its length; and a number showed a pale lateral stripe along the margins of the body.

Here, again, the mention of 'olive' shows the tendency to a brown coloration; but the green variety is, on the whole, much more sharply marked off from the others than the purple and brown from each other.

In all varieties the margins of the head are pale. The numerous pale transverse wrinkles mentioned by MacIntosh were as often absent as present.

The *head* is somewhat flattened, and is marked off from the succeeding part of the body by slight notches. It narrows slightly, but only slightly, towards the anterior end, so that this extremity has a truncated appearance. In a few specimens a minute ciliated papilla was seen at the centre of the anterior end, and once a slight indentation was noticed at this spot; usually neither was visible. The well-marked lateral *grooves* extend from the notches forwards to nearly the anterior end of the head.

I have paid some attention to the *comparative width of head and body* in these forms, since this character is here, as in many other species of Nemertines (*cf. ant.*, on *L. longissimus*), commonly used as a diagnostic mark. I find that the head may be, at its widest part, either very slightly broader, or no broader, than the succeeding part of the body. MacIntosh's expression on this point is that the head is "distinctly wider than the rest of the body," or "decidedly wider than the succeeding part of the body." Bürger defines it as "ein wenig verbreitert."

The *eyes* vary in number from one to five on each side, or three to eight altogether. They are in the majority of cases situated in a regular longitudinal row at the upper edge of the pale lateral margin of the head, the anterior eye on each side being the largest. These two are symmetrically arranged, but the succeeding eyes are usually not symmetrical, nor the same in number on the two sides.

The *mouth* is an elongated median slit, situated in a pale oval area, behind the level of the lateral notches. The *proboscis* reaches back about one-third of the animal's length. The *intestine* gives off small simple or bifurcated diverticula.

Bürger unites under *L. ruber* (Müll.) both *L. gesserensis* and *L. sanguineus*, described as separate species by MacIntosh. Joubin does the same, his first three colour varieties corresponding to *L. gesserensis*, his last two to *L. sanguineus*.

Besides their colour, the two species *gesserensis* and *sanguineus* have been stated to differ in the comparative width of head and body, in the disposition of the eyes, and in their habits; and it is interesting to note that, while agreeing in colour with *gesserensis*, the Millport specimens coincide rather with *sanguineus* in the fact that the head is scarcely wider than the rest of the body, in the usual arrangement of the eyes in regular rows, and also in the fact that they may coil themselves into a firm ball. The last character is, however, occasional rather than common; the animals, when not aggregated together in a heap, usually lie along the water-line on the side of the dish. Thus, though I did not meet with any forms corresponding in colour to MacIntosh's description of *L. sanguineus*, the above facts would seem to confirm the propriety of uniting this with *L. gesserensis* under a common appellation.

Micrura scotica, n. sp.

One specimen only was found; this was dredged in 15 fathoms off Ascog Bank.

Length 2½ inches (about 60 mm.), *breadth* 2½ mm.; body oval in transverse section, margins not flattened; posterior end tapering; in general appearance the specimen was not unlike *Lineus ruber.*

In *colour* the dorsal surface was light brown with a purplish tinge, uniform over all but the posterior part, where the situation of the alimentary canal and its lateral branches appeared pigmented, the rest pale; the margins of the body were white, and the ventral surface whitish; there was a small red area near the tip of the snout, between the anterior eyes; the area of the nerve ganglia was reddish, and the margins of the mouth were whiter than the rest of the ventral surface.

The animal either coiled itself up into a ball when at rest, or lay in loose folds; part of the body might be thrown into a spiral. In contracting itself, it contracted the anterior part most, so that this part of the body then appeared wrinkled.

Locomotion was effected by a rapid gliding. The animal could not swim; but frequently progressed easily and naturally in a backward direction, in its usual gliding manner and not by contractions of the body-wall.

The *head* (fig. 17) was of the shape of an elongated triangle, with a blunt and rounded apex at the snout; it was slightly marked off from the body, and was scarcely as broad as the succeeding region. The cephalic grooves extended along its sides in its whole extent; the posterior part of the depth of the grooves was red. The anterior end of the head bore three retractile papillæ, a dorsal or vertical, and a lateral on each side; each was an elongated, ridge-like elevation, and the three were arranged so as to radiate from a common centre at the anterior end of the axis of the body. In the retracted condition of the head, a groove made its appearance on the anterior end of the ventral surface; and this, conjoined with the retraction of the three papillæ, gave the appearance of the crossing of a horizontal and a vertical groove at the tip of the snout.

The *eyes* were arranged in two rows, one on each side anteriorly, near the lateral margin (fig. 17); they were difficult to see well and to count, as, except the anterior ones, they were small and were just under cover of the pigmented area, not in the marginal pale zone. There were eight on the left and five on the right side; the anterior eye on each side was considerably larger than the others.

The *mouth* was a much elongated slit, situated behind the slight constriction which separated the head from the body.

The *tail* (fig. 18) was a small, whitish, cylindrical submoniliform appendage of the posterior end of the body, ·8 mm. long—hence visible to the naked eye without difficulty.

Examined some months afterwards in spirit, the general colour of the specimen was a light brown, with no distinction between dorsal and ventral surfaces. The cephalic grooves were very distinct; the mouth appeared as a roundish hole.

Examination of Sections.—The anterior end of the animal was sectioned in order to investigate certain other characters which have been used for diagnostic purposes in descriptions of species of this genus. Of these the following may be mentioned :—

The *cephalic grooves* are deep; they would have to be one-third to one-fourth deeper than is actually the case in order to reach the brain. The *cerebral organ* is at first on the outer side of the brain; farther back it fuses with the dorsal ganglion, and then completely surrounds the hinder end of the latter as in a case. The *dorsal ganglia* are larger than the ventral.

As usual in the genus, there is no diagonal muscular layer; and neurochord cells are absent.

I propose the following diagnosis for this form :—*Length* 65 *mm., breadth* 2½ *mm.; resembles* Lineus gesserensis *in appearance. Colour light brown, margins of head and body white, ventral surface whitish. Head slightly marked off from the body, not broader than the succeeding part. Cephalic grooves along margins of head, reaching anteriorly to its tip. Eyes in two rows, one row anteriorly near margin on each side,* 5–8 *in each row, small and inconspicuous except the anterior ones.*

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STEPHENSON: THE NEMERTINES OF MILLPORT.

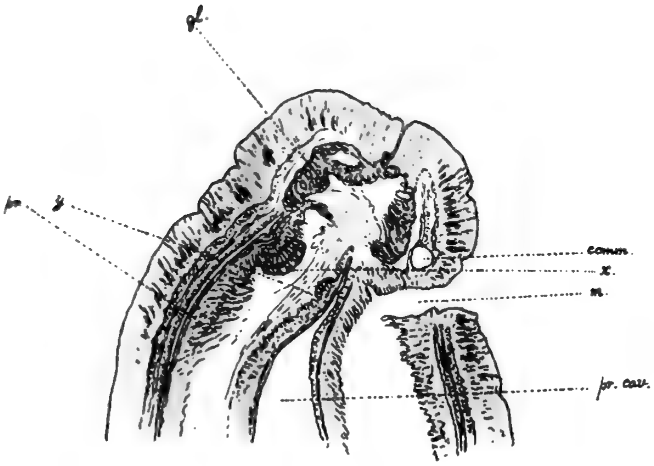


Fig. 4

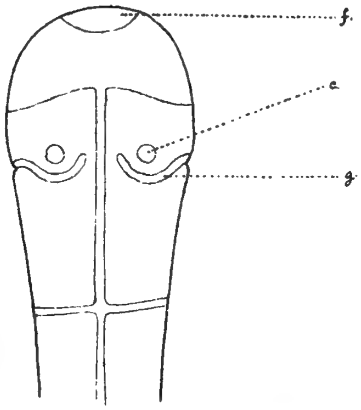


Fig. 1.

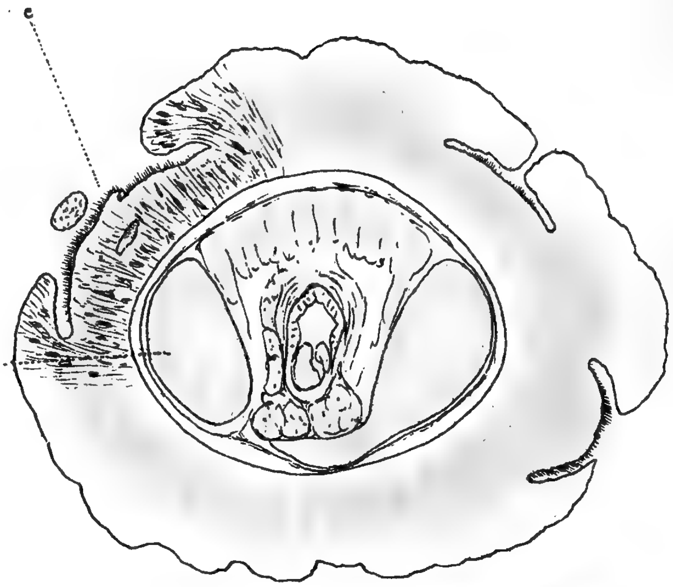
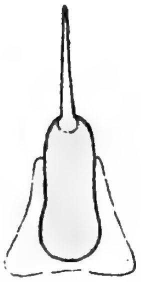


Fig. 3.

Fig. 6



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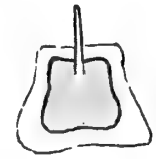

Fig. 8

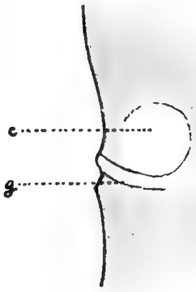

Fig. 2.

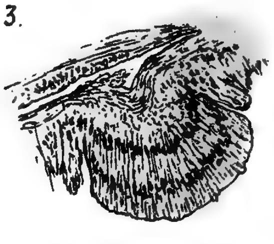

Fig. 5

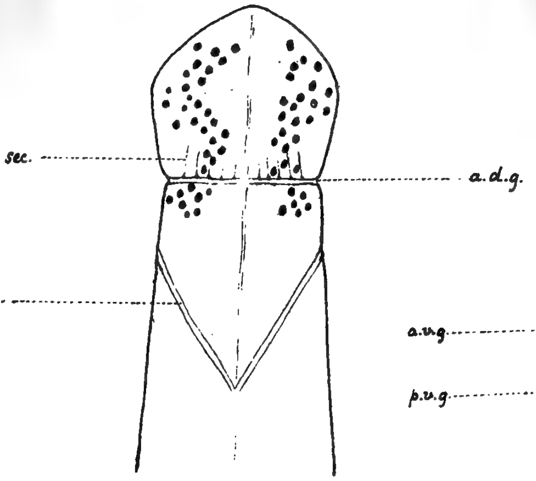

Fig. 9

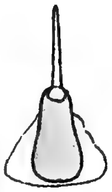

Fig. 16

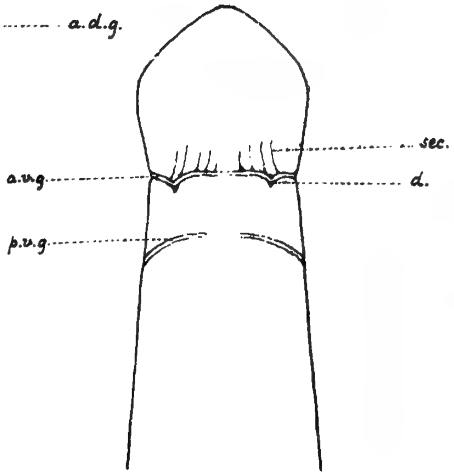

Fig. 10

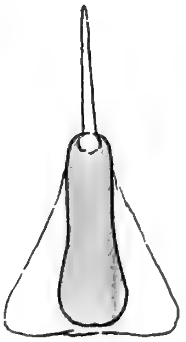

Fig. 15

Fig. 11

Fig. 14

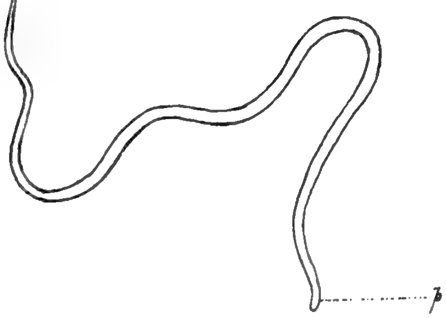

Fig. 12

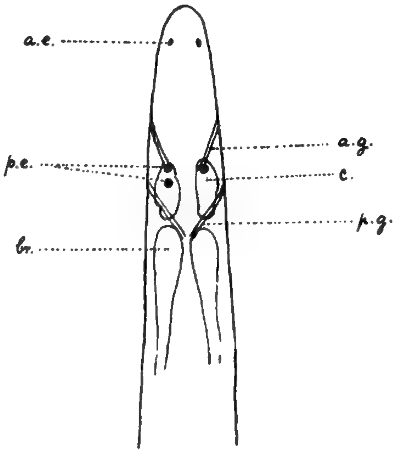

Fig. 13

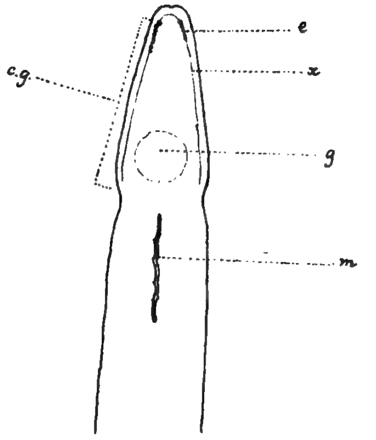

Fig. 17

Fig. 18

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EXPLANATION OF FIGURES.

(Figs. 3, 4, 5 drawn from sections by Zeiss's Abbé's drawing apparatus.)

Fig. 1. Head of *Tubulanus annulatus* from the dorsal surface, to show appearance of grooves and cerebral organs; pigmented areas indicated.

c., cerebral organ; *f.*, frontal pigmented area (*Stirnfeld*); *g.*, cephalic groove.

Fig. 2. Part of the left lateral margin of the head of another specimen of the above; the anterior wall of the cephalic groove, and the circular depressed area (cerebral organ) are lighter in tint than the surrounding parts.

c., cerebral organ; *g.*, cephalic groove.

Fig. 3. Transverse section of head of *Tubulanus annulatus*, through the left cerebral organ. × 55.

c., cerebral organ; *br.*, brain.

Fig. 4. Longitudinal section of head of *Tubulanus annulatus.* × 64.

comm., commissure between the two halves of the brain; *gl.*, head-gland; *m.*, mouth; *pr.*, proboscis; *pr. cav.*, rhynchocœlom; *x.*, cushion of cells described in text; *y.*, the smaller ventral cushion.

Fig. 5. The dorsal cushion of cells in the proboscis of *Tubulanus annulatus*, more highly magnified. × 225.

Fig. 6. Stylet of *Emplectonema gracile.*

Fig. 7. Usual form of stylet of *Amphiporus lactifloreus.*

Fig. 8. Exceptional form of stylet of *Amphiporus lactifloreus.*

Fig. 9. Dorsal surface of head of *Amphiporus pulcher.*

a.d.g., anterior cephalic groove, dorsal; *p.d.g.*, posterior cephalic groove, dorsal; *sec.*, secondary groove.

Fig. 10. Ventral surface of head of *Amphiporus pulcher.*

a.v.g., anterior cephalic groove, ventral; *d.*, dimple in the course of the above; *p.v.g.*, posterior cephalic groove, ventral; *sec.*, secondary groove.

Fig. 11. Stylet of *Amphiporus pulcher.*

Fig. 12. *Amphiporus elongatus*, to show the general form. × $1\frac{3}{4}$.

a., anterior end; *p.*, posterior end.

Fig. 13. Head of *Amphiporus elongatus*, as a transparent object.

a.e., anterior eyes; *a.g.*, anterior cephalic groove; *br.*, brain; *c.*, cerebral organ; *p.e.*, posterior eyes; *p.g.*, posterior cephalic groove.

Fig. 14. Stylet of *Amphiporus elongatus.*

Fig. 15. Stylet of *Prostoma candidum.*

Fig. 16. Stylet of *Oerstedia dorsalis.*

Fig. 17. Head of *Micrura scotica*, from the dorsal surface; the position of the mouth on the ventral surface is, however, also indicated.

c.g., extent of cephalic groove; *e.*, eyes; *g.*, reddish area due to brain; *m.*, relative position of mouth; *x.*, line indicating junction of the pale margin with the pigmented area of the head.

Fig. 18. Posterior end of *Micrura scotica*, to show relative size of tail.

II.—On some littoral Oligochæta of the Clyde.

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CONTENTS.

INTRODUCTION.

The following paper contains an account of certain of the littoral Oligochæta of the Firth of Clyde, found at and near Millport on the Island of Cumbrae, and at Wemyss Bay on the mainland. The investigation was begun during a two months' stay at Millport, from May to July, 1909, at which time I was working in the Marine Biological Station there, and it was completed after my return to India. I have to thank Mr R. Elmhirst, the Superintendent of the Station, for his constant kindness, and for the courtesy with which he placed all the appliances and resources of the Station at my disposal.

In 1906, according to Southern (**12**), of the more than one hundred species of Enchytræids then known, only twelve had been recorded from Great Britain, and only seven from Ireland. The number of known species of Enchytræids, as well as of other limicolous Oligochæta, has been considerably increased since then, and, mainly owing to Southern (**12, 13, 14**), this portion of the fauna of the British Isles has also become better known; but, as that author remarks, "the large number of new species and of additions to the British list shows how much work remains to be done on this order before our knowledge can be considered in any way complete."

The ten species of which an account follows are, with the exception of one Tubificid (*Tubifex costatus*, Clap.), all Enchytræids. I need not say that the list is very far indeed from exhausting the littoral Oligochæte fauna of the Clyde; it contains, indeed, only those forms to which I have devoted a fair amount of attention. The several species are, I think, interesting in various ways—some (*Lumbricillus tuba*, *L. viridis*, *Enchytræus nodosus*, *E. dubius*) because they are new; others (*Tubifex costatus*, *Marionina semifusca*, *Lumbricillus subterraneus*, *Enchytræus sabulosus*) because, though not new, they have hitherto been recorded but once or a few times, and there are still lacunæ to be filled before our knowledge can be considered complete; or lastly, as *Enchytræus albidus*, a well-known and widely distributed form, but at the same time one which appears to be very variable, and the Clyde specimens of which show peculiarities of their own.

One further point may perhaps be noted here, rather than in the body of the paper —namely, the relationship between the genera *Lumbricillus* and *Enchytræus.*

The characters serving to distinguish these genera may be said to be four. (i.) The setæ of *Lumbricillus* have a double, or ʃ-shaped curve; those of *Enchytræus* are straight, with, however, a small hook-like curve at their proximal end. (ii.) The presence or absence of a penial bulb; EISEN (**4**) not only makes this a distinguishing feature between the genera, but proposes it as a chief means of dividing the Enchytræidæ into two subfamilies, the Lumbricillinæ which have, and the Enchytræinæ which have not this structure (*cf.* below, under *Enchytræus nodosus* and *Lumbricillus viridis*). (iii.) The 'copulatory glands' or 'Bauchmarkdrüsen,' are supposed to be distinctive of the genus *Lumbricillus*; thus BEDDARD (**1**) writes: "One of the most characteristic structural features of the genus, though confined to a few species, is the outgrowths of the ventral nerve-chord in certain segments." (iv.) The multilobed testes of *Lumbricillus* are also one of its chief generic characters.

If certain of the forms here described be examined with regard to these characters, the following conditions are found: *Lumbricillus viridis*, while in the other points showing a typical Lumbricilline structure, has, in the anterior part of its body, setæ of the typical *Enchytræus* form, while the posterior setæ show only a very faint double curvature. *Enchytræus nodosus*, though its setæ are for the most part typically those of the genus in which I have placed it, shows in certain cases setæ with an indication of a double curvature, copulatory glands, and a penial bulb, *i.e.* Lumbricilline characters are present; the testes, however, are single on each side. *Enchytræus dubius* has setæ which are throughout similar to those described as typical for the genus to which I have referred it; while in the possession of lobed testes, copulatory glands, and a penial bulb (though this latter is bifid internally), it agrees with *Lumbricillus*; I may add that it has red blood, a feature commoner in the species of *Lumbricillus* than in those of *Enchytræus.* Finally, *Enchytræus albidus*, a very fairly typical species of its genus, has nevertheless an imperfect penial bulb, surrounded, it is true, by other and smaller aggregations of gland cells (*cf.* below, under *E. nodosus*).

It would therefore appear that not only are the two genera closely allied, but that a number of intermediate forms exist which serve to bridge over the interval between the two.*

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* With regard to the existence of copulatory glands in the genus *Enchytræus*, SOUTHERN has recorded their occurrence in *E. lobatus*; and there is also a penial bulb in this species (**14**).

Tubifex costatus (Clap.).

This worm was first very briefly described by CLAPARÈDE in 1863. It was rediscovered by BENHAM in material from Sheerness in 1891, and was fully described by him (2), especially with regard to its setæ and genital organs, in a paper with many excellent illustrations.

The species was placed in a separate genus, *Heterochæta*, by its original discoverer, as well as by BENHAM; and this distinction is also assigned to it by VEJDOVSKY (16) and BEDDARD (1). MICHAELSEN, in the body of his work on the Oligochæta (11), includes it in the genus *Psammoryctes*, but in the appendix (p. 522) unites this genus with *Tubifex*, and the worm thus becomes *Tubifex costatus*.

SOUTHERN (14) records it from between tide-marks on the Irish coast, but gives no description; he refers to its mention by FRIEND, in a paper which I have not seen (*Irish Nat.*, 1897). EVANS (5) records it from the Haddingtonshire coast.

The worm is thus, apparently, described with any degree of completeness only in BENHAM's paper; a few additional particulars, and an account of one or two features in which my specimens differ from BENHAM's, may therefore be of interest.

The worms were found at Fintry Bay, about high-water mark, under moist stones, at a place where fresh water was running down on to the shore. They live for days in half salt, half fresh water. Their average *length* was greater than that of previous records, being about an inch (CLAPARÈDE 16 mm., BENHAM $\frac{5}{8}$ of an inch); specimens were met with up to an inch and a quarter. In *colour* they were of various shades of red, the anterior part of the body being paler; as also the genital segments on account of the presence of genital products. The number of *segments* was sixty-three to sixty-seven (about forty, BENHAM).

The detailed account of the *setæ* given by BENHAM must exhaust the subject. Briefly, the setæ are all of the ordinary double-pronged type, except those of certain dorsal bundles in the anterior part of the body, where they are 'palmate' (segments v.–xiv.). I may add that in length the ventral setæ in the anterior part of the body are about ·11 mm., in the posterior about ·086 mm.; the palmate setæ average ·095 mm. The numbers per bundle in the Millport specimens were rather greater than those found by BENHAM; thus in the ventral bundles there were up to seven in the anterior part of the body, not more than two or three in segments x.–xv., and posterior to this four, three, two, or one only; the palmate dorsal setæ were in bundles of six to thirteen, the double-pronged dorsal setæ posterior to these in bundles of four, three, two, or one, like the corresponding ventral setæ.

BENHAM looked for a long time in vain for intermediate forms between the two types of setæ. These 'multidentate' forms are very common in the Millport specimens; some are figured in fig. 1. As to their distribution, they are found in the segments in front of and behind those containing the palmate setæ; thus the most anterior dorsal bundles (ii. and iii.) may either consist of the usual doubled-pronged setæ or of these irregular forms. In segments xiv.–xviii. doubled-pronged and palmate setæ may be mixed ; or the bundle on one side may consist of double-pronged, on the other side of palmate setæ.

The *circulatory system*, briefly referred to by **Benham**, deserves description (Pl. I. fig. 1). The dorsal vessel is connected with the alimentary wall and covered by chloragogen cells as far forwards as the tenth segment, where it becomes free ; from the seventh to the second segment it gives off prominent lateral loops, non-contractile, tortuous, running on the inner face of the body-wall. The dorsal vessel bifurcates at the junction of prostomium and first segment ; the branches unite again below about the level of the setæ of segment iv. The ventrally situated vessel which is thus formed is outside the chloragogen cells ; it unites posteriorly with the subintestinal in the eighth segment.

The supraintestinal vessel is present on the alimentary canal, covered by chloragogen cells, from about the place where the dorsal vessel leaves the intestine to the fifth segment anteriorly. It gives origin in segment viii. to the two hearts, greatly dilated vessels, one on each side, which contract from above downwards, and, as **Benham** has remarked, alternately ; these hearts, approaching each other ventrally at the level of septum $\frac{8}{9}$, are prolonged almost parallel to each other, without immediately uniting, backwards through the ninth segment ; they then join to form the ventral vessel, which is continued backwards below the alimentary tube in the body cavity.

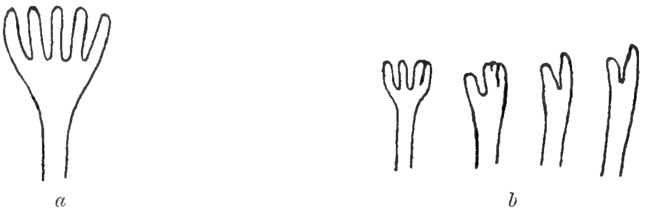


Fig. 1.—*a*, a multidentate seta from the fourth segment of a specimen of *Tubifex costatus*. *b*, intermediate forms of setæ from the fourth segment of a specimen of *Tubifex costatus*.

There remains to be mentioned the subintestinal vessel, a single median channel, on the intestinal wall within the investment of chloragogen cells. This can be distinguished in sections as far back as segment xiv. ; in segment xii. it is equal to the ventral vessel in size, in segment x. larger ; it soon becomes small again, and dies away on the intestine in the anterior part of the eighth segment, after receiving the posterior end of the ventrally situated vessel previously described. The relations of these several vessels are illustrated diagrammatically in Pl. I. fig. 1.

The parietal plexus is most copious in the posterior part of the body ; the loops branch and reunite on the inner surface of the body-wall, but do not penetrate the circular muscular coat ; these branches on the body-wall are of considerable size—indeed, are of the full diameter of the loop which gives origin to them before it divides up.

The shape of the *cerebral ganglion* is sometimes made use of in specific diagnoses.

It may be mentioned that it is about as long as broad, is somewhat narrower behind than in front, and is slightly indented posteriorly. It is contained in segment i.

With regard to the *genital organs*, only certain points in connection with the atrium and spermatheca need be considered. The atrium, according to BENHAM, shows a division into two parts, which he distinguishes as glandular and non-glandular, of almost equal extent, the lining cells of the first part being cubical and vacuolated, as if a secretion had been discharged, while the cells of the second part are flat. In my specimens also, two regions are to be distinguished; but the first region is very much less extensive than described by BENHAM, and extends only for a very short distance on both sides of the entrance of the prostate; the prostate enters the atrium almost immediately beyond the ending of the vas deferens (*cf.* BENHAM'S fig. 18), and the glandular cells extend about equally on both sides of this point. In character these cells are tall and filled with deeply staining granules, but not vacuolated.

The spermathecæ present an external portion, narrowing gradually towards the aperture, with a vertical position in the segment, and a long, more dilated, sausage-shaped cavity, bent into a number of curves; the whole being either confined to segment x., or extending forwards into ix., or backwards to the level of xii. This second internal and far more extensive portion is, in my specimens, lined by tall columnar cells of large size, extensively vacuolated; the vertical portion, or duct, in extent about half the vertical diameter of the segment, is lined by more solid-looking smaller columnar cells, the outlines of the individual cells being often indistinguishable.

Marionina semifusca (Clap.).

This worm was first described in 1861 by CLAPARÈDE (3), who discovered it in the Hebrides. His account deals almost entirely with the reproductive organs; beyond this it includes only a few short statements as to size, colour, nephridia, and cœlomic corpuscles. SOUTHERN (13, 14) has recently recorded the same species in both Ireland (Dublin Bay) and Scotland (Dalmeny, where the specimens were collected by EVANS), and has given (14) further particulars of its anatomy. The following account deals principally with points which have not yet received detailed attention.

The worms were found at Fintry Bay, about high-water mark, under moist stones, at a place where fresh water was running to the shore; and subsequently at Balloch, in a similar locality.

Length 16 mm. *Segments* forty-two. *Colour* light red, whiter in front of the clitellum. Both ends blunt; head-pore at the junction of prostomium and segment i.; clitellum embracing segments xii. and xiii.

The *setæ* are of the same character throughout, in both dorsal and ventral bundles. They are slightly curved in a ʃ-shape, the distal curve, however, being much less in extent than the proximal, which is a long, gentle sweep; they are comparatively slender, and pointed at both ends (fig. 2). In number they are, in front of the clitellum, usually six, varying from five to eight ventrally, and four, five, or six dorsally; in the post-clitellial segments the numbers are about the same, except that nine were once met with in one of the ventral, and seven in one of the dorsal bundles. Ventral setæ are absent in segment xii., in which also the dorsal setæ are few or absent.

The length of the setæ is on the average about ·1 mm. (·095 – ·108 mm.). There is no appreciable difference in length between ventral and lateral setæ, or between those in the anterior and those in the posterior part of the body. There is, however, a difference between the various setæ of a bundle; the setæ are disposed fan-wise in each bundle, and the outer setæ are rather longer than the inner, the length decreasing from the outer to the inner side with some regularity. In illustration, the following figures may be given (*cf.* also fig. 4); the numbers represent the lengths of successive setæ from outer to inner side of the bundles:—

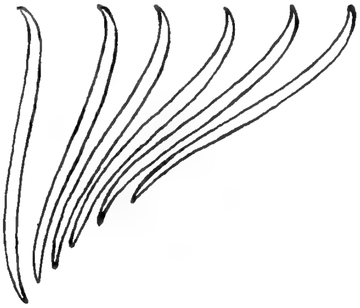


FIG. 2.—A setal bundle of *Marionina semifusca*.

Ventral setæ	·099	·099	·09	·0855	·0855	·0855
	·099	·099	·0967	·09	·09	·09
	·101	·101	·101	·101	·099	·099
	·101	·101	·099	·099	·0945	
Dorsal setæ	·099	·0945	·0855	·09		
	·0945	·0922	·09	·0922		
	·0967	·0967	·0922	·09		
	·101	·0967	·09	·0877	·0832	

As regards the *alimentary canal* and its appendages, the pharynx has the usual form, and occupies segments ii.–iii.; the œsophagus is narrow, and begins to be clothed by chloragogen cells in segment iv.; the tube, though still narrow, dilates a little in segments ix.–x.; it is again very narrow in the genital segments, and finally swells and assumes the usual characters of the intestine in segment xiv. There are no peptonephridia. As remarked by SOUTHERN, the septal glands are large (Pl. I. fig. 2); they extend farther back than usual, one pair being situated always in segment vii. (*cf.* SOUTHERN), and there may be a pair in segment viii. The chloragogen cells are of a very decided brown.

The *dorsal vessel* begins in segment xiv. (xiii. SOUTHERN), and bifurcates at the junction of prostomium and first segment; the two branches into which it divides reunite ventrally in segment iv. to form the *ventral vessel.* The *lateral commissural vessels* are four on each side; the first begins above in segment ii. and ends below in the anterior part of iv.; the second begins above, near the junction of iii. and iv., and ends below, just behind the first; the third is wholly contained in segment iv., the fourth in v. The last two join the ventral vessel below, the first two join the branches which unite to form the ventral vessel.

The *cœlomic corpuscles* are round or broadly oval, disc-shaped, and granular; they are of large size, measuring in the fresh state from 22 to 36 μ; as seen in sections, however, they are smaller, and average 20 μ, the largest measured being 25 μ. They are not obviously nucleated in the fresh condition; the nucleus is conspicuous in stained preparations, lying in the middle of a loose reticulum. They are very numerous, and the body-cavity may be crowded with them.

The *nephridia* begin in segment v., but are absent in xii. and xiii. The ante-septal portion consists of the funnel only; the post-septal is a large ovoid mass, coloured by a brown pigment in its anterior half; the tube is loosely coiled within the mass of the organ. The external openings are in this species easily visible when a specimen is examined from the ventral surface; they are in front of the ventral setæ. According to the evidence of sections, the duct comes off from the mass of the gland well in front of the middle, though this was not made out in the living specimens; but both modes of examination show that it runs backwards to the external aperture, not forwards, as figured by Claparède for his specimens.

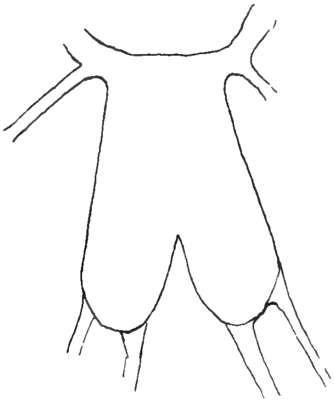


Fig. 3.—Cerebral ganglion of *Marionina semifusca.*

The *cerebral ganglion* is one-and-a-half times as long as broad; anteriorly the margin is straight, posteriorly the ganglion is deeply indented (fig. 3). The *ganglia* on the *ventral nerve-cord* are conspicuous, especially in the anterior part of the body. "*Copulatory glands*" occur in the neighbourhood of the genital segments (*cf.* Southern).

The *testes* are large, equal in length to the anterior half of segment xi.; they are somewhat triangular in shape, attached by their narrow end, with the base of the triangle directed posteriorly. The *funnel* is short, ovoid, one-and-a-half times as long as broad, with an obvious lumen in which ciliary action is very visible; in general structure it resembles related forms. The *sperm morulæ* appear to be confined within the limits of segment xi., septum $\frac{11}{12}$ being slightly bulged backwards. The *vas deferens* is thin, much coiled, and may extend backwards behind the clitellum. The *penial gland* in my specimens seems to differ from the descriptions of CLAPARÈDE and SOUTHERN. According to the former, "ils occupent la cavité periviscérale en entier, dans le onzième segment, produisant même souvent une dilatation du corps dans cette région"; in the diagnosis of the species they are called "énormes," and in the figure are shown as being kidney-shaped. SOUTHERN calls them 'large,' and describes and figures them as cylindrical.

I find that they are somewhat flattened ventrally where they are sessile on the body-wall, but for the rest are spherical, and my specimens seem to give no hint of either a kidney-shaped or cylindrical form. They are large, as in most related species, but not, I think, so large as to call for any special remark; and in my specimens they do not by any means fill the cœlom in their segment, nor cause a bulging of the body-wall.

The *ovaries* are smaller than the testes, and are attached as usual to the posterior face of septum $\frac{11}{12}$. The *ova*, when detached, are seen in sections free in segment xii., and are confined to this; in the living they appear at the level of segment xiii., perhaps through the bulging backwards of the septum. The *funnel* is small, and the *oviduct* short.

The *spermathecæ* consist of an ampulla, duct, and gland-cells, having the appearances and relations described by CLAPARÈDE. The ampulla is continuous with the œsophagus, but I have not been able to trace a continuity of lumen between the two. The wall of the ampulla is thin, and the cells composing it are flattened. The cells of the wall of the duct are in a single layer, and are not covered externally by muscle-fibres. The gland-cells at the base of the duct are continuous on the one hand with the epithelial cells of the surface of the body, and on the other with those of the duct; the muscular layer of the body-wall is continued amongst and between them, the cells being so much elongated that they extend inwards a considerable distance beyond the level of this muscular layer.

The clitellum appears as a mixture of clear and hyaline areas. Clitellar cells are absent over the situation of the penial glands.

Sporozoa occur in the œsophagus.

As BEDDARD (1) remarks, there would seem to be a mistake in CLAPARÈDE's description of the gonads; the testis he places in segment x., and the ovary in xii. (*i.e.* xi. and xiii. according to our notation). I do not understand, also, how he comes to speak of both testis and ovary as being single; he is evidently speaking of the glands themselves, not of the aggregations of sperm morulæ or ova ("les organes sont fixés par un pédoncule à la paroi du corps [or, rather, to the posterior face of the respective septa] . . . les produits, savoir les zoospermes et les œufs, tombent, une fois arrivés à maturité, dans la cavité periviscérale").

I do not consider the identification of the above form with CLAPARÈDE's species to be absolutely certain, since CLAPARÈDE's description is incomplete, and, in regard to the points mentioned by him, there are a number of differences to be taken into account.

The length is perhaps not very important, but the direction of the duct of the nephridia, and the shape and size of the penial glands may also be mentioned. It is principally the characters of the spermathecal apparatus which have determined me to identify my specimens with his description.

Lumbricillus subterraneus (Vejd.).

Under the name *Pachydrilus subterraneus*, VEJDOVSKY (**15**), in 1889, described an Enchytræid which he had first found in a well at Prague; some worms sent to him subsequently from Lille, where they had been discovered in the water-pipes of the town, were found to belong to the same species. The next record of the occurrence of this form is by SOUTHERN (**14**); a large number were sent to him from the sewage works at Belfast, and the same species was also found by him in a stream in Lancashire which was excessively contaminated with trade effluents. In the present case, the third record, the worms occurred on the seashore, about high-water mark, where they must at times be exposed to the influence of salt water.

Though there can be no doubt about the identity of the present form with that described by VEJDOVSKY, I add here a number of anatomical particulars, since in certain points the original description is somewhat brief. This is the case, for example, with regard to the setæ; the structures known as "copulatory glands," or "Bauchmarkdrüsen," were also not described by VEJDOVSKY (and may therefore have been absent); in consequence, this species is represented by BEDDARD (1) (p. 325, in the key to the various species of the genus) as not possessing them, which might possibly lead to some confusion; they were present in SOUTHERN'S specimens.

Found about high-water mark, Fintry Bay, under moist stones, at a part where fresh water was running to the shore; and again at Balloch. The animals live well for several days in a mixture of equal parts of salt and fresh water, and equally well in altogether fresh water.

Length up to 1 inch (25 mm.); fairly stout, tapering towards both ends, most gradually towards the anterior end. *Colour*, various shades of red, whiter about the genital region; ova visible as distinct pinkish-white masses. *Locomotion* by wriggling.

Segments forty-nine to fifty-seven. *Prostomium* blunt, with a number of small papilliform projections. *Clitellum* includes segments xii.–xiii., and may encroach on xi.

Setæ.—The dorsal series are dorsal, not lateral, in position; in the ante-clitellial segments they number four to eight per bundle; in segment xii. fewer, two or three; in the post-clitellial segments three to seven. The ventral series number five to eleven in the ante-clitellial, three to eight in the post-clitellial segments; there are no ventral setæ in segment xii. The setæ are of the same type in the two series of bundles; each seta (fig. 4.) is ʃ-shaped, the proximal of the two curves being the more gradual; each is moderately stout, and is thickest about the middle of its length, but there is no distinct nodulus; the point is single. The setæ of a bundle are arranged fan-wise, and the outer setæ of a bundle are longer than the inner, each bundle forming a gradated series; thus the lengths of the setæ of a bundle of five in segment x. were, from the outer to the inner side, 106, 101, 97, 90, 81 μ; in another bundle the lengths were 104, 100, 94, 90, 83 μ. The longest setæ are thus rather more than ·1 mm. in length; in thickness they are about 5–6 μ. The ante-clitellial of both dorsal and ventral series are on the average rather longer than the post-clitellial.

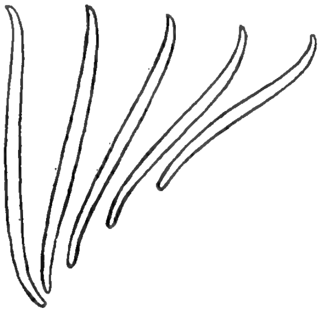


FIG. 4.—A setal bundle of *Lumbricillus subterraneus.*

The *pharynx* occupies segments ii.–iii. The *œsophagus* begins to be covered with chloragogen cells in vi.; it presents no dilatations or diverticula, and passes into the intestine about segment xvi.; this latter portion of the alimentary canal is bulged interseptally and constricted at the septa. *Septal glands* (Pl. I. fig. 3) are present in segments iv., v., and vi.; those of each side are, as usual, longitudinally connected; the glands in iv. are small, in v. are spread out on the septum ($\frac{5}{6}$), and in vi. are large, lying mainly longitudinally in the segment.

The *dorsal vessel* varies somewhat in its place of origin; this may be from the thirteenth to the seventeenth segment; it bifurcates in the prostomium. There are four *lateral commissures* on each side; the first of these arises dorsally in the posterior part of segment iii. and runs forwards into ii., or even i.; the second arises dorsally in the anterior part of iv., and runs forwards into iii.; the third belongs altogether to iv., and the fourth to v. The *ventral vessel* bifurcates anteriorly in iv.; it exists as a definite vessel as far back as the anus, being frequently separated from the intestine, so that a "window" intervenes between the two. The appearance of the '*sinus*' in the alimentary wall when the posterior part of the body was much engorged, the animal dying and the blood coagulating, was that of a thick, close-set network of large vessels, with hardly any interspaces between them. The *blood* is red.

The *nephridia* begin in segment vii.; each is an ovoid mass, with a very small ante-septal portion; there is a slight brown pigmentation in the anterior part of the post-septal. The tube is loosely coiled within the mass; the duct leads forwards from its lower surface in front of its posterior end, and is much shorter than the body of the nephridium. The *cœlomic corpuscles* are irregularly pear-shaped or oval granular nucleated cells. There are also to be seen in the body-cavity a number of smaller spherical refractile bodies.

The *cerebral ganglion* is rather longer than broad, indented posteriorly but not anteriorly; two small dark dots are to be seen, one on each side, in its posterior part (*cf. Enchytræus albidus*). Ganglionic swellings are well marked in the anterior portion of the ventral cord, but some distance behind the genital segments they become scarcely noticeable, the nerve cells being distributed over the whole length of the cord. The cord encloses a "central canal."

The "*copulatory glands*" are present in segments xiii. and xiv. as conspicuous lobed masses around the ventral cord, their centre at a level just posterior to the insertion of the setæ (Pl. I. fig. 4). Each gland consists of a mass of large cells, spherical, pear-shaped, or polygonal, which is situated ventral to and on each side of the cord. These cells do not quite meet above the cord, but, connecting those of one side with those of the other over the dorsal surface of the cord, there appears in sections a deeply staining band. The dorsal surface of the cord is indented between the cells of the two sides in the middle line.

The glands are attached to the ventral body-wall by an almost homogeneous stalk; the circular muscular coat appears interrupted at intervals along the area of attachment (the fibres being presumably displaced), so that the stalk of the gland seems here to fuse with the epidermis. The body of a number of these cells stains very lightly, and shows an appearance something like that of an empty reticulum; the nuclei of the gland-cells stain evenly; those of the nerve ganglion cells which immediately surround the cord show, on the contrary, a number of distinct granules of chromatic material.

The *testes* form a bunch of pear-shaped masses, attached by their narrow ends to septum $\frac{10}{11}$; they shift with the movements of the worm, appearing now on one side, now on the other side of the septum. Their products get forward into segment viii., and fill segments ix. and x.

The *sperm funnels* may be as much as nine times as long as broad. They are, however, here as in other species very contractile, and may shorten (*e.g.* on teasing) to as little as twice as long as broad. Even in the body they may appear only about four times as long as broad, and vary. The *vas deferens* does not extend posteriorly beyond the clitellum; it forms a fairly small coil, equal when uncoiled to about half a dozen segments; it has a fine lumen, in which, in teased specimens, active ciliation can be seen to be going on. The *male apertures* appear as semicircular fissures, convex towards the middle line. The *penial bulb* is a spherical mass of considerable size, its diameter about a quarter of the whole diameter of the body; the vas deferens penetrates the bulb laterally to its centre; the bulb is attached to the body-wall by a strand of tissue which passes dorso-laterally upwards from the upper surface of the mass.

The *ovaries* are on the posterior face of septum $\frac{11}{12}$; ova are found as far forwards as segment viii., and backwards far behind the clitellum.

The *spermathecal apparatus* in the living animal consists of a somewhat spindle-shaped mass, in which ampulla and duct are not to be distinguished; a mass of glandular cells surrounds the aperture. On examining a series of sections, the ampulla is found to comprise the internal half of the mass; it is ovoid or somewhat pear-shaped, communicating with the œsophagus by its narrow end; its walls are lined by a low cubical epithelium, and in the lumen, arranged as a layer all round, are usually numerous deeply staining heads of spermatozoa. The duct, or outer half of the mass, is not sharply delimited from the ampulla, though often, in sections, appearing to be separated from it by a kink in one or other wall; its lumen is narrow, and it is lined by high columnar cells; it has a well-marked muscular investment. The gland-cells near the external aperture are really the lining cells of the duct, which here extend outwards, breaking through the muscular investment of the duct, which can still be seen in places between the cells; their nuclei are peripherally situated, outside the muscular layer, and the cells are continuous at the orifice with the surface epithelium. The above details are shown in Pl. I. fig. 5.

Certain parasites (Gregarines) are seen in the body-cavity in several specimens. The body of these sporozoa is dark and opaque, their nucleus clear; the length of the double animal is about ·5 mm.

The alimentary canal also usually contains numerous sporozoa, with a much-elongated, deeply staining nucleus; the whole width of the lumen of the alimentary tube may be packed with them. In one series of sections one of these forms is present in the spermatheca, into which it had probably wandered from the œsophagus.

The specimens of this species sent to VEJDOVSKY from Lille differed from those previously obtained in Prague in having gland-cells round the apertures of the spermathecæ. It will be seen that in this respect the Millport specimens agree with those from Lille; SOUTHERN's specimens also possessed these glands. It is noteworthy that the same or a similar parasite should occur both in VEJDOVSKY's specimens and mine; in mine, however, two individuals were commonly found joined together, which appears not to have been the case in the previous specimens.

Lumbricillus tuba, n. sp.

Common; found about high-water mark, Millport.

In *length* this species is from ½″ to 1¼″; it is tapering at both ends, more so anteriorly. Its *colour* is pale pink, the anterior half lighter than the posterior; ova may be seen as brilliant white spots; the whole animal is fairly transparent. The worms move when disturbed in an active, wriggling, nematoid manner.

The number of *segments* varies within only narrow limits—thirty-five to thirty-nine.

Prostomium blunt; *head-pore* present, but no dorsal pores.

The *setæ* are of the same type in both ventral and lateral series; they are somewhat ʃ-shaped, but the distal curve is very slight; they are comparatively slender; there is no definite nodulus, but the shaft is slightly thicker a little distal to its middle. They are arranged in a fan-like manner in each bundle; the outer setæ of a bundle are not, as in *L. subterraneus*, longer than the inner.

The ventral setæ are usually four to six (occasionally seven) in a bundle—commonly six in the anterior, five in the posterior part of the body; there are no ventral setæ in segment xii. The lateral setæ are three to five in a bundle, except that in segment xii. there are only two, or one, or none.

In length the setæ are about ·07–·08 mm., the ventral being on the whole a little longer than the lateral.

The *alimentary canal* has the usual relations. *Septal glands* are present in connection with septa $\frac{4}{5}$, $\frac{5}{6}$, and $\frac{6}{7}$; they are enclosed within the septa, which split to contain them, and thus suspend them to the body-wall; they are less bulky than in some other species. *Chloragogen cells* begin in segment vi.; they are very finely granular. There are no *peptonephridia*. The *œsophagus*, narrow as far as segment vii., dilates in a fusiform manner from vii. to x., and in this region it may be intersegmentally constricted like the intestine; it is narrow in the genital segments, and widens to form the intestine in xv.

The *dorsal vessel* begins in the thirteenth, fourteenth, or fifteenth segment, and bifurcates at the junction of the prostomium and first segment. The *ventral vessel* is distinct throughout the body, and bifurcates in segment iv. There are four pairs of *lateral commissures*; the first originates from the dorsal vessel in segment iii. and passes forwards into segment ii.; the last belongs to the fifth segment. The *blood* is a light yellowish red.

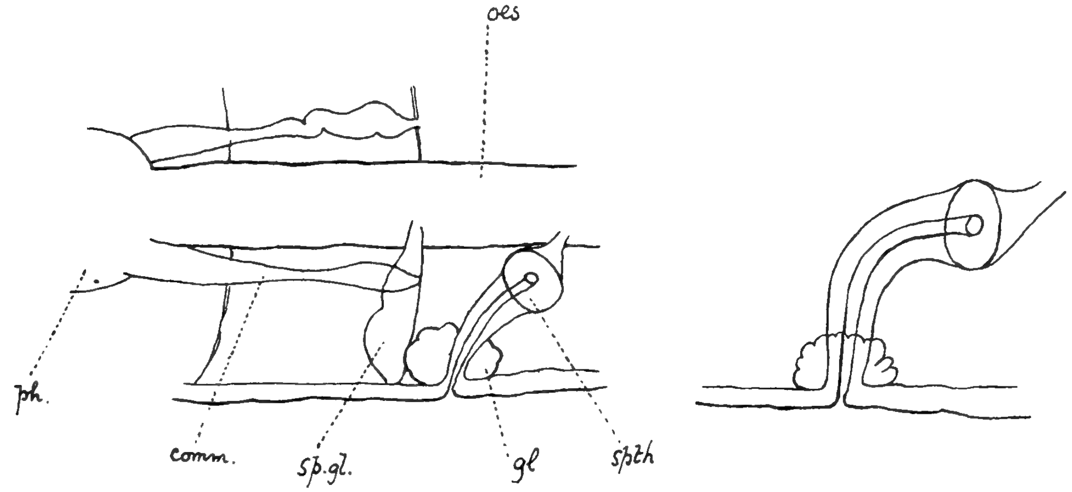
There are numerous *body-cavity corpuscles*, nucleated and granular, mostly of the form of circular, bean-shaped, or elongated pear-shaped discs; some appear to have the form of elongated needles.

The first *nephridium* appears to be situated usually in segment viii.; it was seen in vii. once, and once seemed to be in ix. The ante-septal portion of each is small; the margin of the funnel projects on one side as a tag, from which long cilia wave down the lumen of the tube; there are no outward cilia on the margin of the funnel. The post-septal portion is elongated, and in its anterior part is of a brownish colour (*cf. L. subterraneus*); the duct is shorter than the post-septal portion, and is directed obliquely downwards and backwards to the aperture; just within the aperture the lumen is in sections seen to be dilated to form a small ampulla.

The *cerebral ganglion* is indented posteriorly, while its anterior border is almost straight; its lateral margins diverge somewhat posteriorly. The ganglion is about one-and-a-half times as long as broad. The *ventral nerve-cord* has "*copulatory glands*" associated with it in segments xiii., xiv., xv., and xvi.; these closely embrace the cord laterally, but do not cover it on its dorsal surface.

The *testes* are pear-shaped masses, in two groups, one on each side; they are attached to septum $\frac{10}{11}$ near the body-wall, laterally in the segment; the lobes themselves may be either in segments x. or xi., according as the movements of the animal force them one way or the other; the septum must therefore have considerable deficiencies. Spermatozoa usually occupy segments x. and xi., and may get forward into ix.

The *funnels* are barrel-shaped, and comparatively short—from one-and-a-half to two-and-a-half times as long as broad; they have an everted lip. The *vasa deferentia* are contained in segment xii., and do not extend beyond this; they are long, very narrow, and closely coiled tubes; their length was roughly estimated at about fourteen times that of the funnel. The *male aperture* has associated with it a large spherical penial gland; the apertures lie in an area where the surface epithelium is low and cubical, and sharply marked off from the high clitellar epithelium around (Pl. I. fig. 6); each aperture is at the anterior part of the glandular mass, and is lined by a continuation of the surface epithelium, with characters unchanged; the short tubular passage thus constituted passes obliquely backwards for a short distance from the surface, and after receiving the termination of the vas deferens on its upper wall, ends behind by dividing into about three short branches (Pl. I. fig. 6). The *penial gland* is penetrated by the terminal part of the vas deferens, which enters the mass above, rather towards its lateral surface; the gland has a muscular capsule, and is composed of elongated cells, which are individually very distinct—much more so, for example, than in my specimens of *L. subterraneus*; these cells are arranged so that they radiate around the vas deferens in its course through the mass, and around the branching invagination of the external surface of the body (see description of male aperture above).



a FIG. 5. *b*

a, anterior part of alimentary canal of *Lumbricillus tuba*, with appendages, illustrating appearance of spermatheca in the living animal. *b*, another representation of the appearance of the spermatheca in the same species. *Comm.*, communicating strand between septal glands and pharynx; *gl.*, gland-cells round aperture of spermatheca; *œs.*, œsophagus; *ph.*, pharynx; *spth.*, spermatheca; *sp.gl.*, septal gland.

The *spermathecæ*, with their ducts, present a very characteristic appearance in the living animal, and may be designated as 'trumpet-shaped' (figs. 5*a*, 5*b*). The ampulla is small, subspherical, thin-walled in its equatorial region, but with much thicker walls over its dome, *i.e.* around the situation of its communication with the œsophagus (Pl. I. fig. 7); the difference being due to the different height of its epithelial lining. The duct is thick-walled, much longer than the ampulla, produced from the ampulla without definite external demarcation between the two, and, as a rule, narrowing gradually towards the external aperture, so as to form an elongated and inverted cone. The lumen of the duct is narrow throughout; the cells of which the inner layer of its wall is composed are covered by a conspicuous layer of muscular fibres, arranged longitudinally; a cord of some hyaline matter (? coagulum) almost fills the lumen of the duct, in which may also lie a few spermatozoa. The duct is slightly invaginated into the cavity of the ampulla, though this is not evidenced externally; there is consequently a circular trough around the ampullary opening of the duct, and in this trough the spermatozoa frequently lie coiled (Pl. I. fig. 7). Surrounding the outer end of the duct is a fairly large lobulated gland, the cells of which are continuous with, and a modification of, the external epithelium round the aperture. Their inner ends are prolonged for a considerable distance within the muscular coat, as in other forms (Pl. I. fig. 8) (*cf. L. subterraneus*, *Enchytræus albidus*, *L. viridis*). The whole of the gland-cells are behind the level of septum $\frac{4}{5}$, and the aperture is thus not in the intersegmental furrow, but posterior to this, on the anterior part of segment v.

The characteristic trumpet or funnel-shape previously referred to is due to the gradual increase in the external diameter of the duct as it is followed inwards (the lumen is narrow and of the same diameter throughout); the margin of the funnel (fig. 5*a*) is the optical expression of the junction of the thick-walled duct with the thin-walled ampulla; a small inner circle is the opening of the duct into the cavity of the ampulla.

The *clitellum* extends over segments xii. and xiii.

The intestine, in its anterior part at least, may be full of sporozoan *parasites*.

I was for some time undetermined as to whether I should unite this form with *Lumbricillus* (*Pachydrilus*) *litoreus*, Hesse (9). Though the descriptions agree in a number of points, they vary slightly in certain others, and considerably in the following: (i.) The length of the present form may be nearly twice that given for *L. litoreus*; (ii.) the number of setæ in the ventral bundles is four to six or seven in the present form, six to ten in *L. litoreus*; (iii.) the cœlomic corpuscles are more various in form, and contain a nucleus which is obvious in the fresh condition in the present species; (iv.) the copulatory glands occur in segments xiii.–xvi., *i.e.* extend one segment farther back than in *L. litoreus.*

The chief distinction, however, is in (v.) the spermathecæ and their ducts; in *L. litoreus* the ampulla, according to the original description and its accompanying figure, is of comparatively large size, elongated in shape, with walls of the same thickness throughout, gradually merging into the duct, which latter is much shorter than the ampulla, and has two separate glandular masses at its aperture. In the present form the ampulla is small, subspherical, with extremely thin walls in its equatorial portion, thicker near its junction with the œsophagus; there is, internally, a very sharp demarcation between ampulla and duct, the latter being much longer than the ampulla, and being surrounded by a complete circle of large gland-cells at its aperture. The very characteristic appearance of the spermathecæ in the fresh specimen, by which this form is easily identified, has been alluded to.

Since the form and relations of the spermathecæ and their ducts are among the most valuable characters for the discrimination of species in this group, it would seem advisable to separate this form under a special name; the designation *tuba* is meant to refer to the trumpet-like appearance noted above.

Lumbricillus viridis, n. sp.

Found at Wemyss Bay, under stones below high-water mark, where fresh water was running to the shore.

Length 1 inch; the worm is stout, with a tapering anterior end. All but the anterior part of the body is of a green *colour*, due to the alimentary canal. They are active animals, and exhibit nematode-like contortions. *Segments* forty-five to forty-nine.

The *prostomium* is bluntly conical. Numbers of hyaline cells are found in the superficial epithelium, arranged in fairly regular transverse rows over the whole extent of the body, most regular in its posterior part.

The *setæ* are in the usual four rows, two ventral and two lateral. They are straight, or almost straight, with a slight and usually gentle curve at their proximal end. Their points, especially on the anterior part of the body, are often blunt; indeed the ends may be almost square, with rounded corners; posteriorly sharper points are common. They are arranged fan-wise in the bundles; all the setæ of a bundle are not of the same length, but while in the ventral bundles the inner (ventral) are shortest, in the lateral bundles the shorter setæ are those on the dorsal side of the bundle. Thus in a bundle of seven ventral setæ, in the anterior part of the body, the lengths of the individual setæ, from the outer to the inner, were ·105, ·105, ·105, ·09, ·085, ·078, ·066 mm.; in another bundle, similarly, ·112, ·112, ·105, ·10, ·095; in a lateral bundle situated more posteriorly, the lengths of the setæ, beginning with the ventralmost seta of the bundle, were ·090, ·08, ·075.

The average length of the setæ is therefore about one-tenth of a millimetre, longer ones occurring in the anterior part of the body; their thickness is about ·005 to ·0045 mm. The number of setæ per bundle is five, six, or seven in the ventral series in front of the clitellum, three or four posterior to this; there are no ventral setæ on segment xii. The lateral setæ are four or five, exceptionally three, in a bundle in front of the clitellum, two or three behind this.

Notwithstanding the fact that the setæ have been described above as straight or almost straight, I believe that the majority of them are to be considered as slightly, though very slightly, ʃ-shaped. It is perhaps allowable to dwell for a moment on this point, since the genus *Lumbricillus*, in which the present form must, I think, be included, has ʃ-shaped setæ, and straight setæ would be a curious anomaly.

Fig. 6, *a*, representing a bundle of seven setæ from an anterior segment, and drawn with the camera lucida, shows that the setæ have in this particular instance blunt, in some cases almost square, ends, and are without trace of a distal curvature; their proximal ends, however (with the exception of the innermost seta but one), show a gentle and gradual curvature, not the somewhat sharp curve seen in the genus *Enchytræus.* The figure was drawn from a specimen in glycerin, and since the setal bundles are not perfectly flattened, their two ends are at different levels and there is, perhaps, some optical distortion. This, however, will not apply to the single seta drawn in fig. 6, *b*: this was found in a section mounted in the usual way in balsam; it belongs to segment iv., and was drawn with the camera under an oil immersion lens. It will be seen that its distal portion is perfectly straight, and that it has a hooked inner end, the shape being that characteristic of the genus *Enchytræus.* Such "straight" setæ therefore do occur in the anterior part of the body, in the present form.

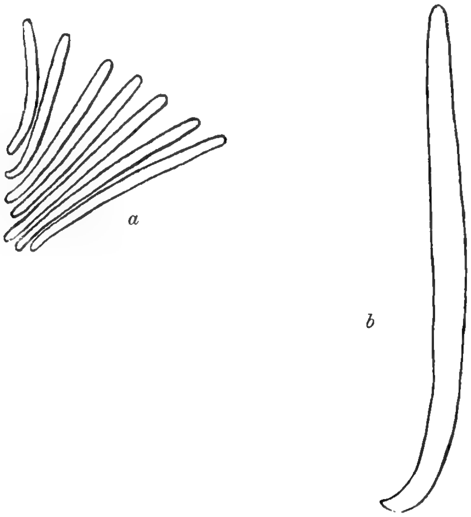


FIG. 6.—*a*, group of setæ from an anterior segment of *Lumbricillus viridis.*
b, straight seta from segment iv. of a specimen of *Lumbricillus viridis.*

Fig. 7, *a*, shows two setæ of a posterior bundle, drawn with a camera under an oil-immersion lens; the ends of the setæ are obliquely pointed as in *Lumbricillus,* not with the straight points seen in the genus *Enchytræus.*

I tried the effect of potash on the worms; but they are so stout and firm that a strong solution of KOH has to act on them for hours before they collapse and flatten so as to present the setal bundles in one plane; the setæ then appear swollen and have evidently lost their true shape. Nevertheless, a double curvature of the *Lumbricillus* type, though not to be recognised in most of the anterior setæ, is then often fairly obvious in the setæ of the posterior bundles. Thus fig. 7, *b*, shows two setæ of a posterior bundle in which this curvature is quite obvious; and fig. 7, *c*, shows a fairly distinct double curve in a seta as far forward as segment viii.

As supporting the view of the affinity of the setæ with the *Lumbricillus* rather than with the *Enchytræus* type, the fact of the difference in length of the setæ of a bundle may be mentioned. In the genus *Enchytræus* the setæ of a bundle are, as is well known, of equal length.

Summing up, it may be stated, that while setæ of the typical *Enchytræus* type occur in the anterior part of the body, those of the posterior segments usually, and even some of those in the anterior segments occasionally, show a faint double curvature of the type found in the genus *Lumbricillus*.

The *cœlomic corpuscles* are grey by transmitted light, flat, oval, or pear-shaped, and granular, with a distinct, clear nucleus. As seen in sections they are mostly ·025 to ·032 mm. in their long diameter.

The *septa* are thick and muscular, in accordance with the general build of the animal. It may be added that the retractor muscles of the pharynx are also very bulky, and that the muscular coat of the œsophagus is very well marked.

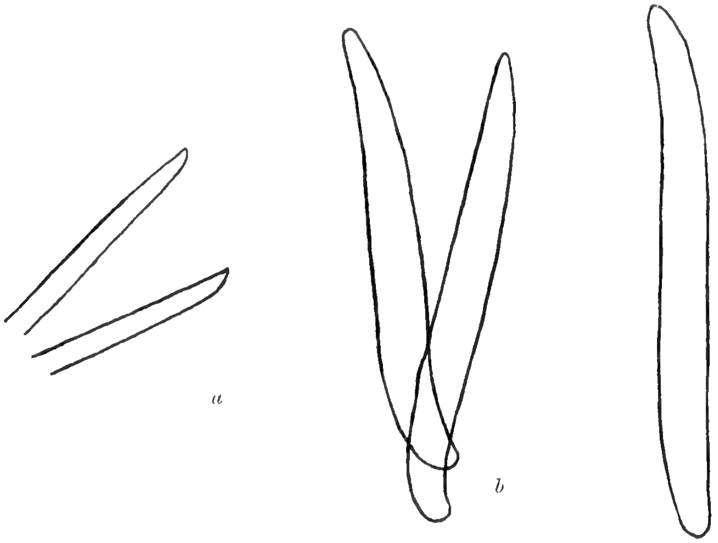


Fig. 7.—*a*, distal ends, obliquely truncated, of two setæ of a posterior bundle of a specimen of the same.
b, two setæ of a posterior segment of a specimen of the same, showing double curvature; the more strongly curved ends are the proximal. The setæ are swollen owing to the action of strong caustic potash solution.
c, seta from segment viii. of a specimen of the same, showing slight double curvature; swollen by the action of caustic potash.

The *alimentary canal* begins to be covered with chloragogen cells in segment iv.; these cells become more numerous behind the septal glands, after which point the canal has a dark green colour. The œsophagus widens a little in segment vii., but there is no marked dilatation at any part of the tube. There are no peptonephridia. Septal glands occur in segments iv., v., and vi.; the last two pairs are bulky, especially those of segment vi., which bulge backwards beyond the setæ of segment vii.

The *dorsal vessel* begins in segment xiii., and the *blood* is red.

The *nephridia* are solid masses, with a very small anteseptal portion. The organs are elongated, ovoid, narrow and compressed laterally, the duct leading downwards from near the posterior end.

The *cerebral ganglion* is comparatively small for the size of the worm, squarish in shape, about as long as broad, and indented posteriorly. The *ventral nerve-cord* is characterised by the possession, through the whole of the anterior part of the body, of aggregations of cells in each segment which embrace the cord ventrally and laterally. These cells, though nowhere forming very prominent masses, correspond in appearance with those which constitute the "Bauchmarkdrüsen" or copulatory glands of other forms. They are mostly, in sections, pear-shaped or spindle-shaped, with very feebly staining, slightly granular protoplasm and deeply staining nucleus; they are of considerable size, and while they leave the dorsal side of the cord uncovered, frequently appear flattened over its sides and ventral surface, so as to give the appearance here of concentric layers. At the site of their occurrence the cord appears stalked in transverse section, being connected with the surface epithelium by prolongations of the cells.

The *testes* are composed of six, seven, or more elongated club-shaped or pear-shaped masses on each side, springing from the ventral part of septem $\frac{10}{11}$. Sperm morulæ collect in segments x. and xi. The *funnel* is long, nine or ten times as long as broad; the length, however, varies, and may appear to be only about seven times the breadth; the funnels are bent on themselves; the nuclei of the cells of which they are composed are, as usual, peripherally situated. The *vas deferens* is considerably coiled; it does not, however, extend backwards behind the clitellum; in diameter it measures ·02 mm. There is a *penial bulb* of considerable size, its diameter being more than a quarter, nearly a third, of the diameter of the animal's body; the bulb has a well-developed muscular covering; the cells of which it is mainly composed are much elongated, radially arranged, the nuclei being crowded together peripherally; the lumen is almost central.

Ova are found in segments xii. and xiii.

The *spermathecæ* are characterised by a spindle-shaped ampulla which communicates with the œsophagus; its external end is continued into the duct without evident demarcation. The duct is somewhat longer than the ampulla, and of about half the diameter of the latter; it is surrounded by prominent gland-cells round its external aperture. The epithelium of the ampulla is columnar, but of very irregular height; the nuclei of the cells are much elongated. In the duct, the epithelium is lower, and the nuclei are spherical; the muscular coat of the duct is situated between and amongst the cells, the nuclei of the latter being all external to the muscular layer; in the ampulla the muscular coat is, however, quite external to the epithelium. Both ampulla and duct are lined by a thick cuticular coat, continuous at the orifice with the very thin cuticle of the body-surface. The prominent collection of gland-cells round the duct near its external aperture consists of the epithelium of the duct, here much elongated and extending outwards far beyond the muscular layer of the duct.

The *clitellum* is only peculiar in that it dies away gradually in front, without any definite line of demarcation.

Sporozoa are present in the alimentary canal.

This species has a very distinctive appearance, and can be immediately recognised by its stout form, active, wriggling, nematode-like movements, and especially by its green colour.

The position of this species with regard to the setæ has been discussed above, where it was shown that it holds, in this respect, an intermediate position. The lobed testes and the large compact penial bulb, however, determine the decision to place it in the genus *Lumbricillus*. The importance of this last feature, the penial bulb, in classification, has lately been insisted on by EISEN (**4**), who distinguishes two subfamilies, *Lumbricillinæ* and *Enchytræinæ*, according to whether the penial glandular structures are or are not confined within a single bulb; in the Lumbricillinæ are included *Lumbricillus*, *Marionina*, *Buchholzia*, *Stercutus*, *Bryodrilus*, *Henlea*; in the Enchytræinæ, *Enchytræus*, and *Michaelsena*.

The 'Bauchmarkdrüsen' are also a feature of the genus *Lumbricillus*. In the present species they are widely distributed, occurring throughout the whole of the anterior part of the body, but are small in size, and are only recognisable as such from the character of their cells as seen in sections. This comparatively undifferentiated condition may be contrasted with that which occurs in *Lumbricillus subterraneus*, where the glands, though few in number, are individually large and prominent.

In a number of species in which the aperture of the spermathecal duct is surrounded by gland-cells, the muscular layer of the body-wall is continued between these cells, in the manner described and figured for *Lumbricillus tuba* (*v. ant.*; also *cf. Enchytræus albidus, post.*); when, following the duct inwards, these gland-cells give place to the ordinary epithelium of the duct, we find, however, that the muscular layer is usually to be found outside the duct epithelium. In this species, however, the muscular layer is still to be found amongst and between the duct epithelium, having the same relations here as near the aperture.

Enchytræus nodosus, n. sp.

Found at Wemyss Bay, near high-water mark, where fresh water ran to the shore.

Length $\frac{1}{3}$ inch (8 mm.); small and thin, not tapering at either end. In *colour* the animals are intensely white over part, especially the posterior part, of their extent, but clear and transparent for the rest; there may be only irregularly distributed white spots, or, as commonly, the posterior half of the body has intensely (opaque) white margins; this opaque white coloration is due to aggregations of cœlomic corpuscles. Under the microscope the animal is, except for these aggregations, extremely transparent; and the *clitellum*, which extends over segments xii. and half of xiii. (to the level of the setæ of the latter), is hardly less transparent than the rest of the body. *Segments* thirty-two to thirty-nine.

The *setæ* are of the straight type, with proximal hook (fig. 8, *a*); the sharpness of this hook varies, and in certain cases there is a faint indication of a double (ʃ-shaped) curvature (fig. 8, *b*). Setæ are absent (both ventral and lateral) in segment xii.; elsewhere they are regularly two per bundle in both series throughout the body; three were noted once only, one occasionally.

There are no *peptonephridia*. *Septal glands* occur in the usual segments, those of iv. and v. being single, bulky, and situated dorsally over the œsophagus; in segment vi. there is a pair, elongated and extending a considerable distance backwards (Pl. I. fig. 9). The *œsophagus*, narrow in the region of the septal glands, is wider in segments vii.–ix.; it narrows again in the genital region, and widens to become the intestine in segment xiv. The *intestine* is not constricted at the septa. The *chloragogen cells* are noteworthy; they are large, with large refractile oil globules; in sections they appear colourless, without brown or yellow granular pigment, and very markedly vacuolated, as if their contents had been dissolved out; there are several or many large vacuoles in each cell. They are present here and there in segments v. and vi., though they can hardly be said to begin before vii.; they are numerous and distinct in viii.–x., though not completely covering the œsophagus, and in particular they leave the tract of the dorsal vessel uncovered; they are absent in the genital region, and begin again, thenceforward forming a complete investment of the intestine, in segment xiv.

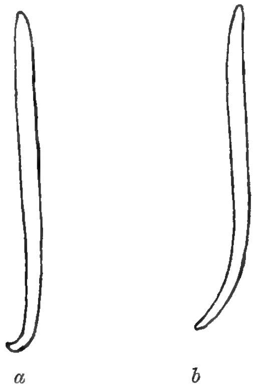


FIG. 8.—*a*, seta of *Enchytræus nodosus*.
b, a seta of *Enchytræus nodosus* showing a slight double curvature.

The *dorsal vessel* begins at the level of the setæ of segment xiii., and bifurcates at the junction of the prostomium and first segment. The *blood* is colourless.

The *cœlomic corpuscles* are flat, circular, and, as measured in sections, are from ·014 or less up to ·019 mm. in diameter. They are opaque by transmitted light, with a clearer nucleus; the opacity is due to numerous refractile oil-like corpuscles crowded together so as to fill up the whole body of the cell.

The *nephridia* (fig. 9) begin in segment viii. The ante-septal portion is of considerable size, somewhat ovoid in shape, about one-third as long as the post-septal; the open mouth of the tube is clothed with fine cilia, and its margin projects on one side as a short, overhanging process; cilia beat in the tube in a downward direction, and the tube undergoes many windings before it reaches the level of the septum. A narrower neck connects the ante-septal with the post-septal portion; the latter is elongated, narrow from side to side, with many and irregular windings of the lumen. The duct is stout, and leads downwards from the posterior end of the body of the organ; in length it is about one-third of the post-septal.

The *cerebral ganglion* is elongated, reaching as far as the level of the setæ of segment ii. Its lateral margins diverge posteriorly, where it is indented at a blunt angle, as shown in Pl. I. fig. 9. The *ventral nerve-cord* shows small "copulatory glands" (Bauchmarkdrüsen) in segments xiv. and xv.; the cells of the glands embrace the cord laterally and ventrally, but not dorsally; owing to the connection of these cells with the surface epithelium, the cord appears stalked in transverse sections at these situations; there is externally a small transverse ridge opposite each gland.

The *testes* are one on each side, in the usual position. The *seminal funnels* are four times as long as broad, of the usual cylindrical form, but a little narrower towards their attachment to the septum; the lumen is obvious in the living condition, and in sections is seen to be not central but nearer the inner side; the margin of the internal aperture, where the spermatozoa enter the tube, is everted, so as to form a small true funnel, of a single layer of low columnar cells, perched on the cylindrical structure that usually goes by the name of 'funnel.' The *vas deferens* is thin, ·0075 mm. in diameter; it is but little coiled, reaches back to the level of segment xiii., and penetrates the penial gland nearer the outer than the inner side of the latter. The *male aperture*, in segment xii., consists of an invagination of the surface epithelium in a direction obliquely upwards and outwards (Pl. II. fig. 10); this invagination, narrow from side to side, receives the end of the *vas deferens*, not at its upper extremity, but on its inner wall; the invagination and its immediate neighbourhood are covered by a distinct and fairly thick cuticle. The *penial gland* (Pl. II. fig. 10) is a single ovoid mass on each side, consisting of much-elongated cells with nuclei near their internal ends; their external ends form the inner wall of the invagination previously referred to; the gland has a distinct though feeble muscular covering, and muscular strands pass obliquely upwards from its surface towards the lateral body-wall; other strands, passing over it obliquely from the ventral to the lateral body-wall, appear, so to speak, to bind it down.

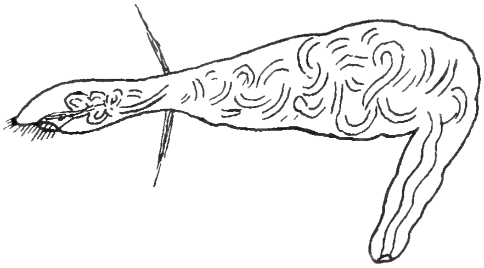


FIG. 9.—Nephridium of the same.

The *spermathecæ* consist of ampulla and duct, both of which present, especially in sections, a peculiar appearance, from the fact that the cells of which they are composed are irregular in size, shape, and disposition, and thus are very far from forming a regular epithelial lining (Pl. II. fig. 11). The ampulla communicates as usual with the œsophagus; in the living specimen it appears somewhat irregularly spherical, with projecting bosses. In sections the cavity is irregular in shape, possessing a few small saccular diverticula; the cells composing the wall are comparatively few, large in size, irregular in shape and arrangement, and do not form a regular epithelial layer. The spermatozoa penetrate between the cells, and the appearances in sections seem to show that they burrow into the cells themselves; they also seem to penetrate the wall, and are found lying on the outer surface (Pl. II. fig. 11). The ampulla possesses no muscular covering. The duct leads obliquely forwards to the exterior; it is a little longer than the ampulla, and, like the latter, appears in the living condition to be studded with small rounded projections, smaller, however, than those of the ampulla; round the external aperture these projecting cells are again larger, and form a distinct rosette of glands. The statements as to irregularity of shape and disposition of the cells, and absence of a definite epithelium, already made for the ampulla, hold also for the duct; so that, except near the external aperture, it is difficult to follow the lumen in sections. The cuticle of the surface is invaginated for some little distance at the external aperture, and muscular fibres continuous with those of the body-wall are conspicuous among the cells of the duct; but these latter are not continued on to the ampulla.

The *clitellar cells* are entirely wanting over the mid-ventral region of the body, along an area whose breadth is the distance between the male apertures of the two sides (Pl. II. fig. 10).

The species to which the present form shows most resemblance, at least externally, seems undoubtedly to be *Enchytræus argenteus*, MICHAELSEN (11). The same opaque white colour characterises both, and in both is due to the same cause—the presence of opaque granular cœlomic corpuscles; further, owing to the varying aggregations of these corpuscles in different parts of the body, the whiteness is not uniform in either.

But, apart from such indifferent features as the colourless blood and the absence of peptonephridia in both (probably, since MICHAELSEN does not mention these structures), the resemblances seem to end here. The differences in size (*E. argenteus*, 2·5–5 mm., present form 8 mm.), in number of segments (*E. a.* twenty-three to thirty, present form thirty-two to thirty-nine), and in number of setæ per bundle (*E. a.* two or three, present form regularly two), are not very great; the chief differences are those of the cerebral ganglion, nephridia, seminal funnel, and spermathecæ.

The cerebral ganglion has a rounded posterior end in *E. argenteus*, while in the present form it is indented posteriorly; the seminal funnel is short, somewhat longer than broad in the former, while it is four times as long as broad in the latter. The ampulla of the spermatheca is of an inverted pear-shape in the former, and the duct is simple (without gland-cells); the peculiarities of these structures in the present form have been described above. The nephridia of *E. argenteus* are not constricted at their passage through the septa, and the lumen forms a small number of regularly arranged and consecutive loops in the post-septal portion; in the form under description there is a constriction at the septum, and the lumen undergoes many and irregular windings in the post-septal portion. I propose, therefore, to consider the present form as a new species, under the name *Enchytræus nodosus.*[*]

It is interesting to note here again, as has already been done from the other side in the case of *Lumbricillus viridis*, indications of transition between the genus *Enchytræus* and the Lumbricilline group. In the present case these are (1) the seta shown in fig. 8, *b*, with its double curvature, as opposed to the straight setæ of *Enchytræus*; (2) the presence of small 'copulatory glands' in segments xiv. and xv.; and (3) the definite and single penial bulb. I have already referred to the importance assigned by EISEN to this structure, and to the fact that this author distinguishes two sub-families, the Lumbricillinæ and Enchytræinæ, according to the presence of a single penial bulb, or its substitution by a number of separate aggregates of gland-cells.

It seems doubtful whether the presence or absence of a penial bulb is of sufficient importance to serve as a basis for the distinction of sub-families, or even, perhaps, of genera. And it is interesting in this connection to compare MICHAELSEN's figure (10) of the structures round the male genital aperture in *Enchytræus möbii* (= *albidus*), which shows that there is there a true "penial bulb" surrounding the end of the vas deferens, such as is met with in *Lumbricillus*; it is, however, of comparatively small size, and there are in addition separate aggregates of gland-cells on each side of the bulb. In other words, there is a condition intermediate between, or representing a combination of, those described by EISEN as characteristic of his two sub-families.

Enchytræus dubius, n. sp.

Found under stones, between tide-marks, at Wemyss Bay. While the majority of specimens of other species of Enchytræids were sexually mature from May to July, in this case the greater number of specimens were without sexual organs.

The animals showed a great tendency to curl up. In *length* they were half an inch (12 mm.) or less. In *colour* they were whitish; examined with a lens they were only moderately translucent under pressure, and showed a considerable amount of white opacity in the middle region of the body along the borders of the alimentary canal, due to aggregations of cœlomic corpuscles and chloragogen cells. The clitellar region was no more opaque than the rest of the body.

Segments, forty-four. *Prostomium* rounded or very bluntly conical, with minute secondary projections. *Head-pore* between prostomium and first segment.

The *setæ* are in four rows, two ventral and two lateral. With very rare exceptions, there are two setæ per bundle throughout, except that ventral setæ are always absent in segment xii. Both ventral and lateral setæ are of the same shape, straight, with a

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[*] The *E. parvulus* of FRIEND (6, 7), is doubtfully identified by MICHAELSEN (11), with *E. argenteus*. The data do not permit a detailed comparison of *E. parvulus* with the present form; but the two would seem to differ, at any rate, in the numbers of the setæ and shape of the cerebral ganglion, and less markedly in size and number of segments.

proximal curve, thickest in the middle (*v.* fig. 10, *a*). In length, the setæ vary considerably, from ·045 to ·072 mm.; the average is about ·06 mm. There is no constant difference between the lengths of ventral and lateral setæ; nor between those of the anterior and posterior regions of the body, except that the average length of the posterior is perhaps a little less than that of the anterior setæ.

The setæ also vary considerably in thickness, viz. from ·006 mm. to ·0045 mm. The sharpness of their points varies, probably to some extent at least with age; newly formed setæ (in which the basal curved portion is not yet present) have sharp points, while in others they may be quite blunt, almost truncated.

Many setæ show a refractile, elongated, sometimes spindle-shaped body in their centre, about the middle of their length (in glycerin preparations); the appearance is possibly due to some separation of the component fibrils (fig. 10, *a*). The setæ appear to be shed periodically; there may occasionally be seen two newly forming setæ with an old one, in the same bundle, and thus there is presented the appearance of three setæ per bundle.

The *alimentary tract* shows no demarcation into separate regions between the pharynx in the second and third segments and the intestine, which begins suddenly in the fourteenth. The septal glands in segments iv. and v. are of moderate size, those in segment vi. are large; the individual cells composing the glands are visible in the fresh state. There are no peptonephridia. Chloragogen cells begin in segment vii., or there may be a few in segment vi.; they are comparatively few and discrete up to xi., absent in xii. and xiii., numerous and close-set from xiv. onwards till near the posterior end, where they are fewer, and finally absent. The cells are of large size, with prominent oil-drops; in sections they are tall, elongated vertically to the alimentary wall, and present numbers of vacuoles. The alimentary canal is attached by stout strands to the ventral body-wall in each segment.

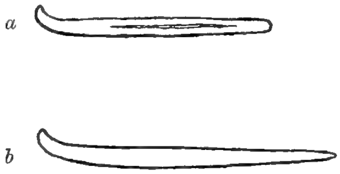


FIG. 10.—Setæ of *Enchytræus dubius*: *a*, pointed; *b*, blunt, with refractile appearance in its centre.

The *dorsal vessel* may begin in segment xiv., or at the posterior boundary of segment xii.; it bifurcates in the prostomium. The *ventral vessel* is formed about the level of septum $\frac{3}{4}$ by the union of the two terminal branches of the dorsal vessel. There are four *commissural loops* in the anterior part of the body; these are contained mostly in the third and fourth segments, but their exact position is not, apparently, always the same. The *blood* is red.

The ante-septal portion of the *nephridia* is small; very fine cilia are attached to the rim of the funnel, and longer cilia beat down the lumen; the post-septal is of a stout ovoid shape; the duct or terminal portion of the nephridium comes from the posterior end of the post-septal, is remarkably stout, constricted at the orifice, has a vertical course, and is equal to the post-septal in length.

The *cœlomic corpuscles* are numerous, and have the form of large flat discs, irregularly circular or oval in shape, very coarsely granular, with a small nucleus which is not obvious in the fresh state but is visible in stained preparations. By transmitted light the corpuscles are grey. In diameter, they were estimated at about ·045 mm. in the living animal; but in sections they are about ·03 mm., the largest being ·033. As in so many species, they may be discharged in large numbers from near the anus under pressure; after being shed they become regularly circular in outline.

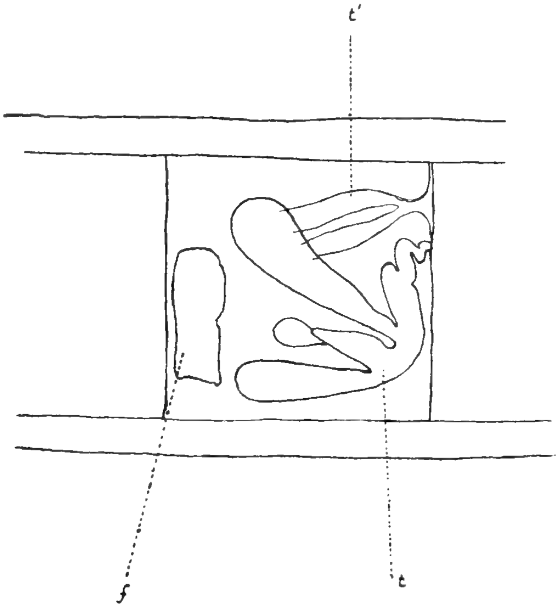


FIG. 11.—Outline of male organs in segment xi. of a specimen of the same (sketch from the living animal): *f.*, funnel; *t.*, testis of one side; *t.*^{1}, testis of the other side, faintly seen.

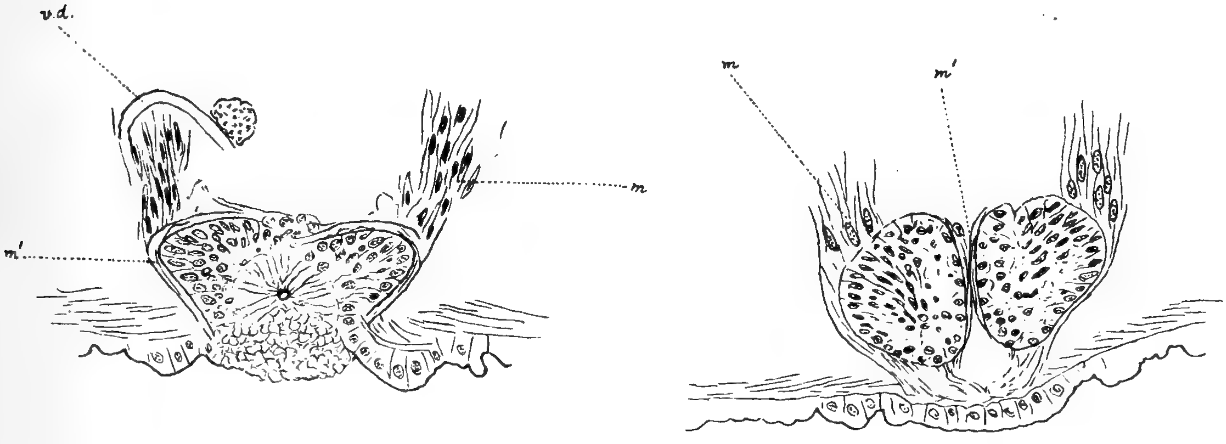
The *cerebral ganglion* is nearly twice as long as it is broad, is deeply indented posteriorly, and extends back as far as the level of the setæ of the second segment.

The *testes*, on the posterior face of septum $\frac{10}{11}$, are large, and resemble somewhat those found in the genus *Lumbricillus.* They have a limited origin from the septum; from this limited origin there springs an elongated, coiled, or bent cellular cord, which may swell to an irregular bulky mass, and gives off, near or at some distance from its base, two or three branches, of the same character, and, it may be, almost of the same size as itself (fig. 11, Pl. II. fig. 12). Sperm morulæ may be present in all segments from vi. to xiii.

The *funnels* are comparatively small, about four times as long as broad, narrower towards their attachment to the septum. The *vas deferens* is long, thin, coiled, in segment xii. The *penial gland* is not large; its peculiarity is that it is bifid internally; thus in a series of longitudinal sections it is first met with as a single mass (fig. 12, *a*), while, nearer the middle line, it is completely double (fig. 12, *b*). It is attached by two thick strands, composed of cells with large oval nuclei, to the dorso-lateral body-wall. A portion of the strands, which are so disposed as to be one anterior and one posterior, passes internal to the gland ventrally to be inserted into the ventral body-wall; the glands are thus to some extent bound down by the strands. Dorsally the strands split up and radiate to their attachments.

The *ovaries* have the usual position. Ova are found in segments xii. and xiii.

The *spermathecæ* in segment v. are not large, and have the form of an elongated spindle, somewhat bent on itself. The communication with the œsophagus is narrow. Gland-cells are disposed in radial masses round the external aperture. There is no distinction of ampulla and duct to be made out in the entire animal; sections, however, show a small ampulla with thin walls, and a much longer and thicker walled duct, with a fairly wide lumen (Pl. II. fig. 13). The walls of the duct are composed of columnar cells, and appear markedly transversely striated in the living condition (Pl. II. fig. 14).



a FIG. 12. *b*

a, longitudinal section through outer part of penial gland of the same.

b, a similar section, a little internal to the previous one. The penial gland here appears double.

m., muscular (cellular) strands attaching penial gland to body-wall; $m.^1$, muscular covering of gland itself; *v.d.*, vas deferens before entering the gland.

It is possible that the ampulla would be relatively larger if it were swollen by spermatozoa; none of the organs in my preparations, however, contain any.

Copulatory glands ("Bauchmarkdrüsen") are well marked in segment xv.; the mass of cells closely invests the cord, and projects upwards on each side above the level of the cord; there is, in longitudinal sections, a small papilliform projection of the surface of the body at the level of the middle of the gland.

In xiv. the copulatory gland is smaller, but still projects on each side above the level of the cord. In segments anterior to this, from xiii. to ix., the cells around the cord in the posterior part of each segment appear to be of the same nature, as evidenced either by the papillary projection on the surface or by the fact that the cells penetrate the muscular layers of the body-wall to become continuous with the surface epithelium.

I have referred in the Introduction to the several Lumbricilline features exhibited by this worm.

Enchytræus sabulosus, Southern.

This species was discovered by SOUTHERN (12) in Dublin Bay, living under stones and amongst the gravel at high-water mark. This is apparently the only record of its occurrence; I therefore give a few notes on Scotch specimens which I believe to be identical with it.

The worm was found at Wemyss Bay, under stones near high-water mark, at a spot where fresh water was running to the shore.

Length about $\frac{3}{4}$ inch (18 mm.); *colour* white. Anterior end tapers somewhat, posterior end blunter. *Prostomium* bluntly conical. *Segments* forty-six to forty-nine. *Clitellum* on segments xii.–xiii.

Setæ of the form usual in the genus, in length ·071 to ·088 mm. Their peculiarity lies in the number per bundle—with few exceptions three in the ante-clitellial, two in the post-clitellial bundles; occasionally there are three setæ in a post-clitellial bundle, and young replacing bundles are sometimes seen near the functioning bundles. In segment xii. there are no ventral setæ, and the dorsal setæ are in this segment two per bundle. The fact that in my specimens the post-clitellial bundles have only two setæ is the most important difference from SOUTHERN's description; for he states that the number is regularly three throughout the body.

Septal glands bulky, the last pair being the largest. *Peptonephridia* (Pl. II. fig. 15) as small hollow tubes, bent once or twice, or slightly coiled, extending backwards as far as the first pair of septal glands, and opening anteriorly close together into the pharynx on its dorsal wall. I have no note of any special peculiarity of the *chloragogen cells,* which begin in segment vii.; SOUTHERN considers their large size and their oil-drops to be of value as a specific distinction.

The *dorsal vessel* begins in segment xv. (junction xvi. and xvii., SOUTHERN). The *blood* is colourless. The *cœlomic corpuscles* are irregular, ovoid or pear-shaped, granular, with a clear nucleus. The *nephridia* are as described by SOUTHERN; they begin in segment vii.

The *cerebral ganglion* is one-and-a-half times as long as broad (Pl. II. fig. 15), its sides nearly parallel, its posterior end rounded, not indented. Two small dark spots may be seen on it, as in specimens of *E. albidus*; but they are not so conspicuous in the present form. The *ventral nerve-cord* shows ganglionic swellings in segments ii., iii., and iv.; thereafter the swellings are slight or absent, and the cord, as seen in the living animal, is of the same thickness throughout.

The *sperm morulæ* may bulge forwards as far as the level of the setæ of segment viii. The *sperm funnels*, about four times as long as broad, are as described by SOUTHERN. The *vas deferens* is a stout tube, not much coiled, extending back as far as segment xviii. The *glands* round the male aperture are constituted by a number of separate aggregations of cells, and do not form a single penial bulb.

The *spermathecal apparatus* is represented in Pl. II. fig. 15; the general form is somewhat similar to that illustrated in SOUTHERN's figures; the ampulla, comparatively small, spherical or slightly elongated, is smaller, and the duct, tuberculated as in *E. albidus*, is thicker than there depicted.

Enchytræus albidus (Henle).

This worm has frequently been described, but under a very large number of different names. According to the synonymy given by MICHAELSEN (11), thirteen authors have, in eighteen papers, given to this animal five generic and twelve specific names. Perhaps the fullest account of the worm is that given by MICHAELSEN (10) in 1886, in his thesis *Untersuchungen über* Enchytræus Möbii, *Mich., und andere Enchytræiden*; GOODRICH (8) has more recently, under the name *E. hortensis*, described a form which MICHAELSEN considers identical with the above, and has paid special attention to the nephridia and cœlomic corpuscles. A few remarks, chiefly in regard to points in which the Millport specimens vary from the above descriptions, will therefore be sufficient.

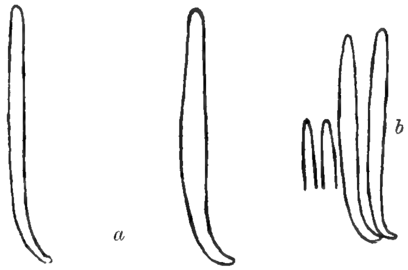


FIG. 13.—*a*, two setæ of *Enchytræus albidus*.
b, a bundle of setæ of *Enchytræus albidus*, showing two immature replacing setæ, along with two fully formed setæ which are destined to drop out.

The worms were found about high-water mark in places where fresh water was running to the shore; it was common under stones, and also among the roots of plants. In *length* specimens are $\frac{2}{3}$ to $1\frac{1}{4}$ inches; they are comparatively stout, the anterior end tapering, the posterior blunter; they are whitish in *colour*, fairly transparent, and easy to examine by the microscope in the living state. *Segments* fifty-two to sixty-six. The *clitellum* occupies segments xii. and xiii. The animals move by crawling, or at times by wriggling; they often throw themselves into nematode-like contortions; at rest, in a dish, they curl themselves up.

As to the *setæ*, previous descriptions, and fig. 13, *a*, will be a sufficient guide as to their shape. There are no ventral setæ in segment xii.; they are more numerous in the anterior than the posterior segments, the numbers being three to five (commonly four) in the ante-clitellial ventral bundles, two to four (commonly three) in the post-clitellial ventral bundles; for the lateral bundles the numbers are two to four ante-clitellial, and two or three post-clitellial. In length the setæ of the posterior part of the body appear to be, on the average, rather longer than those of the anterior; the longest may measure up to ·1 mm. The bundles are replaced during the life of the animal (fig. 13); thus there may appear to be eight setæ in a bundle, but of these one group of four will be immature, wanting the proximal hooked end.

The *alimentary tract* (Pl. II. fig. 16), with its appendages (septal glands, pepto-nephridia), corresponds with previous descriptions, except that I have not found, as Goodrich states for his form, the last pair of septal glands smaller than the others. The *dorsal vessel* may take its origin from the intestinal sinus in segments xiv., xv., xvi., xvii., or xviii; the *lateral commissures* may be four in number, in segments ii., iii., iv., and v., but I am not satisfied that this number and arrangement are constant. The *blood* is colourless.

One kind of *lymph corpuscles* only is mentioned by Michaelsen—flat, oval, or pear-shaped cells, nucleated, with a large nucleolus; Goodrich mentions three kinds, and gives a detailed description of each. In my specimens I noted two forms of cœlomic corpuscles—one granular, flat, irregularly pear-shaped or oval, and nucleated, corresponding to Michaelsen's description; the other spherical or irregular, not flattened, homogeneous, more refractile than the first type, apparently not nucleated and not so numerous as the first kind. These may perhaps correspond to the first type of cœlomic corpuscle described by Goodrich.

The *cerebral ganglion* lies in segment i., attached to the dorsal wall of the buccal cavity; it is one-and-a-half times as long as broad when the head is extended; its posterior border is convex or flattened. The two authors already quoted both found it to be slightly indented behind. A pair of spots occur near the posterior margin of the ganglion, dark by transmitted light. They were often very large and conspicuous, and sometimes contained a few refractile particles besides the usual granular matter of which they seemed to be made up. They were not always quite symmetrically placed (Pl. II. fig. 16).

There is a well-marked tubular cavity dorsally in the substance of the *ventral nerve-cord* all through the clitellar region, and for some distance in front of this; it splits up into several smaller tubes in the region of the last septal glands, and some of these tubes can be followed for some distance farther towards the head.

The *funnels* of the vasa deferentia vary much in shape; when the animal stretches itself out, they may be seven or eight times as long as broad; ordinarily they are perhaps about five times, and sometimes may appear as little as three times as long as broad. The *vasa deferentia* may extend backwards as far as segment xxi. The *vesiculæ seminales* are constituted by a bulging forwards of septum $\frac{10}{11}$; thus masses of spermatozoa are seen to surround the œsophagus in segments x. and xi., or ix., x., and xi.

The shape of the *spermathecæ* deserves mention, since it differs from that described by the two authors previously quoted. Thus Michaelsen's figure shows the cavity of the spermatheca as squarish, with no special bulging anywhere; while, according to Goodrich, the œsophageal and external openings of the spermatheca are about at the same level, but the cavity of the ampulla is produced backwards into a large posterior sac. In my specimens the spermathecæ appear in an early stage of their development as simple tubes, not dilated anywhere, passing obliquely backwards from their external opening between segments iv. and v. to the œsophagus. In the fully formed organ the ampulla is large, ovoid in shape, with long diameter antero-posterior; it fills up the space on each side between the œsophagus and body-wall. It opens into the œsophagus near its posterior end, the aperture of communication being ventrally placed with regard to the cavity of the ampulla. In front the ampulla passes into the duct, the boundary between the two being, in the fully dilated condition of the ampulla, quite sudden. The duct is about as long as the ampulla, and forms a stout tube, straight, or more usually, in the contracted condition of the animal, somewhat bent; the outline of the tube is irregular, appearing to be studded with small excrescences; these irregularities are due to the projection of the cells of which it is composed beyond the muscular layer.

Some ciliated *parasites* were seen on one occasion in the body-cavity.

I think there is no doubt that this worm is most suitably included under *E. albidus*, in spite of a few divergences from previous descriptions. These divergences seem to be the following:—(i.) Extent of clitellum; this Michaelsen gives as half xi. to half xiii., while his figure shows it as extending nearly to the anterior border of xi., and leaving a large part of xiii. unincluded; (ii.) the lymph-corpuscles (*v. sup.*); (iii.) the dark spots on the cerebral ganglion (which may, however, merely have gone unrecorded); (iv.) the difference in the canals of the ventral nerve-cord in Michaelsen's description and mine; (v.) the difference in the shape of the spermathecæ. To these may be added the fact that I have not noted in my specimens collections of sensory cells near the apertures of the spermathecæ, as figured by Michaelsen.

Fridericia bulbosa (Rosa).

This species is widely distributed, and has recently been recorded from Ireland (14). It appears, however, to be somewhat variable, and different authors have given different descriptions of, for example, the shape of the cerebral ganglion, the form of the pepto-nephridia, and the ducts of the spermathecæ with regard to the presence or absence of gland-cells round the orifice. A brief account of the features in which, from the descriptions of previous observers, some amount of variation appears to have been established, may therefore be of interest.

The first point is the habitat of the Millport specimens. They were found under stones, between tide-marks, at Balloch. The species lives, according to Michaelsen (10), in rotten wood or damp leaves; indeed the genus *Fridericia* as a whole "is terrestrial, and found in the driest localities" (Beddard, 1, p. 312), a fact which Beddard brings into relation with the occurrence of dorsal pores in the genus.

As to its anatomical features, the worm was $\frac{1}{3}$ to $\frac{1}{2}$ inch (8 to 12 mm.), in length, filiform, white in colour, very sluggish. Prostomium short, rounded; head-pore visible as a somewhat elongated slit, at the junction of prostomium and first segment; clitellum extending over most of xii. and half or more of xiii.; segments thirty-eight to forty-five. Dorsal pores from vii. onwards, some little distance behind the septa; with two cells in relation to each, granular and with large nuclei, one anterior and one posterior.

The *setæ* are absent in xii.; form, numbers, and distribution as previously recorded. The larger (outer pair) setæ are comparatively short in the first segments (·047 mm.), and their length increases towards the clitellar region, near which it attains a first maximum (·066 mm.); diminishing in the middle region of the body (·048 mm.), the length again increases, and reaches a second maximum, higher than the first (·075 mm.), near the posterior end. Their thickness varies a little; it is often about a tenth of their length, or even more, *i.e.* ·0044 to ·0057 mm. (*cf.* fig. 14, *a*).

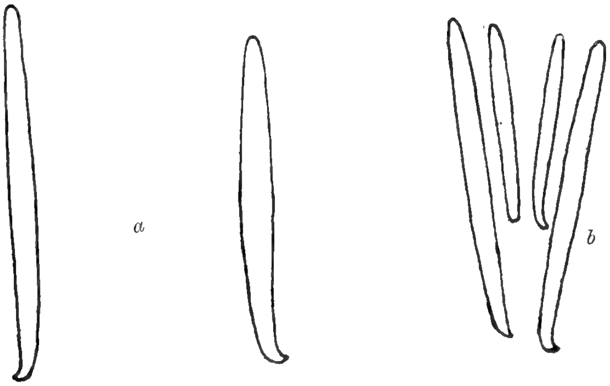


FIG. 14.—*a*, large setæ of *Fridericia bulbosa*. *b*, a group of setæ of the same, showing relation of smaller setæ to the larger.

The smaller setæ, included between the larger in the anterior part of the body, have their outer ends on a level, or almost so, with the ends of the large setæ, but their hooked inner ends are at a more superficial level. In length they are about two-thirds the size of the larger, *i.e.* ·03 to ·04 mm. (*cf.* fig. 14, *b*).

The *peptonephridia* enter the œsophagus in segment iv., and extend back to the level of the setæ of v. They are not, in my specimens, branched or expanded at their ends.

The *dorsal vessel* originates in segments xix., xx., or xxi. The *blood* is colourless.

The *cœlomic corpuscles* are all of one kind, large, flat, oval discs, granular, nucleated, up to ·022 mm. in diameter. The *nephridia* have the characters given in previous descriptions, the ante-septal portion being comparatively large, about one-third to one-fourth the length of the post-septal. The *cerebral ganglion* is twice as long as broad, with a rounded posterior end; it extends back a considerable distance into segment ii.; its lateral margins converge somewhat towards the front. The ventral *nerve-cord* has copulatory glands ("Bauchmarkdrüsen") associated with it in segments xiii. and xiv.

This species shows the commencement of definite *sperm* and *ovisac*; septum $\frac{11}{12}$ is markedly bulged backwards, so as to reach what would normally be the hinder limit of the next posterior segment, and the developing sperm-morulæ, contained in the sac so formed, do not pass beyond it; similarly the ova are contained in a posterior bulging of septum $\frac{12}{13}$.

The *funnels* are between two and three times as long as broad; the *vas deferens* is a coiled narrow tube, confined to segment xii.; there is a well-marked *penial bulb* immediately on the inner side of the termination of the vas deferens at the male aperture; the vas can thus hardly be said to perforate the bulb (Pl. II. fig. 17). The *spermatheca* and its duct have the form and relations described by previous observers; there are, in my specimens, no glands round the duct or its aperture.

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EXPLANATION OF PLATES.

Fig. 1. Diagram of the vascular system of *Tubifex costatus*.

Fig. 2. Part of the anterior end of *Marionina semifusca*.

Amp., ampulla of spermatheca; *comm.*, communicating cord from septal glands to pharynx; *d.*, duct of spermatheca; *gl.*, gland-cells round spermathecal aperture; *n.*, nephridium of segment v.; *œs.*, œsophagus; s^4–s^6, septal glands of the fourth to the sixth segment; *ph.*, pharynx; *sp.*, septum $\frac{5}{6}$.

Fig. 3. Part of the anterior end of *Lumbricillus subterraneus.*

Comm.^{1}, communicating strand from septal gland of the fifth to that of the fourth segment; *spth.*, spermatheca (duct and ampulla not distinguishable). Other references as for fig. 5.

Fig. 4. Transverse section of ventral nerve-cord and 'copulatory gland' of *Lumbricillus subterraneus.* × 640.

b. bridge of deeply staining tissue connecting the two sides of the gland dorsal to the cord; *c.*, central canal of the nerve-cord; *c.m.*, circular muscular layer; *ep.*, surface epithelium, in which cell outlines are indistinguishable; *gl.*, a cell of the copulatory gland, the body of the cell staining equably; *gl.*^{1}, another gland-cell, the cell body showing a reticular structure and staining very slightly; *l.m.*, longitudinal muscular layer; *n.*, fibrous part of nerve-cord, below and to the right of which are seen the granular nuclei of the ganglion cells; *st.*, 'stalk' of attachment of copulatory gland to the surface epithelium.

Fig. 5. Longitudinal section through spermathecal apparatus of *Lumbricillus subterraneus.* × 220.

Al., alimentary canal; *amp.*, ampulla of spermatheca; *ap.*, aperture of its duct; *c.*, circular muscular layer of body-wall; *d.*, duct of spermatheca; *ep.*, surface epithelium; *gl.*, gland-cells near aperture of spermatheca; *l.*, longitudinal muscular layer of body-wall; *m.*, muscular layer of duct of spermatheca; *m.*^{1}, the same layer between the cells, where these are elongated and glandular; *s.gl.*, septal gland; *spz.*, spermatozoa in ampulla of spermatheca.

Fig. 6. Longitudinal section through male aperture of *Lumbricillus tuba.* × 250.

Cl., clitellar epithelium; *ep.*, lower, more deeply staining epithelium round male aperture; *m.*, muscular capsule of penial gland; *m.*^{1}, muscular strand of attachment, cut through; *v.d.*, vas deferens; ♂, male aperture.

Fig. 7. Longitudinal section through ampulla and first part of duct of spermatheca of the same. × 250.

Amp., ampulla; *d.*, duct; *œs.*, œsophagus; *s.gl.*, septal gland of fourth segment.

Fig. 8. Longitudinal section through aperture of duct of spermatheca of the same, to show the continuity of the surrounding gland-cells with the cells of the surface epithelium and of the duct, and their relation to the muscular layer. × 250.

M., muscular layer clothing duct, continued ventrally between gland-cells; *s.gl.*, septal gland.

Fig. 9. Anterior part of the body of *Enchytræus nodosus*, semi-diagrammatic.

Amp., ampulla of spermatheca; *c.g.*, cerebral ganglion; *conn.*, connection between septal glands and pharynx; *conn.*^{1}, that between the glands of segments v. and iv.; *d.*, duct of spermatheca; *g.*, gland-cells round aperture of spermatheca; *m.*, muscular strands attaching pharynx to body-wall; *œs.*, œsophagus; *ph.*, pharynx; *s.gl.*$^{1-3}$, septal glands of segments iv.–vi.; *vac.*, vacuole-like appearances in posterior part of cerebral ganglion.

Fig. 10. Transverse section through male aperture of the same. × 550.

Cl., clitellar epithelium; *cut.*, cuticle; *ep.*, lower, non-glandular epithelium over area around and between male apertures; *invag.*, the invagination representing the male aperture, at the place where it receives the termination of the vas deferens; *m.*, muscular strand from penial bulb to body-wall; *m.*^{1}, muscular covering of penial bulb; *p.*, cells of penial bulb; *v.d.*, vas deferens before penetrating penial bulb; *v.n.c.*, ventral nerve-cord.

Fig. 11. Longitudinal (somewhat oblique) section through spermatheca of the same. × 640.

Amp., cells composing wall of ampulla; *c.m.*, circular muscle layer of body-wall; *cut.*, cuticle; *ep.*, surface epithelium; *g.*, gland-cells near aperture of spermatheca; *l.m.*, longitudinal muscle layer of body-wall; *per.*, peritoneal cells; *s. gl.*, septal gland of segment iv.; *spz.*^{1}, spermatozoa in ampulla; *spz.*^{2}, spermatozoa between cells of wall of ampulla; *spz.*^{3}, spermatozoa outside ampulla.

Fig. 12. Longitudinal section through segment xi. of a specimen of *Enchytræus dubius.* × 250.

B.-v., a blood-vessel; *corp.*, cœlomic corpuscle; *dis.*, dissepiment $\frac{11}{12}$; *f.*, sperm funnel; *sp.*, mass of developing sperm cells; *t.*, testis at its attachment to septum $\frac{10}{11}$; *t.*^{1}, other portions of the branching testis.

Fig. 13. Longitudinal section through spermatheca of *Enchytræus dubius.* × 250.

Amp., small dilatation, with thinner walls, at œsophageal end of spermathecal apparatus, representing the ampulla; *c.*, circular muscular fibres of body-wall; *œs.*, œsophagus; *s.gl.*, septal glands; *spth.*, main portion of spermathecal apparatus, representing the duct; *v.*, vacuole in surface epithelium.

FIG. 14. Sketch illustrating the appearance of the spermathecæ of *Enchytræus dubius* in the living animal.

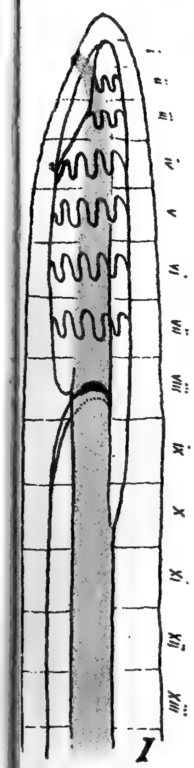
FIG. 15. Anterior part of the body of *Enchytræus sabulosus*; semi-diagrammatic, from the living animal.
Amp., ampulla of spermatheca; *c.g.*, cerebral ganglion; *d.*, duct of spermatheca; *œs.*, œsophagus; *pnph.*, peptonephridium; *ph.*, pharynx; *pr.*, prostomium; *s.g.*$^{1-3}$, the septal glands of segments iv.–vi.; *i.–vii.*, segments i.–vii.

FIG. 16. Anterior part of the body of *Enchytræus albidus*, semi-diagrammatic.
Amp., ampulla of spermatheca; *c.g.*, cerebral ganglion; *comm.*, communicating cord from septal glands to pharynx, splitting up into numerous smaller strands at its junction with pharynx; *d.*, duct of spermatheca; *œs.*, œsophagus; *pnph.*, peptonephridium; *ph.*, pharynx; *pr.*, prostomium; *s.*, dark spot in cerebral ganglion; *s.gl.*$^{1-3}$, the three pairs of septal glands.

FIG. 17. Ventral portion of a transverse section through the penial bulbs of *Fridericia bulbosa*. × 250.
Al., alimentary canal, ventral to which are seen the ventral nerve-cord and ventral vessel; *p.*, penial bulb of one side; *sp.*, septum $\frac{11}{12}$ bulged backwards to form a sperm-sac; ♂, male aperture.

FIGS. 4, 6, 7, 8, 10, 11, 12, 13, 17 drawn from sections by means of Zeiss's Abbé's drawing apparatus.

STEPHENSON: SOME LITTORAL OLIGOCHÆTA OF THE CLYDE—PLATE I.



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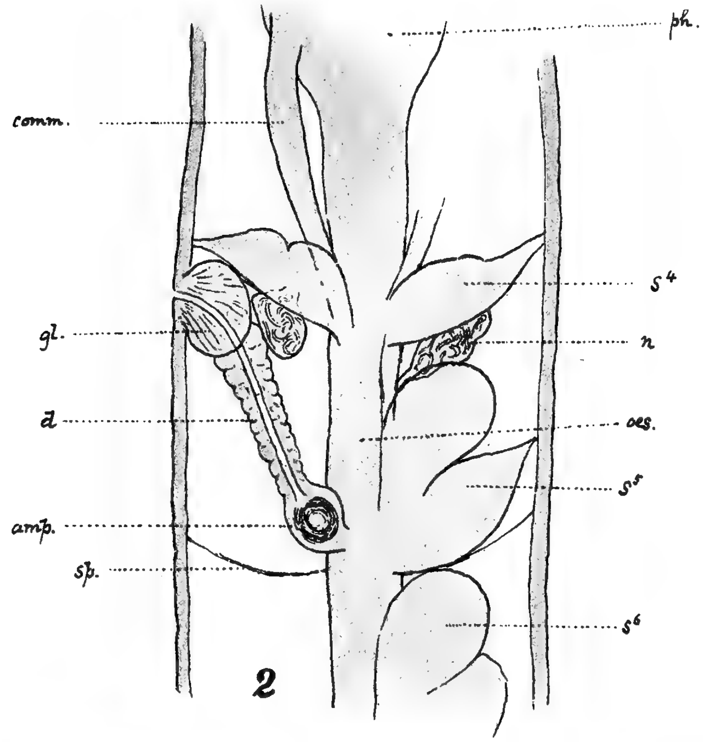

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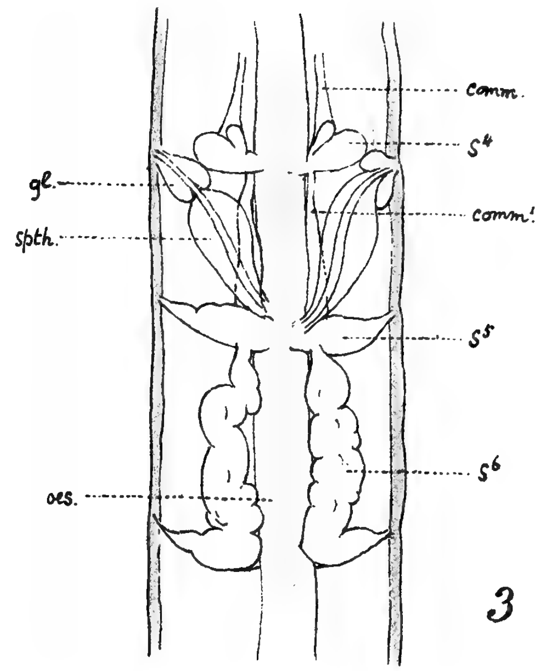

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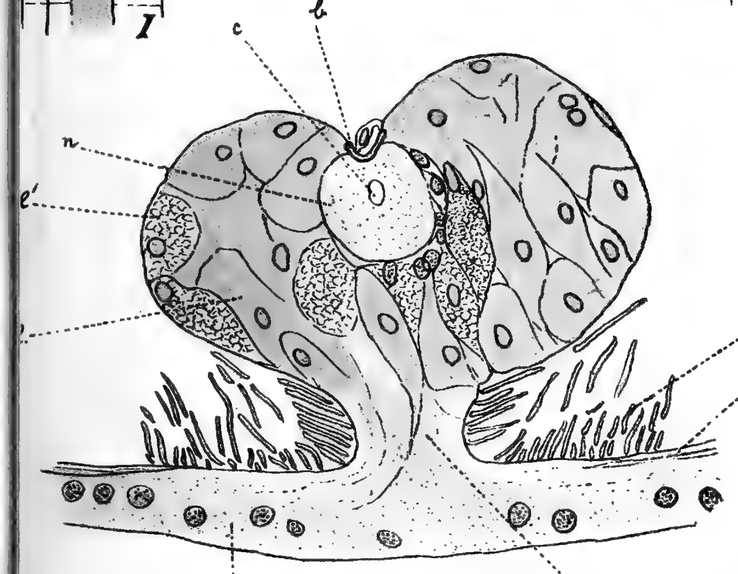

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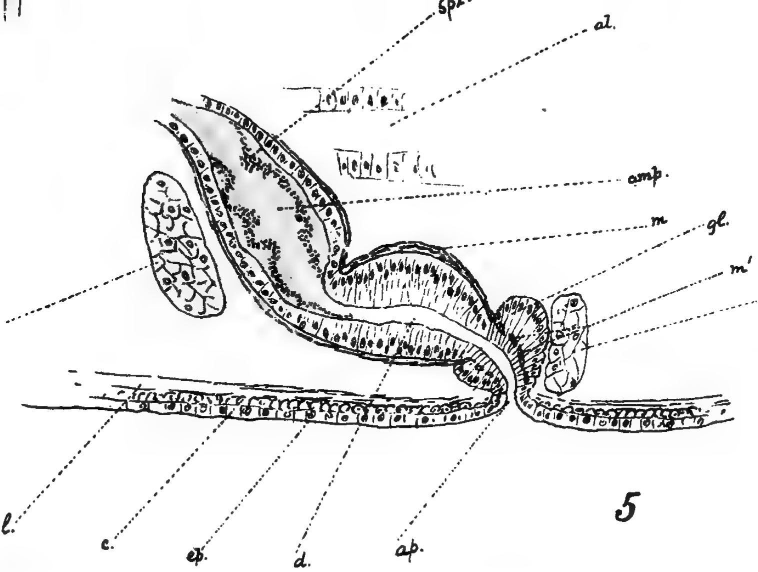

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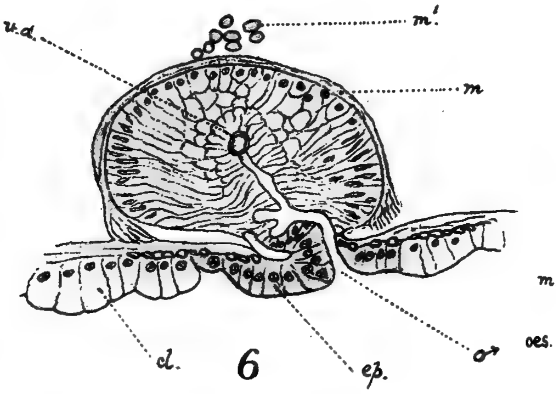

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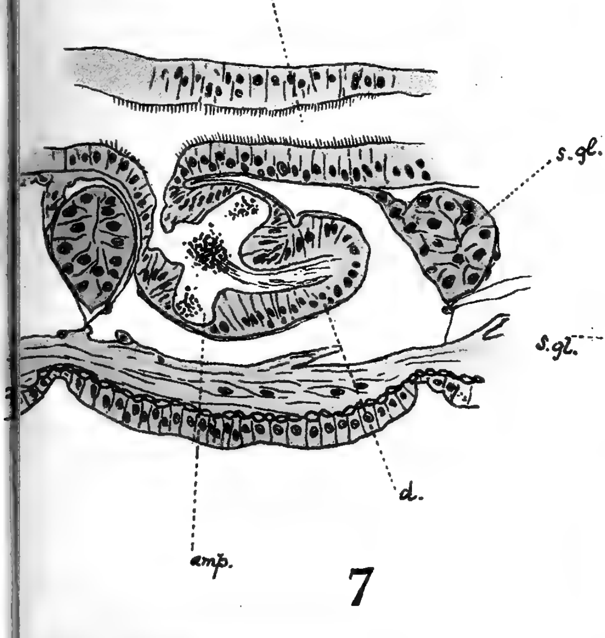

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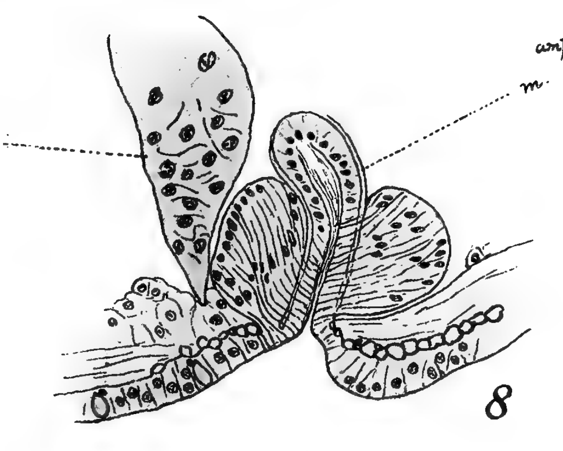

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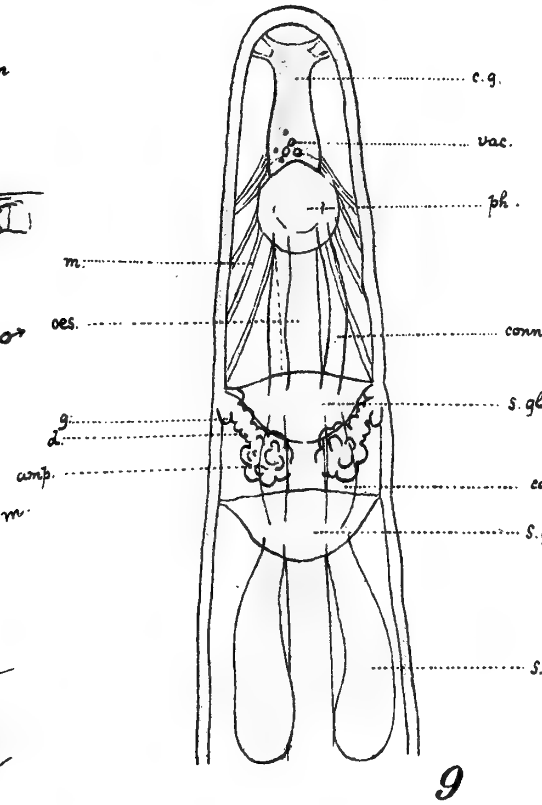

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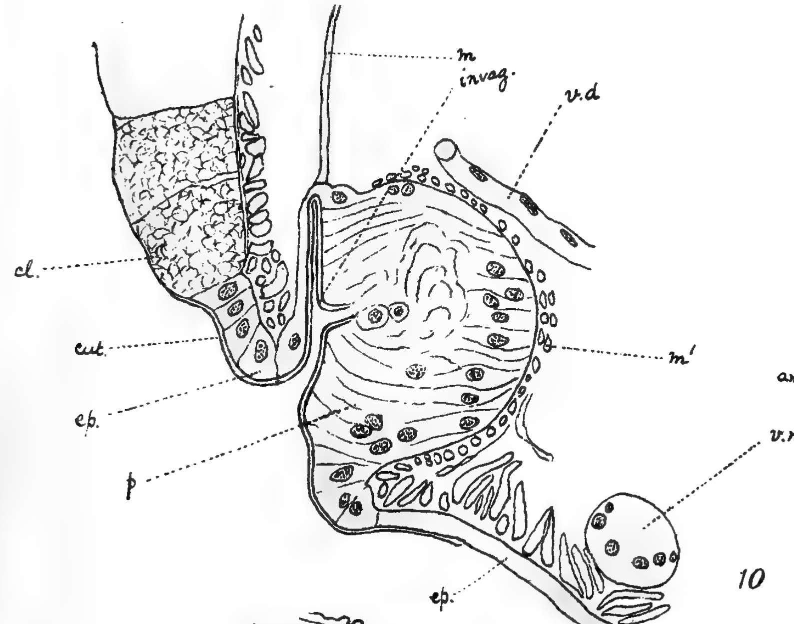
STEPHENSON: SOME LITTORAL OLIGOCHÆTA OF THE CLYDE—PLATE II.



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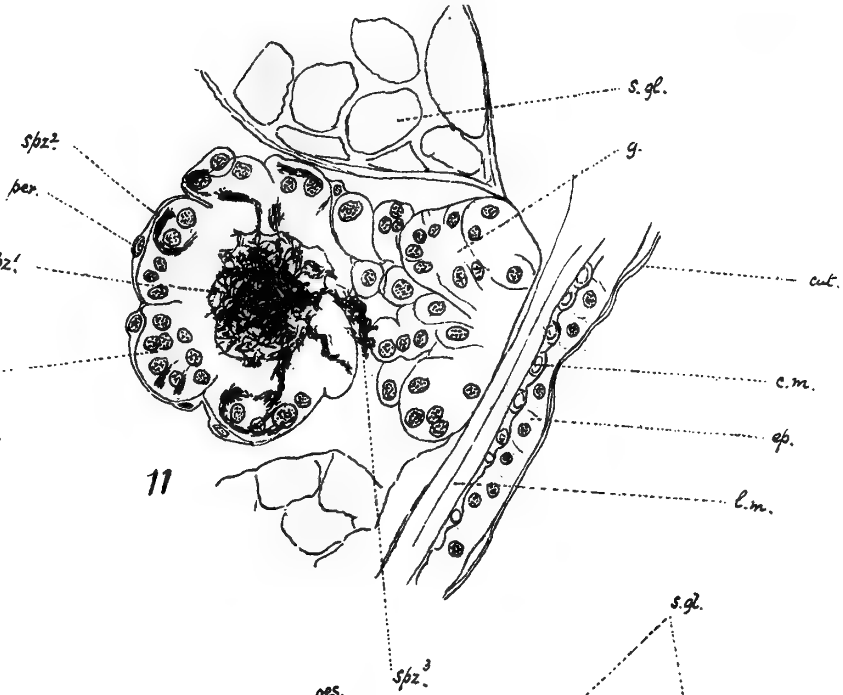

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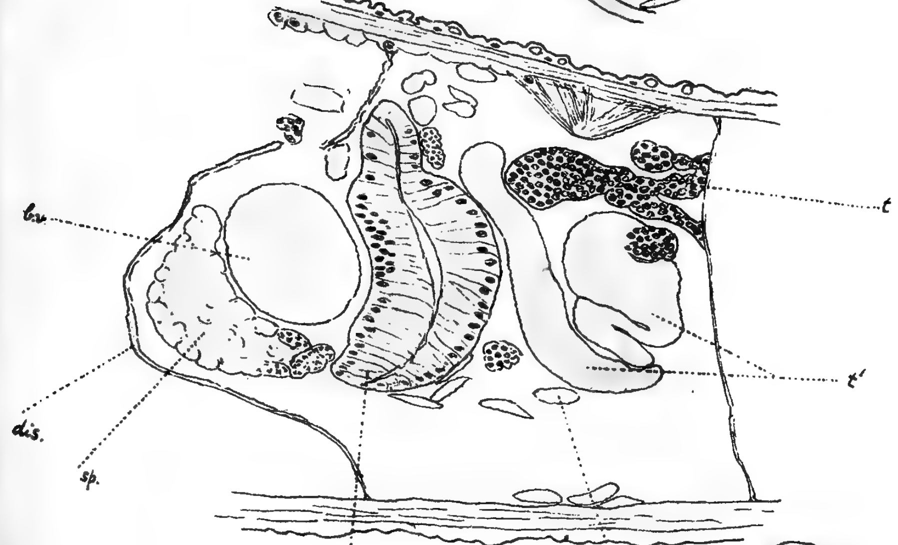

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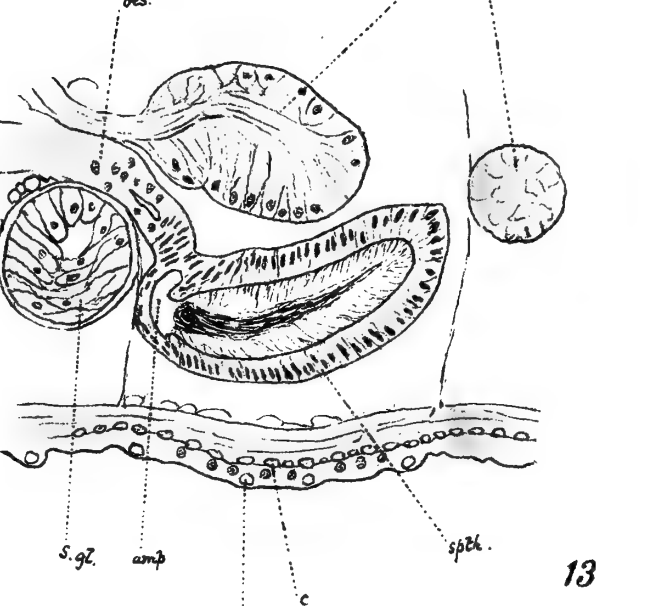

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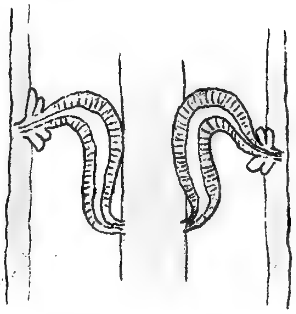

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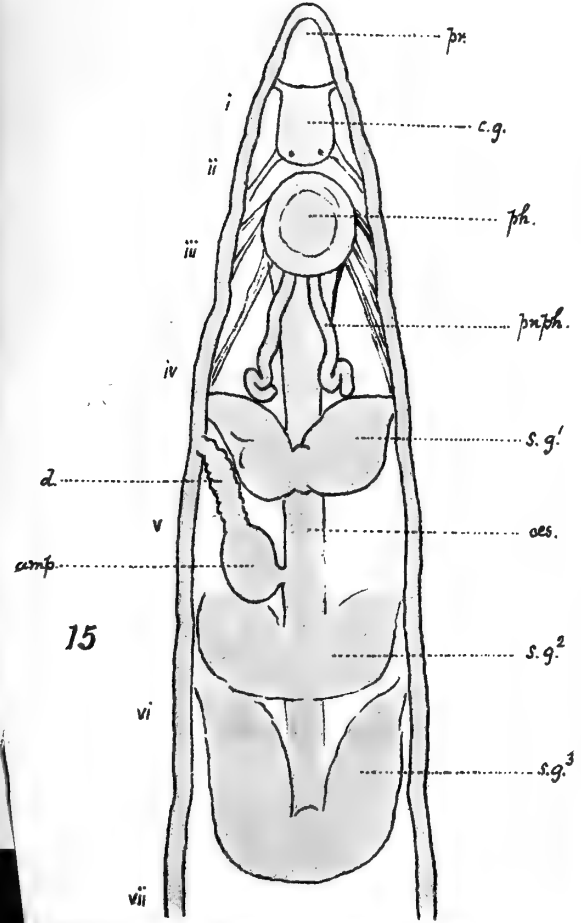

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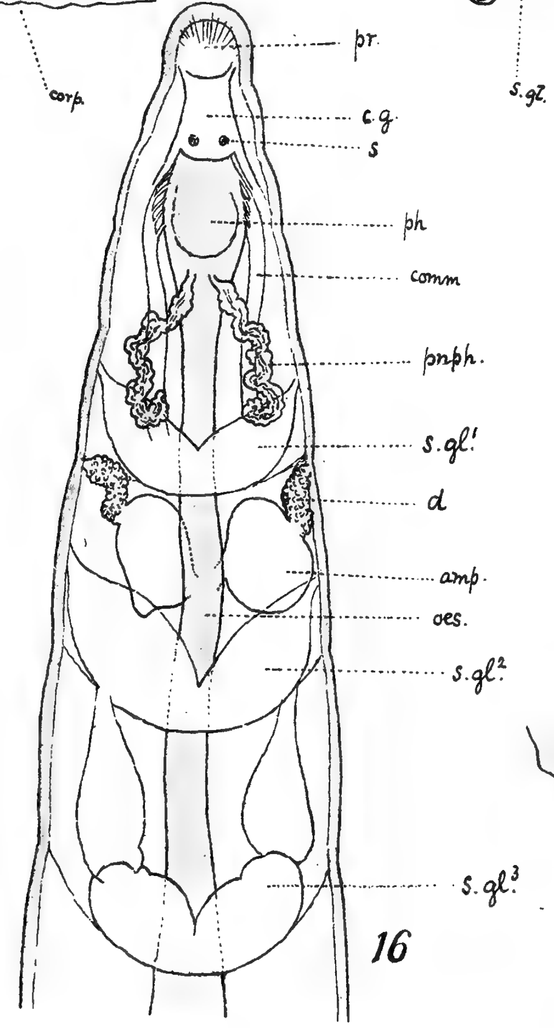

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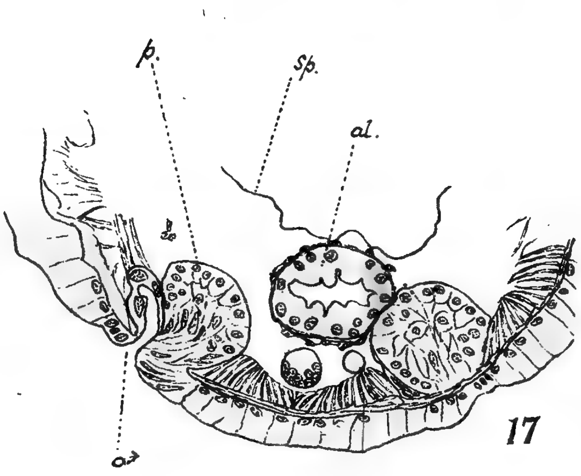

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III.—Les Mousses de l'Expédition nationale antarctique écossaise. Par Jules Cardot. *Présenté par le* Professeur I. Bayley Balfour, M.D., F.R.S. (Avec trois Planches.)

(MS. received March 9, 1911. Read June 19, 1911. Issued separately July 3, 1911.)

AVERTISSEMENT.

Les Mousses rapportées par l'Expédition nationale antarctique écossaise ne sont pas très nombreuses, mais elles présentent cependant de l'intérêt, parce que la plupart proviennent de localités qui étaient restées jusque là totalement inexplorées. Le plus grand nombre des espèces a été récolté à l'île Gough ou Diego Alvarez, dont la florule bryologique était tout à fait inconnue ; les récoltes de M. le Dr R. N. Rudmose Brown nous ont fourni 21 espèces pour cette petite île. Dix espèces ont été recueillies à l'île Laurie, l'une des Orcades méridionales, dans la région antarctique proprement dite ; enfin, 6 espèces proviennent de l'Ascension.

Nous étudierons séparément les espèces de ces trois localités. Des listes provisoires, mais incomplètes et partiellement inexactes, ont été publiées en 1905 et en 1906 par M. C. H. Wright, dans *Linnean Society's Journal* et dans *Transactions and Proceedings of the Botanical Society of Edinburgh.*

J'ai à remercier MM. le Dr W. S. Bruce et le Dr R. N. Rudmose Brown, ainsi que les autorités du Jardin botanique de Kew, qui ont bien voulu mettre à ma disposition les matériaux de ce travail.

Charleville,
1^{er} *décembre* 1910.

I.—MOUSSES DE L'ÎLE LAURIE.*

L'île Laurie fait partie du groupe des Orcades méridionales, qui appartient déjà au domaine antarctique proprement dit. M. Rudmose Brown y a recueilli 10 espèces de Mousses, dont on trouvera plus loin l'énumération ; mais il m'a communiqué en outre une série de 6 espèces récoltées en 1904, sur la même île, par M. L. H. Valette, de l'Observatoire météorologique de la République Argentine. Quatre des espèces rapportées par M. Valette ne se trouvant pas dans les récoltes de M. Rudmose Brown le chiffre des Mousses actuellement constatées a l'île Laurie se trouve ainsi porté à 14, dont voici la liste :

---

* Voir Cardot, "La Flore bryologique des Terres magellaniques, de la Géorgie du Sud et de l'Antarctide," pp. 243–244 (*Wissensch. Ergebn. der schwed. Südpolar-Exped.*, 1901–1903, Bd. iv. Lief 8).

Andreæa depressinervis Card.
Dicranoweisia grimmiacea Broth.
Dicranum aciphyllum Hook. fil. et Wils.
„ *Nordenskjöldii* Card.
Blindia Skottsbergii Card.
Distichium capillaceum Br. et Sch. var. *brevifolium* Br. et Sch.
Ceratodon purpureus (?) Brid.
Grimmia Antarctici Card.
„ *apocarpa* Hedw.
Webera Racovitzæ Card.
Polytrichum alpinum L.
„ *subpiliferum* Card.
Brachythecium antarcticum Card. var. *cavifolium* Card.
Drepanocladus uncinatus (Hedw.) Warnst.

Sur ces 14 espèces, aucune n'est spéciale à l'île Laurie, mais 4 : *Andreæa depressinervis*, *Grimmia Antarctici*, *Webera Racovitzæ* et *Brachythecium antarcticum*, n'ont pas été rencontrées jusqu'ici en dehors du domaine antarctique. Quant aux autres espèces, voici leur dispersion :

Dicranoweisia grimmiacea. Géorgie du Sud, Kerguelen.
Dicranum aciphyllum. Géorgie du Sud, domaine magellanique
„ *Nordenskjöldii.* Géorgie du Sud.
Blindia Skottsbergii. Géorgie du Sud.
Distichium capillaceum. Plus ou moins cosmopolite ; domaine magellanique.
Ceratodon purpureus. Cosmopolite ; domaine magellanique.
Grimmia apocarpa. Cosmopolite ; domaine magellanique.
Polytrichum alpinum. Cosmopolite ; domaine magellanique, Géorgie du Sud, Kerguelen.
„ *subpiliferum.* Domaine magellanique.
Drepanocladus uncinatus. Cosmopolite ; domaine magellanique, Géorgie du Sud, Kerguelen.

ANDREÆACEÆ.

Andreæa.

A. depressinervis Card., in *Rev. bryol.*, 1900, p. 43, et *Résult. voyage* "*Belgica*," *Mousses*, p. 22, pl. i., figs. 22–33.

Andreæa sp. Wright, in *Trans. and Proceed. Bot. Soc. Edinb.*, xxxiii., part i.

WEISIACEÆ.

Dicranoweisia.

D. grimmiacea (C. Müll.) Broth., in *Nat. Pflanzenfam.*, *Musci*, p. 318.

DICRANACEÆ.

Dicranum.

D. aciphyllum Hook. fil. et Wils., in *Lond. Journ. of Bot.*, 1844, p. 541.

D. Nordenskjöldii Card., in *Bull. Herb. Boissier*, 2ème sér., vi. p. 14, et *Fl. bryol. Terres magell.*, etc., pp. 265–266, fig. 59.

Campylopus introflexus Wright, *loc. cit.*, non Mitt.

SELIGERIACEÆ.

Blindia.

B. Skottsbergii Card., in *Bull. Herb. Boissier*, 2ème sér., vi. p. 4, et *Fl. bryol. Terres magell.*, etc., p. 207, fig. 44.

Campylopus vesticaulis Wright, *loc. cit.*, non Mitt.

GRIMMIACEÆ.

Grimmia.

G. apocarpa (L.) Hedw., *Sp. Musc.*, p. 76.

"*G. cf. apocarpa* Hedw.," Wright, *loc. cit.*

G. Antarctici Card., in *Bull. Herb. Boissier*, 2ème sér., vi. p. 15, et *Fl. bryol. Terres magell.*, etc., p. 271, pl. v. figs. 16–25, pl. vi. figs. 1–5.

G. amblyophylla Wright, *loc. cit.*, non C. Müll.

BRYACEÆ.

Webera.

W. Racovitzæ Card., in *Rev. bryol.*, 1900, p. 44, et *Résult. voyage "Belgica," Mousses*, p. 35, pl. xiii. figs. 1–14.

Bryum sp. Wright, *loc. cit.*

POLYTRICHACEÆ.

Polytrichum.

P. subpiliferum Card., in *Rev. bryol.*, 1900, p. 42, et *Résult. voyage "Belgica," Mousses*, p. 39, pl. xii. figs. 1–14.

HYPNACEÆ.

Drepanocladus.

D. uncinatus (Hedw.) Warnst., *Beih. zum Bot. Centralbl.*, xiii. p. 417.

II.—MOUSSES DE L'ÎLE GOUGH OU DIEGO ALVAREZ.

Sur les 21 espèces de Mousses récoltées à l'île Gough par M. RUDMOSE BROWN, 11 espèces sont endémiques; du moins, elles ne me semblent pas pouvoir être rapportées à des espèces signalées ailleurs. Un *Dicranella*, représenté seulement par la plante mâle, est indéterminable. Restent 9 espèces, sur lesquelles 6 appartiennent à la flore magellanique :

Rhacomitrium symphyodontum Jaeg. Existe aussi au Chili, en Tasmanie et en Nouvelle-Zélande.

Rhacomitrium subnigritum Par., représenté à l'île Gough par une variété endémique.

Webera nutans Hedw. }
,, *albicans* Sch. } Plus ou moins cosmopolites.

Polytrichadelphus magellanicus Mitt. Existe aussi dans la région australo-néozélandaise.

Brachythecium subpilosum Jaeg. Se retrouve encore aux îles Marion, Kerguelen, Géorgie du Sud et dans l'Antarctide.

Deux espèces se retrouvent à Tristan d'Acunha :

Rhacomitrium symphyodontum Jaeg. = *R. membranaceum* Par.
Philonotis capillata Par.

et une à l'Ascension :

Sphagnum Scotiæ Card.

Enfin, une dernière espèce: *Cyclodictyon lætevirens* Mitt., existe en Irlande, à Madère et à Fernando-Po.

Les espèces endémiques montrent des affinités avec des Mousses de Tristan d'Acunha, de la région magellanique, de l'Afrique australe, et même de la Réunion, de l'île St Paul et de Kerguelen, dans l'Océan Indien, mais c'est, en somme, avec la végétation de la région magellanique que la florule bryologique de l'île Gough paraît avoir le plus de rapports. Il est toutefois probable que quand les Mousses de Tristan d'Acunha et celles de l'île Gough seront mieux connues, on relèvera un plus grand nombre d'espèces communes à ces deux îles, qui présentent les plus grandes analogies quant à la flore supérieure.

SPHAGNACEÆ.

Sphagnum.

S. Scotiæ Card. *sp. nova.*

S. acutifolium Wright, in *Linn. Soc. Journ., Bot.*, xxxvii. p. 264, non Ehrh.

Molle, pallide viride. Caulis cellulæ epidermicæ distinctæ, magnæ, bistratosæ, cylindrum lignosum pallidum, cellulis vix vel parum incrassatis formatum. Rami 3 vel 4 in singulo fasciculo, quorum 1 vel 2 penduli. Folia caulina magna, 1·75–2 millim. longa, 0·8–1 millim. lata, oblongo-lingulata, basi haud vel vix angustata, apice obtuso, integro, plus minus cucullato, superne vel fere e basi fibrosa, limbo angusto ubique æquilato marginata. Folia ramorum divergentium ovato-lanceolata, concava, 1·5–1·6 millim. longa, 0·7–0·75 lata, marginibus superne inflexis, apice truncatulo et denticulato; leucocystæ valde fibrosæ, poris majusculis, in parte superiore paginæ dorsalis secundum chlorocystas sat numerosis, in pagina ventrali nullis vel perpaucis; chlorocystæ ventrales, in sectione transversali trapezoidales, utraque pagina inter leucocystas emergentes.

Je n'ai vu que deux petits fragments de cette espèce, l'un provenant de l'île Gough, l'autre de l'Ascension. Elle est voisine du *S. Reichardtii* Hpe., de l'île St Paul, mais celui-ci a les feuilles caulinaires plus courtes, ovales et à leucocystes toutes divisées par plusieurs cloisons obliques, ce qui n'a lieu, dans l'espèce nouvelle, que sur un petit nombre de leucocystes.

DICRANACEÆ.

Trematodon.

T. intermixtus Card. *sp. nova.*

Aliis muscis commixtus gregarie crescens. Caulis gracilis, mollis, erectus, laxifolius, 6–10 millim. longus. Folia mollia, e basi subvaginante breviter oblonga in subulam elongatam, canaliculatam, plus minus flexuosam, integerrimam vel apice minute denticulatam sat abrupte constricta, media et superiora 4·5–5·5 millim. longa, 0·6–0·75 basi lata, inferiora breviora, costa basi angusta, superne dilatata et totam fere subulam occupante, cellulis basis elongatis, linearibus, in subula brevioribus, minute rectangulis. Folia perichætialia longiora, e basi laxius reticulata magis sensim angustata. Capsula in pedicello pallide stramineo, 12–15 millim. longo erecta inclinatave, ætate arcuata, collo sporangio longiore basi strumuloso instructa, 3–4 millim. longa, operculo longirostro. Peristomii dentes anguste lanceolati, circa 0·35 millim. longi, rubro-aurantiaci, dorso longitudinaliter striati, intus papillosi, lamellis paucis ornati, usque ad basin in 2 crura apice cohærentia divisi. Sporæ luteo-virides, minute granulosæ, diam. 18–20 μ. Flores masculi gemmiformes, aggregati, terminales.

Se rapprochant par ses feuilles longuement subulées du *T. setaceus* Hpe., de l'île St Paul, cette espèce m'en paraît suffisamment distincte par sa capsule à col plus long que le sporange, et par ses dents péristomiales divisées jusqu'à la base en deux branches distinctes, plus ou moins cohérentes seulement au sommet. Les échantillons trop pauvres dont je disposais ne m'ont pas permis de reconnaître si les fleurs mâles naissent sur des tiges spéciales, ou bien au sommet de rameaux basilaires de la plante fructifère.

Dicranella.

D. sp., planta mascula.

Probablement une espèce nouvelle, dont nous n'avons malheureusement que la plante mâle. Petite Mousse de 2 à 4 millimètres, à feuilles étalées-dressées, flexueuses, planes aux bords, à subule généralement plus ou moins obtuse ou un peu tronquée et denticulée au sommet.

Campylopus.

C. alvarezianus Card. *sp. nova.*

Cespites superne lutescentes, intus fusco-tomentosi, 1–4 centim. alti. Caulis simplex vel parce divisus, sæpe basi ramos filiformes gracillimos emittens. Folia plus minus conferta, superiora comosa, subsecunda, anguste lanceolata et sensim in subulam canaliculatam, acutam, dorso scaberulam, apicem versus dentatam, rarius subintegram protracta, 4·5–5 millim. longa, 0·5–0·65 millim. basi lata, inferiora minora, appressa, costa latissima, $\frac{1}{2}$–$\frac{2}{3}$ basis et totam fere subulam occupante, elamellosa, in sectione transversali a cellulis ventralibus majusculis, eurycystis dorso stereidis et substereidis tectis, cellulisque epidermicis dorsalibus composita, cellulis alaribus tenerrimis, hyalinis, marcescentibus, parum distinctis, cæteris lineari-rectangulis et subquadratis, parietibus incrassatis. Reliqua desiderantur.

On peut comparer cette espèce au *C. vesticaulis* Mitt., de Tristan d'Acunha, mais celui-ci est plus robuste, ses tiges sont recouvertes d'un tomentum plus abondant, et ses feuilles, plus grandes, présentent dans la partie moyenne un tissu fort différent, composé de cellules irrégulières, plus ou moins obliques, atténuées, subrhomboïdales. Le *C. alvarezianus* rappelle assez, par son aspect extérieur, le *C. eximius* Reich., de l'île St Paul, mais s'en sépare d'ailleurs complétement par ses feuilles épilifères et par son tissu.

J'ai trouvé dans les récoltes de M. Rudmose Brown quelques tiges d'un *Campylopus* à feuilles plus molles, plus flexueuses à l'état sec, et à tissu formé jusque près de la base de cellules plus courtes, carrées ou brièvement rectangulaires, qui, bien qu'assez différent de l'espèce que je viens de décrire, me semble cependant n'en être qu'une simple forme.

GRIMMIACEÆ.

Rhacomitrium.

R. symphyodontum (C. Müll.) Jaeg., *Ad.*, i. p. 375.

R. flavescens Card., in *Rev. bryol.*, 1900, p. 41 ; Wright, *loc. cit.*, *pro parte.*

Echantillon stérile.

La forme récoltée à l'île Gough par M. Rudmose Brown ne diffère pas de la plante magellanique, qui est très variable ; mais elle ne représente pas exactement le *R. flavescens* Card., que je ne considère plus, d'ailleurs, que comme une des nombreuses formes du *R. symphyodontum.* Le *R. membranaceum* (Mitt.) Par., de Tristan d'Acunha, ne me paraît être également qu'une forme de la même espèce, caractérisée par ses feuilles étroites et son pédicelle extrêmement court.

R. subnigritum (C. Müll.) Par., *Ind. bryol.*, ed. i., p. 1080. Var. *alvarezianum* Card. *var nova.*

R. flavescens Wright, *loc. cit.*, *pro parte.*

A forma typica patagonica et fuegiana differt : colore minus nigricante, obscure vel sordide viridi, foliis majoribus, latioribus (3·3–3·75 millim. longis, 1–1·2 latis), mollioribus, siccitate minus imbricatis, marginibus minus late incrassatis, costaque validiore, basi 180–220 μ lata (loco 112–140 in forma genuina). Sterile.

ORTHOTRICHACEÆ.

Macromitrium.

M. antarcticum Wright, in *Linn. Soc. Journ.*, *Bot.*, xxxvii. p. 264.

Cespites densi, lutescenti-virides. Caulis repens, ramis confertis, brevissimis, subnodulosis dense pinnatus. Folia conferta, sicca cirrata, madida patenti-erecta, anguste oblongo-lanceolata vel subligulata, carinata, acuminata, acuta obtusulave, integerrima, 1–1·8 millim. longa, 0·25–0·45 lata, marginibus ubique planis vel inferne anguste reflexis, costa percurrente vel subpercurrente, cellulis omnibus lævissimis, inferioribus vermicularibus, angustissimis, parietibus perincrassatis, cæteris quadratis vel subrotundatis. Folia perichætialia intima caulinis latiora, oblongo-lanceolata. Capsula in pedicello lævi, 4–6 millim. longo, erecta, ovata, pachyderma, 1–1·25 millim. longa, 0·5–0·7 lata, ore rubro, vernicoso, siccitate plicato, operculo longirostri. Peristomium simplex, dentibus griseis, granulosis, truncatis. Calyptra nuda.

Espèce de la section *Goniostoma*, très voisine du *M. borbonicum* (Besch.) Broth., mais ayant les feuilles plus longues, les capsules et les pédicelles plus courts ; elle se rapproche aussi beaucoup du *M. Seemanni* Mitt., de Ste Hélène, qui s'en distingue par son port plus robuste, sa teinte d'un jaune brun, ses feuilles plus rétrécies dans le haut, les cellules allongées occupant une plus grande partie de la feuille et s'avançant jusqu'au delà du milieu (tandis qu'elles s'arrêtent généralement au dessous du milieu dans le *M. antarcticum*), les cellules supérieures plus arrondies, à parois plus épaissies, jaunâtres, le pédicelle plus épais, et la capsule plus solide.

BRYACEÆ.

Webera.

W. nutans (Schreb.) Hedw., *Sp. Musc.*, p. 168.

Quelques tiges dépourvues de capsules, mélangées au *Campylopus alvarezianus* ; inflorescence paroïque ou subsynoïque. Paraît bien identique au type de l'hémisphère boréal.

W. albicans (Wahlenb.) Sch., *Coroll.*, p. 67.

Tiges stériles, au milieu des gazons de *Philonotis capillata*. C'est une forme grêle, comme on en trouve également en Europe.

Bryum.

B. tenellicaule Card. *sp. nova.*

Cespites tenelli, densiusculi, nitiduli, viridi-lutescentes, laxe cohærentes. Caulis gracillimus, ruber, laxifolius, parce radiculosus, 7–12 millim. altus, simplex vel parcissime divisus. Folia siccitate patenti-erecta, subflexuosa, madore patentia, caviuscula, anguste lanceolata, acuminata, costa excurrente cuspidata, 1·25–1·5 millim. longa, 0·25–0·45 lata, marginibus nunc planis, nunc reflexis vel anguste revolutis, apicem versus remote et minute denticulatis, costa valida, basi 50–70 μ lata, viridi vel lutescente, in subulam crassam, parce denticulatam vel subintegram longiuscule excedente, cellulis inferioribus rectangulis et subrectangulis, cæteris oblongo-rhomboideis. Flores fructusque desiderantur.

Cette petite espèce, de la section *Doliolidium*, peut être comparée au *B. coronatum* Schw. ; elle en diffère par sa petite taille, ses tiges plus grêles, ses feuilles beaucoup plus petites, etc.

B. subulinerve Card. *sp. nova.*

Cespites densiusculi, pallide vel sordide virides. Caulis superne dense, inferne laxius foliosus, 6–12 millim. altus, dichotome divisus et subfastigiato-ramosus. Folia madida patentia, sicca suberecta, concava, inferiora lanceolata, acuminata, superiora late ovato-lanceolata, brevius acuminata, costa longe excurrente cuspidata, 1·3–1·6 millim. longa, 0·5–0·7 lata, marginibus plerumque e basi usque apicem versus revolutis, rarius subplanis, integris vel superne sinuato-subdenticulatis, costa valida, 70–80 μ basi lata, viridi-lutescente, in subulam crassam, remote denticulatam longe excedente, cellulis mediis et superioribus oblongo-rhomboideis, parietibus crassiusculis, inferioribus breviter rectangulis et subquadratis, infimis laxis, teneris, rubellis vel subhyalinis. Cætera desiderantur.

Appartenant également à la section *Doliolidium*, cette espèce se distingue du *B. coronatum* Schw. par ses feuilles généralement révolutées, pourvues d'une nervure plus forte, formant une subule plus épaisse et plus longue, les feuilles supérieures plus larges et plus courtes.

BARTRAMIACEÆ.

Bartramia.

B. stenobasis Card. *sp. nova.*

Cespites densi, lutescenti-virides. Caulis erectus, simplex, parum radiculosus, 1·5–2 centim. altus. Folia sicca et madida erecto-flexuosa vel patenti-erecta, fragilia, facillime decidua, e basi parva, angusta, vix dilatata longissime subulata, setacea, utraque pagina papillosa, 4–5 millim. longa, basi vix 0·12 lata, marginibus serrulatis, costa dilatata, in subulam dentatam, scabram exeunte, cellulis basilaribus laxis, pellucidis, elongatis, lævibus, cæteris linearibus, angustis, 2–3-stratosis, parietibus transversis prominentibus papillosis. Cætera desunt.

Rappelle assez le *B. patens* Brid., mais en diffère par ses feuilles à partie basilaire plus petite, plus étroite et moins brusquement contractée. Espèce remarquable par le peu de développement de la partie basilaire de la feuille, très différente du *B. radicosa* Mitt., de Tristan d'Acunha, qui est beaucoup plus robuste, et a les feuilles moins finement subulées, brusquement et fortement dilatées à la base, et les tiges très radiculeuses.

Philonotis.

Ph. capillata (Mitt.) Par., *Ind. bryol.*, ed. i., p. 919.

Echantillons stériles et plante mâle.

Il y a deux formes différentes dans les récoltes de M. RUDMOSE BROWN. L'une est complétement identique à la plante originale de Tristan d'Acunha ; l'autre est plus grêle, plus petite, d'une vert glauque, plus molle dans toutes ses parties ; mais elle ne diffère pas autrement du type. Cette dernière forme croissait intimement mélangée au *Webera albicans*, dont elle a un peu l'aspect.

POLYTRICHACEÆ.

Polytrichadelphus.

P. magellanicus (L.) Mitt., in *Journ. Linn. Soc.*, 1859, p. 97.

Polytrichum commune Wright, in *Linn. Soc. Journ., Bot.,* xxxvii. p. 265, non Linn.

Tiges stériles, mais la structure de la feuille et des lamelles ne laisse aucun doute sur leur détermination.

HOOKERIACEÆ.

Cyclodictyon.

C. lætevirens (Hook. et Tayl.) Mitt., in *Journ. Linn. Soc.*, 1864, p. 163.

Echantillon stérile, bien identique à ceux d'Irlande.

LESKEACEÆ.

Thuïdium.

Th. alvarezianum Card. *sp. nova.*

Humile, gracile. Caulis primarius repens, tenellus, secundarius erectus ascendensve, 1–2 centim. longus, remote et irregulariter pinnatus et parcissime bipinnatus, paraphylliis sat numerosis, brevibus, simplicibus, papilloso-dentatis obtectus. Folia madida undique patentia, sicca incurvato-crispata, caulina e basi late cordata abrupte acuminata, 0·4–0·5 millim. longa, 0·25–0·35 lata, ramea aliquid minora, magis sensim latiuscule acuminata, 0·3–0·4 millim. longa, 0·18–0·20 lata, ramulina minima, ovato-lanceolata, 0·15–0·18 millim. longa, vix 0·08 lata, omnia caviuscula, acuta, marginibus planis, crenulatis, superne serrulatis, costa in acumine evanida, cellulis quadratis vel subrotundatis, utraque pagina papilla singula medio notatis. Cætera desiderantur.

Cette espèce se rapproche du *Th. curvatum* Mitt., de Tristan d'Acunha ; elle en diffère par sa taille plus faible, son port beaucoup plus grêle, et ses feuilles caulinaires et raméales moins dimorphes, plus petites, plus courtes et plus brièvement acuminées. Le *Th. curvatum*, que M. Brotherus place dans les *Thuidiella*, est certainement, d'après l'échantillon original que j'ai pu examiner, un *Thuidiopsis*, très voisin des *Th. unguiculatum* (Hook. fil. et Wils.), *furfurosum* (Hook. fil. et Wils.) et *hastatum* (C. Müll.), de la Nouvelle-Zélande. C'est donc également dans la section *Thuidiopsis* que doit prendre place l'espèce nouvelle.

Hypnaceæ.

Isopterygium.

I. Brownii Card. *sp. nova.*

Tenellum, intricato-repens, lutescenti-viride, nitidulum. Caulis gracillimus, 8–12 millim. longus, irregulariter ramosus, ramis complanatulis, attenuatis. Folia laxiuscula, subdistiche patentia vel sursum leniter homomalla, anguste lanceolata, sensim longeque acuminata, lateralia falcatula, obsolete binervia vel enervia, media 1·1–1·35 millim. longa, 0·25–0·37 lata, marginibus planis, superne serrulatis, cellulis anguste linearibus, mediis longissimis, alaribus perpaucis subindistinctis. Cætera desiderantur.

Cette petite espèce rappelle assez les *I. antarcticum* (Mitt.) Card. et *fuegianum* Besch.; elle s'en distingue par ses feuilles étroitement lancéolées et terminées par un acumen moins long, moins étroit et denticulé. Elle croissait au milieu des tiges du *Bartramia stenobasis.*

A propos de l'*I. antarcticum*, je ferai remarquer que la Mousse de Kerguelen que C. Müller a décrite en 1890 sous le nom de *Hypnum* (*Plagiothecium*) *antarcticum* (*Forschungsreise S.M.S. "Gazelle," Laubmoose*, p. 34) n'est nullement le *Plagiothecium antarcticum* de Mitten, qui est un *Isopterygium*, tandis que la plante de Müller est un *Plagiothecium.* Müller reconnaissait, d'ailleurs, qu'il n'était pas certain de l'identité des deux plantes, qui, de fait, sont fort différentes. Mais le *P. antarcticum* C. Müll. non Mitt., de Kerguelen, est exactement la même chose que l'espèce décrite l'année précédente par Müller sous le nom de *Hypnum* (*Plagiothecium*) *georgico-antarcticum* ("Bryologia Austro-Georgiæ," in *Ergebn. der deutsch. Polar-Exped.*, All. Theil, Bd. ii., 11, p. 321). Les différences que l'auteur indique entre les deux plantes ne sont pas constantes et n'ont aucune valeur: le tissu des feuilles n'est pas plus chlorophylleux dans l'une que dans l'autre, et l'acumen est souvent denticulé au sommet sur la Mousse de la Géorgie du Sud. C'est l'espèce de Müller, et non celle de Mitten, que M. Brotherus a mentionnée sous le nom de *Plagiothecium antarcticum* dans son tableau synoptique du genre (in Engler et Prantl, *Pflanzenfamil.*, *Musci*, p. 1086). J'ajouterai que le *Hypnum austropulchellum* de Müller (*Forschungsreise*, etc., p. 35) pourrait bien être l'espèce de Mitten.

I. ambiguum Card. *sp. nova.*

Molle, lutescens, nitidulum, robustulum, intricato-cespitosum. Caulis 2–3 centim. longus, irregulariter divisus, ramis flaccidis, complanatis, obtusis. Folia compressa, disticha patentia vel subhomomalla, e basi sæpe subdecurrente oblongo-lanceolata, longiuscule et acute acuminata, lateralia aliquid asymmetrica et curvatula, 2–2·5 millim. longa, 0·5–0·75 lata, marginibus planis ubique integris vel apicem versus remote et minute denticulatis, costa gemella vel furcata, ad $\frac{1}{4}$–$\frac{1}{3}$ producta obsoletave, cellulis anguste linearibus, flexuosis, mediis longissimis, alaribus plerumque distinctis, laxis, ovatis, oblongisve, subinflatis. Cætera ignota.

En raison de ses cellules alaires ordinairement assez différenciées et souvent subdécurrentes, cette espèce occupe une place indécise entre les genres *Isopterygium* et *Plagiothecium*.

Brachythecium.

B. pallidoflavens Card. *sp. nova.*

Gracile, pallidoflavens, nitidulum. Caulis longe repens, flexuosus, rhizoidis fasciculatis radiculosus, irregulariter pinnatus, ramis teretibus, patulis, siccitate julaceis, breviter attenuatis. Folia ramea madida erecto-patentia, sicca erecta, subappressa, oblongo-lanceolata, sensim tenuiterque acuminato-subulata, plicata, 1·5–1·8 millim. longa, 0·35–0·5 lata, marginibus planis vel plus minus revolutis, inferne integris, superne remote et minute denticulatis, costa tenui, ad $\frac{2}{3}$ evanida, reti pallido, cellulis anguste linearibus, parietibus crassiusculis, alaribus distinctis, quadratis vel rectangulis. Folia caulina laxiora, haud vel vix plicata, costa breviore, medium versus evanida. Cætera desunt.

Cette espèce, dont je n'ai trouvé que quelques tiges en mélange avec les autres Mousses, est voisine des *B. austrosalebrosum* et *austroglareosum* (C. Müll.) Par. ; elle diffère du premier par ses dimensions plus faibles, par ses rameaux julacés à l'état sec, et par ses feuilles plus étroites, denticulées dans la partie supérieure ; elle se distingue du second par ses rameaux plus grêles, et par ses feuilles plus étroites, à bords plans ou moins régulièrement révolutés.

B. subpilosum (Hook. fil. et Wils.) Jaeg., *Ad.*, ii. p. 410.

Un petit échantillon stérile, dont l'attribution à cette espèce ne me paraît cependant pas douteuse.

Rhynchostegium.

R. isopterygioides Card. *sp. nova.*

R. rhaphidorhynchum Wright, in *Linn. Soc. Journ.*, *Bot.*, xxxvii. p. 265, non *Hypnum raphidorrhynchum* C. Müll., *Syn.*, ii. p. 354.

Autoicum, lutescens, nitidum. Caulis procumbens, vage pinnatus, ramis complanatulis, isopterygioideis, obtusis. Folia caulina erecto-patentia, ramea compressula, late ovato-lanceolata, acuminata, acumine acuto plerumque semitorto, 1·5–1·75 millim. longa, 0·7–0·85 lata, marginibus planis e basi serrulatis, costa tenui, ad $\frac{2}{3}$ evanida, cellulis pellucidis, linearibus, subflexuosis, alaribus paucis, brevioribus, subrectangulis et subquadratis. Folia perichætialia intima e basi oblonga, convoluta, in acumen longiusculum serrulatum protracta. Pedicellus rubellus, lævis, 10–12 millim. longus. Cætera ignota.

Cette Mousse diffère du *R. raphidorrhynchum* (C. Müll.) Jaeg., de l'Afrique australe, par ses feuilles plus fortement dentées, terminées par un acumen moins étroit, en général à demi tordu, et par son tissu moins serré. Elle se rapproche beaucoup du *R. confertum* Br. eur., d'Europe, mais s'en distingue cependant par son port, ses rameaux comprimés, qui lui donnent l'aspect d'un *Isopterygium*, et ses feuilles plus dentées. Peut-être est-ce la même plante qui à été indiquée par MITTEN à Tristan d'Acunha sous le nom de *Hypnum raphidorrhynchum.*

III.—MOUSSES DE L'ASCENSION.

D'après le *Bryologia atlantica,* œuvre posthume du regretté A. GEHEEB, qui vient de paraître tout récemment, la florule bryologique de l'Ascension comprend 20 espèces ; ce chiffre se trouve maintenant porté à 24 par les récoltes de M. RUDMOSE BROWN. Voici l'énumération complète de ces espèces :

Sphagnum Scotiæ Card.
Dicranella pygmæa Card.
,, *ascensionica* Mitt.
Campylopus smaragdinus (Brid.) Jaeg.
,, *introflexus* (Hedw.) Mitt.
,, *Naumanni* (C. Müll.) Par.
Calymperes Ascensionis C. Müll.
Gymnostomum Lessonii Besch.
,, *Bescherellei* Broth. et Geh.
Hyophila Ascensionis Card.
Barbula leucochlora C. Müll.
,, *cuspidatissima* C. Müll.
Bryum zygodontoides C. Müll.
,, *argentatum* C. Müll.
,, *rubrocostatum* C. Müll.
Philonotis penicillata Wright.
,, *pergracilis* Card.
,, *subolescens* (C. Müll.) Par.
Leucodon Bescherellei Broth. et Geh.
Neckera Ascensionis Besch.
Callicostella Ascensionis C. Müll.
Rhacopilum gracile Mitt.
,, *Naumanni* C. Müll.
Taxithelium planum Brid.

Il est fort possible que le *Rhacopilum gracile* Mitt. (1885) soit la même espèce que le *R. Naumanni* C. Müll. (1883). Le *Gymnostomum Bescherellei* est une espèce nouvelle, qui est figurée dans l'ouvrage de GEHEEB ; le *Leucodon Bescherellei* est une autre espèce nouvelle, malheureusement restée à l'état de *nomen nudum.*

Sauf trois, toutes les espèces sont spéciales à l'île de l'Ascension. Les trois espèces non endémiques sont :

Sphagnum Scotiæ Card., qui se retrouve, ainsi que nous l'avons vu, à l'île Gough.

Campylopus introflexus (Hedw.) Mitt. (*C. polytrichoides* De Not.), plus ou moins cosmopolite.

Taxithelium planum Brid., espèce de l'Amérique tropicale, dont l'existence réelle à l'Ascension reste bien douteuse.

SPHAGNACEÆ.

Sphagnum.

S. Scotiæ Card. (*vide supra*, p. 70).

S. cuspidatum Wright, in *Trans. and Proceed. Bot. Soc. Edinb.*, xxiii., ii. p. 203, non Ehrh.

Le petit fragment que j'ai vu provenant de l'Ascension ne paraît pas différer de la Sphaigne de l'île Gough.

DICRANACEÆ.

Dicranella.

D. pygmæa Card. *sp. nova.*

Dioica, humillima, lutescenti-viridis, 5–6 millim. alta. Folia erecta vel leniter subsecunda, anguste triangulari-lanceolata, sensim in acumen canaliculatum, crassiusculum, integrum, acutum vel obtusulum producta, 0·9–1·35 millim. longa, 0·18–0·25 lata, marginibus superne inflexis, cæterum planis et ubique integerrimis, costa valida, lutescente, bene limitata, quartam vel tertiam partem basis occupante, continua vel subexcurrente, cellulis oblongis, rectangulis et linearibus, parietibus firmis, incrassatis. Folia perichætialia majora, anguste oblongo-lanceolata, laxius reticulata. Capsula in pedicello pallido, circa 2 millim. longo, siccitate apice leniter dextrorsum torto minima, erecta vel suberecta, sicca ovata, madida subglobosa, aperta late truncata, circa 0·5 millim. longa, 0·3–0·4 lata, operculo longirostri capsulæ æquilongo. Annulus duplex et triplex. Peristomium rudimentarium, dentibus minimis, rubellis, irregularibus, annulo vix æquilongis et quidem brevioribus. Planta mascula ignota.

Très voisine du *D. minuta* (Hpe.) Broth., de Madagascar, cette espèce en diffère cependant par ses feuilles plus longues et plus étroitement acuminées. Elle était mélangée à l'espèce suivante.

D. ascensionica Mitt., in MELLIS, *St Helena*, p. 357.

Par son pédicelle fortement flexueux et courbé, cette espèce se rapproche des *Campylopodium*, mais les feuilles sont moins brusquement dilatées à la base que celles de ce genre. M. BROTHERUS a fait d'ailleurs observer avec raison que le genre *Campylopodium* est très faiblement caractérisé, et qu'il serait peut-être préférable de le considérer comme un sous-genre de *Dicranella* (*Musci*, in *Pflanzenfamil.*, p. 312).

Campylopus.

C. smaragdinus (Brid.) Jaeg., *Ad.*, i. p. 136.

Il y a, dans l'herbier du Museum de Paris, deux échantillons de cette espèce. L'un, provenant de l'herbier THURET, récolté par LESSON en 1829, et étiqueté par BESCHERELLE, est du *C. smaragdinus* pur. L'autre, provenant de l'herbier BRONGNIART, est un échantillon de la plante originale récoltée par DUMONT D'URVILLE en 1825, et sur laquelle Bridel a établi son *Didymodon smaragdinus* (*Bryol. univ.*, i. p. 819). Cet échantillon était étiqueté primitivement "*Thisanomitrium introflexum*," puis a été rapporté plus tard par Bescherelle au *C. smaragdinus.* Mais, en réalité, il comprend deux espèces : la plus grande partie de la touffe est bien du *C. smaragdinus*, au milieu duquel on trouve des brins d'une espèce à feuilles pilifères, à nervure fortement lamellifère sur le dos, qui est, conformément à la première étiquette, du *C. introflexus* (Hedw.) Mitt., si toutefois, avec Mitten, on réunit au *Dicranum introflexum* d'Hedwig le *C. polytrichoides* De Not., mais à laquelle il faudrait attribuer ce dernier nom, si l'on réserve celui de *C. introflexus* aux formes australes à poil réfléchi ou plus ou moins étalé.

L'échantillon des récoltes de M. Rudmose Brown qui m'a été communiqué par l'Herbier royal de Kew, appartient au *C. smaragdinus* ; mais il est fort possible qu'il y avait dans la récolte de M. Brown le même mélange que dans celle de Dumont d'Urville, car sur la liste qui a été publiée dans *Trans. and Proceed. of the Bot. Soc. Edin.*, vol. xxiii., part ii., on ne trouve cité que *C. introflexus*, bien que les deux espèces soient totalement différentes.

Pottiaceæ.

Hyophila.

H. Ascensionis Card. *sp. nova.*

"*Barbula* cf. *leucochlora* C. Müll.," Wright, *loc. cit.*

Cespites fusco-virides. Caulis erectus, apicem versus dichotome vel fastigiato-ramosus, 12–15 millim. altus. Folia siccitate crispata, madore erecto-patentia, oblongo-lingulata, brevissime acuminata vel subapiculata, in singula innovatione annua ascendendo majora, media et superiora 1·75–2·25 millim. longa, 0·5–0·7 lata, marginibus plus minus inflexis, superne irregulariter crenato-subdenticulatis, costa rufa, valida, 100–120 μ basi crassa, continua vel brevissime excedente, cellulis majusculis, subrotundatis vel subquadratis, papillosis, chlorophyllosis, parietibus lutescentibus incrassatis, inferioribus rectangulis, pellucidis. Cætera desiderantur.

Cette espèce rappelle assez, par son aspect général, le *H. crenulatula* C. Müll., du Cameroun, mais s'en distingue aisément par ses feuilles plus courtes, formés de cellules 3 à 4 fois plus grandes.

Bartramiaceæ.

Philonotis.

Ph. pergracilis Card. *sp. nova.*

"*Bartramia* cf. *subolescens* C. Müll.," Wright, *loc. cit.*

Cespites tenelli, virides, intus dense fusco-tomentosi. Caulis erectus, gracillimus, parcissime ramosus vel subsimplex, 15–25 millim. altus. Folia erecto-patentia, anguste lanceolata, sensim cuspidata, minima, 0·9–1·1 millim. longa, 0·15–0·2 lata, marginibus plerumque e basi longe et anguste revolutis, apicem versus planis, ubique simpliciter serrulatis, costa basi 30–40 μ crassa, dorso scabra, in cuspidem denticulatam, validiusculam excedente, cellulis angustis, linearibus, parietibus transversis prominentibus, inferioribus laxioribus, rectangulis quadratisve. Cætera ignota.

Bien distinct du *Ph. subolescens* (C. Müll.) Par. par ses tiges plus élancées, ses feuilles beaucoup plus longues, révolutées aux bords, et son tissu plus serré et plus chlorophylleux. Je ne connais pas le *Ph. penicillata* Wright, qui est également particulier à l'Ascension, mais il est probable que ce n'est pas la même chose que la Mousse que je viens de décrire, puisque M. Wright, qui a vu celle-ci, n'y a pas reconnu son espèce, et l'a rapprochée de préférence du *Ph. subolescens*.

EXPLICATION DES PLANCHES.

Planche I.

Fig. 1. *Sphagnum Scotiæ.*—*a*, feuille caulinaire; × 13. *b*, *c*, feuilles d'un rameau divergent; × 13. *d*, tissu dans le haut d'une feuille caulinaire; × 270. *e*, tissu dans la moitié supérieure d'une feuille raméale, vu par la face dorsale; × 270. *f*, portion d'une section transversale vers le milieu d'une feuille raméale; × 270.

Fig. 2. *Trematodon intermixtus.*—*a*, plantes, gr. nat. *b*, *c*, feuilles; × 13. *d*, *e*, capsules déoperculées; × 13. *f*, fragment du péristome et spores; × 138.

Fig. 3. *Campylopus alvarezianus.*—*a*, plante, gr. nat. *b*, *c*, *d*, feuilles; × 13. *e*, tissu basilaire d'une feuille; × 138. *f*, tissu vers le milieu d'une feuille; × 270. *g*, sommet d'une feuille; × 138. *h*, partie d'une coupe transversale de la nervure, dans la moitié supérieure; × 270.

Fig. 4. *Macromitrium antarcticum.*—*a*, plante, gr. nat. *b*, *c*, *d*, *e*, feuilles; × 26. *f*, tissu basilaire d'une feuille; × 270. *g*, tissu vers le milieu d'une feuille; × 270. *h*, sommet d'une feuille; × 270. *i*, capsule jeune et encore operculée; × 13. *j*, capsule mûre, déoperculée, à l'état sec; × 13. *k*, fragment du péristome; × 138. *l*, coiffe; × 13.

Fig. 5. *Bryum tenellicaule.*—*a*, plante, gr. nat. *b*, extrémité d'une tige; × 13. *c*, *d*, *e*, feuilles; × 26. *f*, tissu basilaire d'une feuille; × 138. *g*, sommet d'une feuille; × 138.

Fig. 6. *Bryum subulinerve.*—*a*, *b*, plantes, gr. nat. *c*, extrémité d'une tige; × 13. *d*, *e*, *f*, *g*, feuilles; × 26. *h*, tissu basilaire d'une feuille; × 138. *i*, sommet d'une feuille; × 138.

Planche II.

Fig. 7. *Bartramia stenobasis.*—*a*, plante, gr. nat.; *b*, *c*, feuilles; × 13. *d*, tissu de la partie supérieure de la base d'une feuille; × 138. *e*, tissu marginal vers le milieu d'une feuille; × 138. *f*, sommet d'une feuille; × 138.

Fig. 8. *Thuidium alvarezianum.*—*a*, *b*, plantes, gr. nat. *c*, extrémité d'une tige; × 13. *d*, *e*, *f*, feuilles caulinaires; × 32. *g*, *h*, *i*, feuilles d'un rameau primaire; × 32. *j*, *k*, *l*, feuilles d'un rameau secondaire; × 32. *m*, tissu marginal vers le milieu d'une feuille caulinaire; × 270. *n*, sommet d'une feuille caulinaire; × 270. *o*, paraphylles; × 270.

Fig 9. *Isopterygium Brownii.*—*a*, *b*, *c*, plantes, gr. nat. *d*, extrémité d'une tige; × 13. *e*, *f*, *g*, *h*, feuilles; × 26. *i*, tissu basilaire d'une feuille; × 270. *j*, sommet d'une feuille; × 270.

Fig. 10. *Isopterygium ambiguum.*—*a*, plante, gr. nat. *b*, extrémité d'une tige; × 13. *c*, *d*, *e*, *f*, *g*, feuilles; × 13. *h*, tissu basilaire d'une feuille; × 270. *i*, sommet d'une feuille; × 270.

Fig. 11. *Brachythecium pallidoflavens.*—*a*, plante, gr. nat. *b*, extrémité d'un rameau ; × 13. *c*, *d*, *e*, feuilles ; × 26. *f*, tissu basilaire d'une feuille ; × 270. *g*, tissu marginal dans la moitié supérieure d'une feuille ; × 270. *h*, sommet d'une feuille ; × 270.

PLANCHE III.

Fig. 12. *Rhynchostegium isopterygioides.* — *a*, plante, gr. nat. *b*, extrémité d'un rameau ; × 13. *c*, *d*, *e*, *f*, *g*, feuilles ; × 13. *h*, tissu basilaire d'une feuille ; × 138. *i*, tissu marginal vers le milieu d'une feuille ; × 138. *j*, sommet d'une feuille ; × 138. *k*, feuille périchétiale intime ; × 13.

Fig. 13. *Dicranella pygmæa.*—*a*, *b*, plantes ; × 3. *c*, *d*, *e*, feuilles ; × 26. *f*, tissu basilaire d'une feuille ; × 138. *g*, sommet d'une feuille ; × 138. *h*, feuille périchétiale ; × 26. *i*, *j*, capsules operculées, á l'état sec ; × 26. *k*, capsule mûre, ouverte, à l'état humide ; × 26. *l*, fragment du péristome et de l'anneau ; × 138. *m*, feuille de *D. minuta* (Hpe.) Broth. ; × 26.

Fig. 14. *Hyophila Ascensionis.*—*a*, *b*, plantes, gr. nat. *c*, extrémité d'une tige ; × 13. *d*, *e*, *f*, *g*, *h*, feuilles ; × 13. *i*, tissu basilaire d'une feuille ; × 138. *j*, tissu dans la partie moyenne d'une feuille ; × 270. *k*, sommet d'une feuille ; × 138.

Fig. 15. *Philonotis pergracilis.*—*a*, plante, gr. nat. *b*, *c*, extrémité de deux tiges ; × 13. *d*, *e*, *f*, feuilles ; × 32. *g*, tissu basilaire d'une feuille ; × 138. *h*, tissu marginal d'une feuille, vers le milieu ; × 270. *i*, sommet d'une feuille ; × 138.

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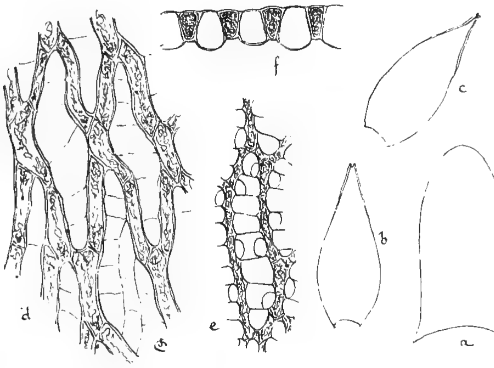
JULES CARDOT: LES MOUSSES DE L'EXPÉDITION NATIONALE ANTARCTIQUE ÉCOSSAISE.– PLANCHE I.



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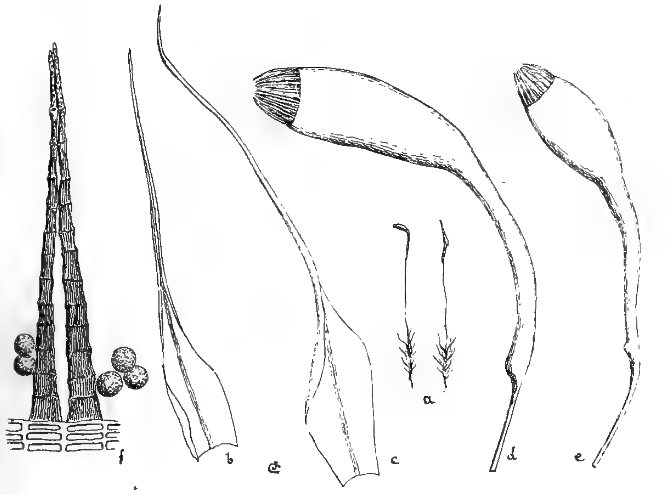

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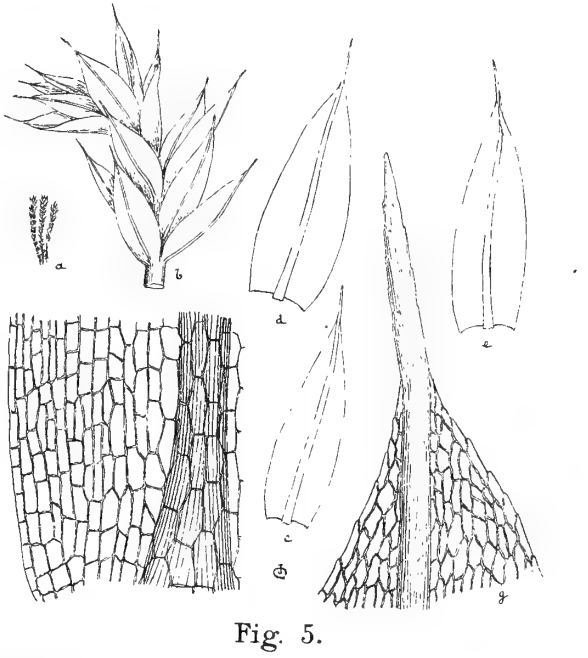

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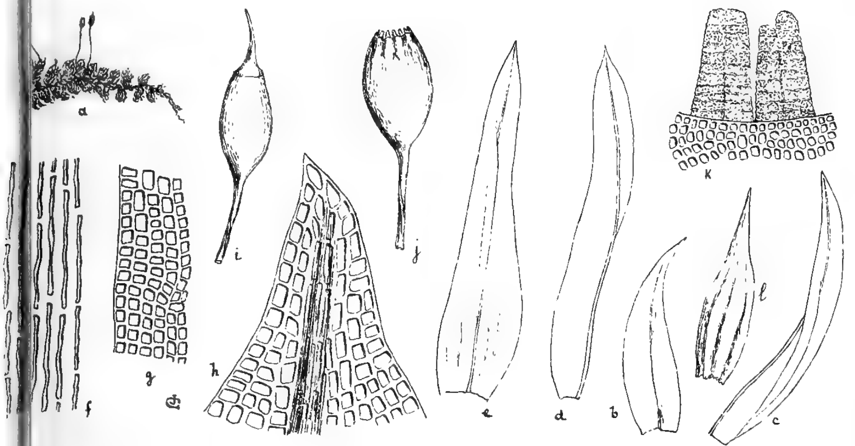

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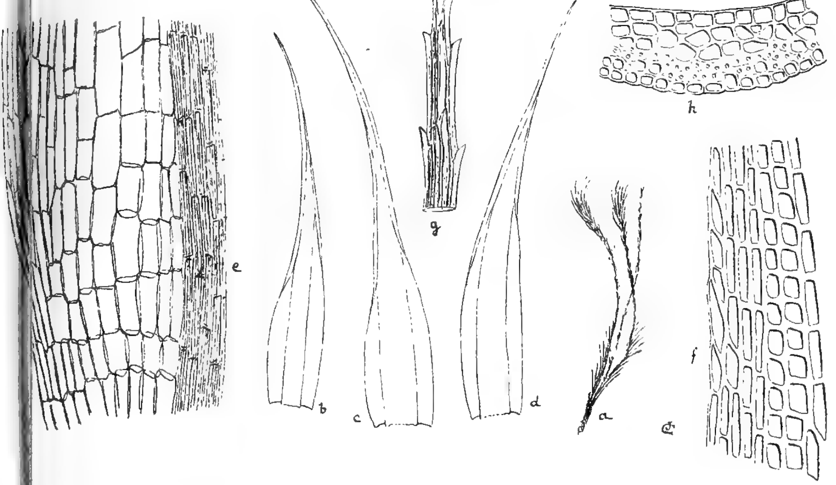

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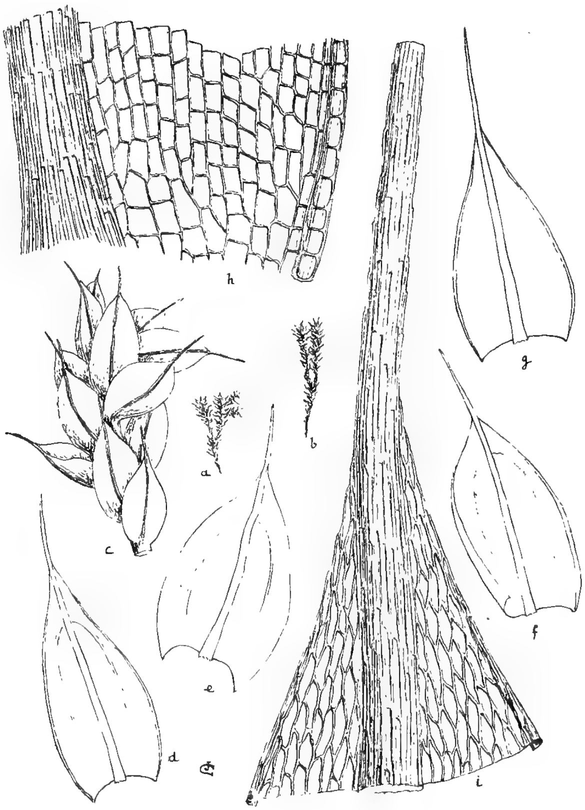
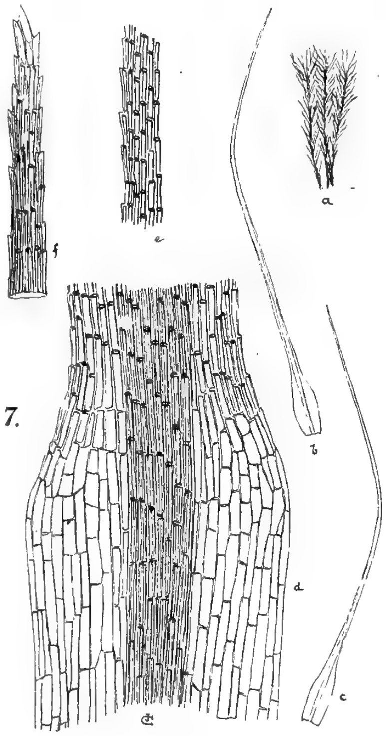


Fig. 6.

M'Farlane & Erskine, Lith., Edin.

JULES CARDOT: LES MOUSSES DE L'EXPÉDITION NATIONALE ANTARCTIQUE ÉCOSSAISE. PLANCHE II.



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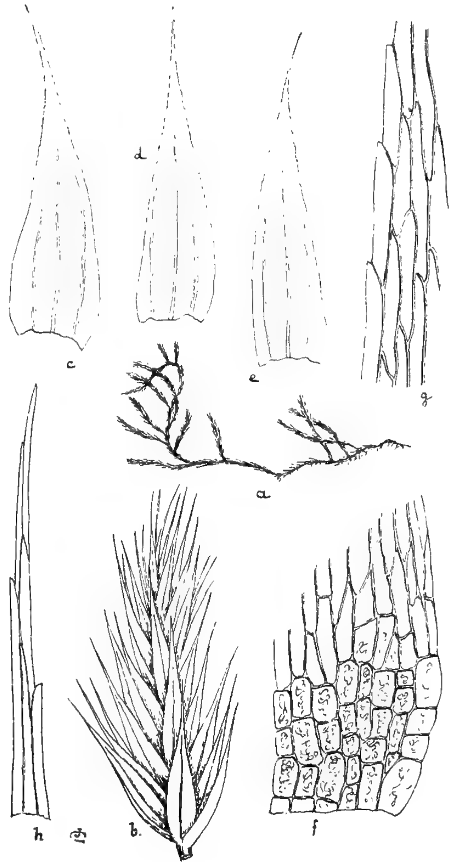

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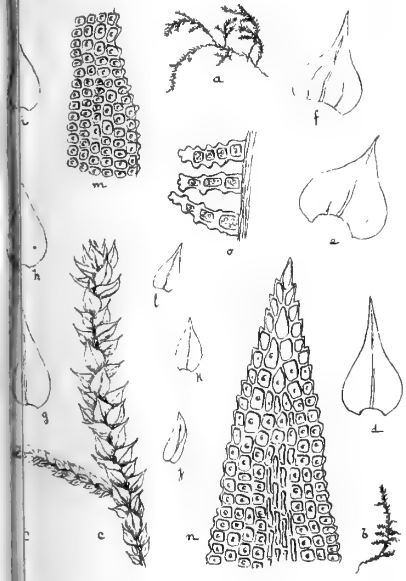

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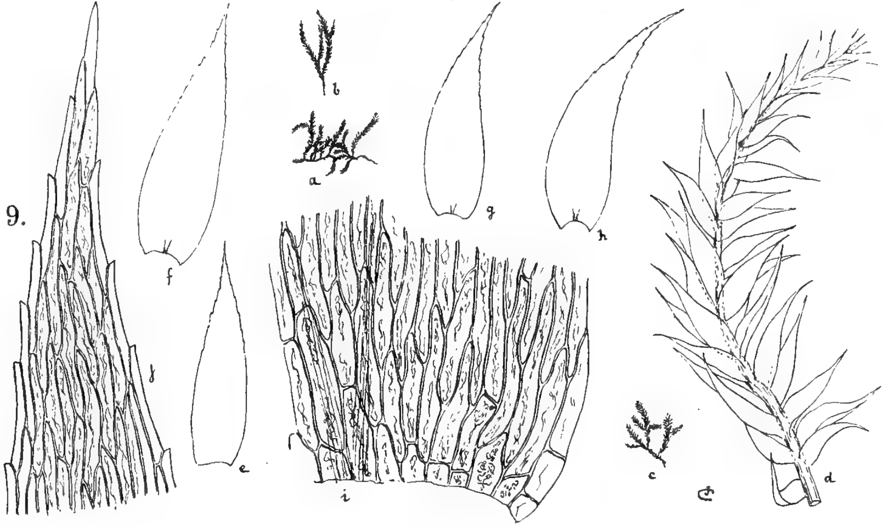

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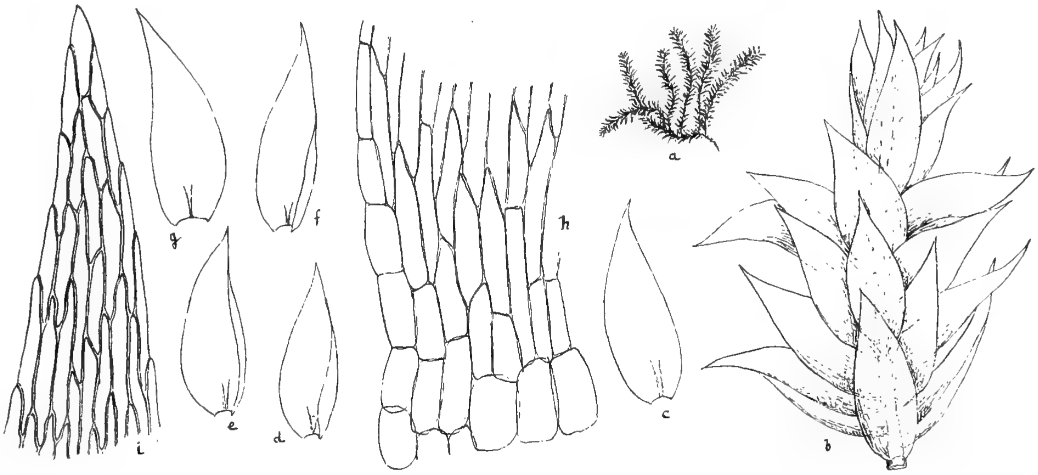
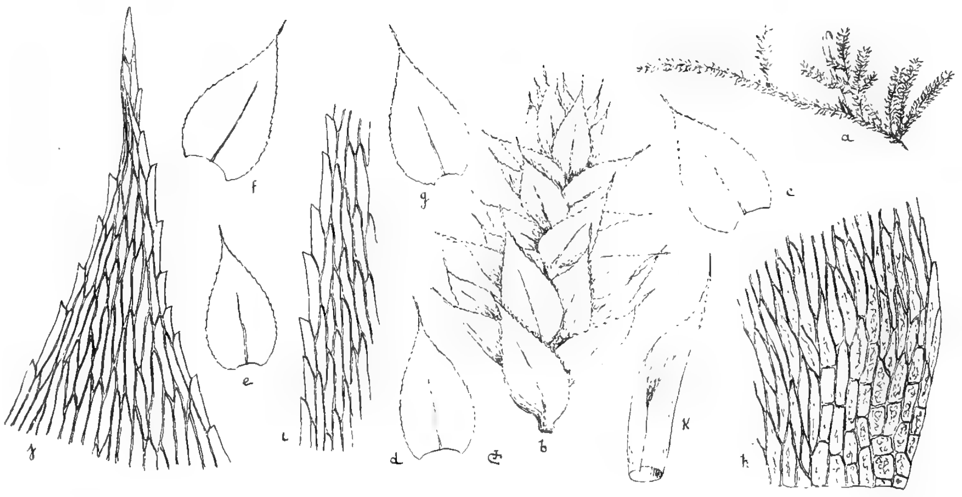


Fig. 10.

M'Farlane & Erskine, Lith., Edin.



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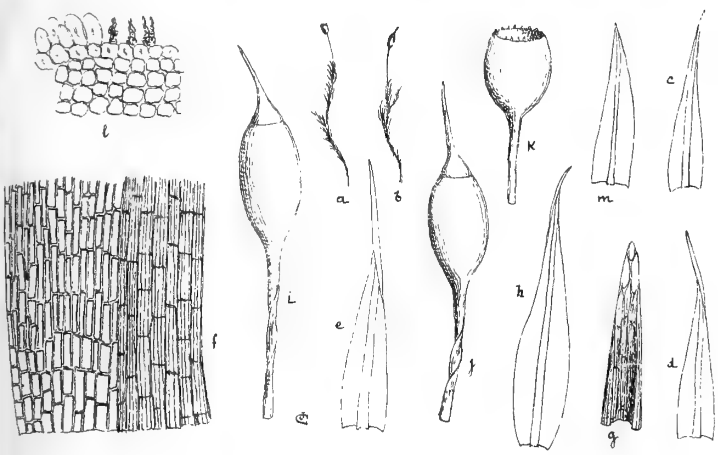

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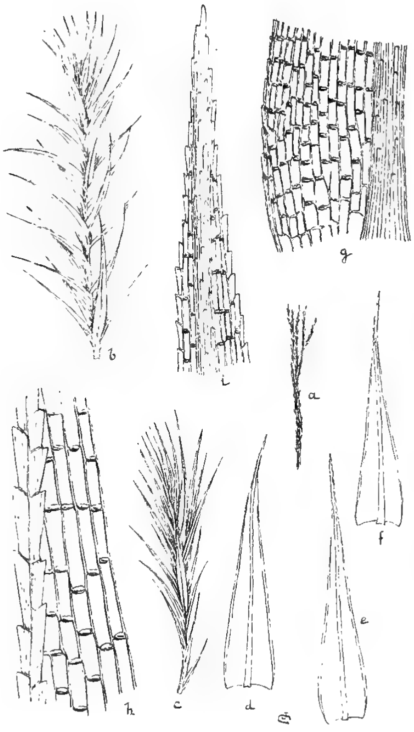

Fig. 15.

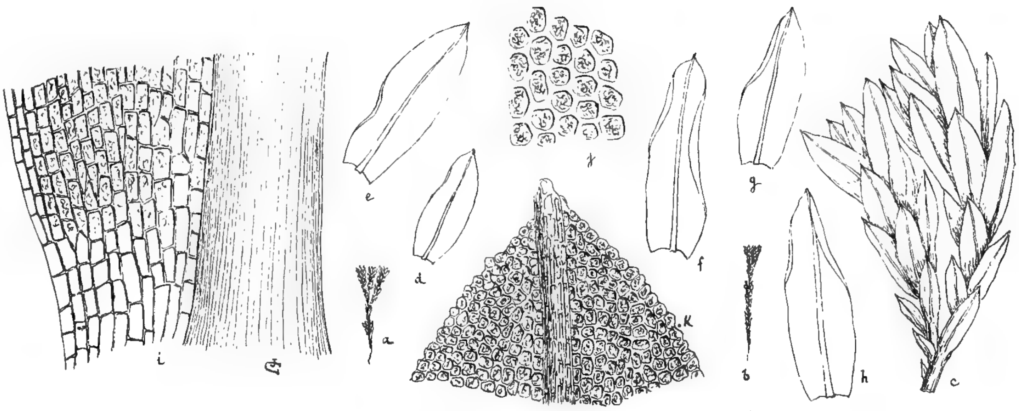

Fig. 14.

M'Farlane & Erskine, Lith., Edin.

IV.—The Pharmacological Action of Harmine. By James A. Gunn, M.A., M.D., D.Sc. (From the Pharmacology Laboratory of the University of Edinburgh.)

(MS received March 20, 1911. Read same date. Issued separately August 9, 1911.)

CONTENTS.

INTRODUCTORY.

The seeds of *Peganum Harmala* contain two alkaloids, Harmaline and Harmine. The pharmacological actions of the former alkaloid have been described in a previous communication to this Society;* in this paper an account is given of the pharmacology of the second alkaloid, Harmine.

Harmine ($C_{13}H_{12}N_2O$) was discovered by FRITCHE in 1847. Apart from a few observations by TAPPEINER, its pharmacology has not been investigated. TAPPEINER† states that, in mammals at least, the general nature of poisoning by harmine is qualitatively the same as by harmaline, but that the former alkaloid is weaker in action. He found that a dose of 0·2 gramme per kilo of harmine is fatal to the guinea-pig in about 12 hours, while the same dose is fatal to the rabbit in about 1 hour, and that a frog is killed in about 7 hours by a dose of 0·03 gramme (per kilo?). He states further that there appears to be one qualitative difference between the actions of the two alkaloids, in that harmine produces paralysis of reflex excitability before arrest of the heart. It may be stated here that this does not constitute a qualitative difference between the actions of harmaline and harmine, because the same effect is produced by harmaline.

My investigation of harmaline having shown that the actions of this alkaloid very intimately resemble those of quinine, a more extended investigation seemed

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* GUNN, *Trans. Roy. Soc. Edin.*, xlvii., 1909, pp. 245–272.

† TAPPEINER, *Archiv für exper. Pathol. u. Pharmakologie*, Bd. xxxv., 1895, p. 69.

desirable also of the pharmacology of harmine, especially as there seems some prospect of the alkaloids being of therapeutic value.

I am much indebted to Dr J. F. THORPE, F.R.S., for his great kindness in giving me several grammes of pure harmine for pharmacological investigation. From the base I prepared, according to his directions, the hydrochloride of the alkaloid, and with this salt all the experiments to be described were performed.

A. LETHALITY OF HARMINE.

The lethality of harmine was determined for frogs, guinea-pigs, rabbits, rats, and pigeons, with the following results :—

TABLE I.—MINIMUM LETHAL DOSE BY SUBCUTANEOUS INJECTION FOR FROGS.

No. of Experiment.	Weight of Frog in Grammes.	Dose per Kilogramme in Grammes.	Actual Dose in Grammes.	Result.
1	18	0·4	0·0072	Recovery.
2	20	0·5	0·01	„
3	16	0·6	0·0096	Death in about 6½ hours.
4	23	0·8	0·0184	„ „ „

TABLE II.—MINIMUM LETHAL DOSE BY SUBCUTANEOUS INJECTION FOR GUINEA-PIGS.

No. of Experiment.	Weight of Guinea-pig in Grammes.	Dose per Kilogramme in Grammes.	Actual Dose in Grammes.	Result.
5	620	0·08	0·05	Recovery.
6	750	0·1	0·075	„
7	700	0·12	0·084	Death in 2 hours.

TABLE III.—MINIMUM LETHAL DOSE BY SUBCUTANEOUS INJECTION FOR RABBITS.

No. of Experiment.	Weight of Rabbit in Grammes.	Dose per Kilogramme in Grammes.	Actual Dose in Grammes.	Result.
8	1200	0·15	0·18	Recovery.
9	1750	0·2	0·35	„
10	1600	0·23	0·368	Death in 2 hours 40 minutes.
11	1550	0·3	0·465	„ 1 hour 12 minutes.

TABLE IV.—MINIMUM LETHAL DOSE BY SUBCUTANEOUS INJECTION FOR RATS.

No. of Experiment.	Weight of Rat in Grammes.	Dose per Kilogramme in Grammes.	Actual Dose in Grammes.	Result.
12	155	0·1	0·0155	Recovery.
13	100	0·15	0·015	„
14	150	0·2	0·03	„
15	100	0·2	0·02	Death in 3 days.
16	115	0·3	0·035	„ 5–20 hours.
17	115	0·4	0·046	„ 7–20 „

TABLE V.—MINIMUM LETHAL DOSE BY SUBCUTANEOUS INJECTION FOR PIGEONS.

No. of Experiment.	Weight of Pigeon in Grammes.	Dose per Kilogramme in Grammes.	Actual Dose in Grammes.	Result.
18	300	0·1	0·03	Recovery.
19	430	0·12	0·051	„
20	420	0·15	0·063	Death in 10 minutes.

For determination of the minimum lethal dose in frogs, and for all subsequent experiments on frogs, the species *Rana temporaria* was used. In frogs, injections were made into the dorsal lymph sac, in mammals under the skin of the right flank, and in pigeons under the skin of the right thigh.

From the above tables it is seen that the minimum lethal dose by subcutaneous injection per kilogramme is, for the frog, 0·6 gramme; for the guinea-pig, 0·12 gramme; for the rabbit, 0·23 gramme; and for the rat, about 0·2 gramme; and for the pigeon, 0·15 gramme.

B. SYMPTOMS PRODUCED BY HARMINE.

(*a*) *In Frogs.*

Experiment 3.—*Rana temporaria*, male, weight 16 grammes. At 12.30 p.m. the throat respirations were twenty in ten seconds and the cardiac impacts seven in ten seconds.

At 12.40, 0·0096 gramme of harmine hydrochloride dissolved in 0·48 c.c. of saline solution was injected into the dorsal lymph sac. This was equivalent to 0·6 gramme per kilogramme.

At 1.40 the respirations were feebler and somewhat irregular, the average rate being about 14 per ten seconds. The cardiac impacts were five in ten seconds and less distinct than before injection. The back was stiff owing to rigidity of the back muscles. The frog was unable to jump, and turned over with difficulty when placed on its back, an effect partly due to some stiffness of the thigh muscles caused by diffusion of the injected solution. The conjunctival reflex was sluggish, and there was some impairment of the reflex excitability of the cord as determined by electrical stimulation.

At 2.30 the frog was unable to jump, and could not recover the ventral posture when laid on its back.

At 3.0 the respirations had ceased and the cardiac impacts were not visible; but, when the web of the foot was examined under the microscope, the blood was found to be circulating sluggishly. Stimulation of the skin of one leg produced no movements of the opposite leg, even with the coil at 30 mm.; but stimulation of the skin over the sciatic nerve produced a contraction of the gastrocnemius muscle of the same side, with the coil at 120 mm.

At 4.30 the circulation was found to be arrested in the web. The brain was pithed and the heart exposed. The heart was beating feebly at the rate of 2 in ten seconds. It ceased beating in ten minutes. No reflex movements could be elicited even by direct stimulation of the sciatic nerve with the secondary coil at 20 mm., but contraction of the gastrocnemius muscle of the same side was induced by stimulation of the nerve at 100 mm.

(*b*) *In Mammals.*

Experiment 11.—Rabbit, 1550 grammes. At 10.55 a.m. the cardiac impacts were 46, and the respirations 34, in ten seconds. The temperature was 99° C.

At 11.0, 0·465 gramme dissolved in 10 c.c. of warm saline solution was injected under the skin of the right flank. This was equivalent to 0·3 gramme per kilogramme.

At 11.5 there were marked tremors of the head and fore part of the body, and the hind limbs were extended so that the abdomen touched the ground. Three minutes later the tremors were more violent and the animal made frequent spasmodic movements forwards, the hind limbs being unable properly to support or propel the body.

At 11.12 a slight epileptiform convulsion occurred, marked especially by clonic movements of the limbs, after which the animal lay quiet. A similar but more violent convulsion occurred a minute later, during which the animal fell on its side and rolled over sideways two or three times. After this the rabbit lay on its side with feeble pawing movements of the limbs. The respirations were 20, and the cardiac impacts 35, in ten seconds. The temperature was 100° C.

Up to 11.30 the symptoms were similar, but the convulsive movements became gradually less violent. At the end of that time the respirations were 12 in ten seconds, regular and deep. The cardiac impacts were palpated with difficulty, and were about 28 in ten seconds. The skin was colder.

At 11.50 there was almost complete motor paralysis, the animal lying continuously on its side and making feeble running movements occasionally. When held up by the ears it made no movements. Pinching the skin evoked no reflex movements, and the conjunctival reflex was sluggish.

At 11.55 the conjunctival reflex was with difficulty elicitable. The thigh muscles and muscles of the right flank were stiff. The temperature was 96·4° C.

At 12.9 the animal made no movements, apart from those of respiration which were feeble and irregular, the rate being about 9 in ten seconds. The heart beats were feeble, irregular, and infrequent.

At 12.12 the respirations ceased. The thorax was opened, and at 12.13 the heart found to be beating very feebly. It ceased beating in the diastolic position at 12.15. The muscles round the seat of injection were rigid and inexcitable. The muscles of the fore limbs reacted to weak stimulation of their nerves, as also did the diaphragm to stimulation of the phrenic nerve.

C. Action on the Central Nervous System.

(*a*) *In Frogs.*—The description given of the symptoms produced by lethal doses of harmine in the frog has shown that the chief effects referable to an action on the central nervous system are loss of co-ordination and of the power of jumping, arrest of respiration, and paralysis of reflex excitability. Since these effects come on at a time when they cannot be accounted for by paralysis of the peripheral neuro-muscular mechanism, they indicate that harmine paralyses the mid-brain, medulla oblongata, and spinal cord.

(*b*) *In Mammals and Pigeons.*—Epileptiform convulsions form the most conspicuous symptom produced by large doses of harmine in warm-blooded animals. They are clonic in nature and are usually intermittent, intervals of quiescence ensuing between the convulsions. They are generally aggravated by any voluntary movement. All the facts observed in regard to these convulsions, among which may be mentioned their clonic nature, their occurrence apart from any marked increase of spinal reflex excitability, and their absence in frogs, point to their being due to an exciting action on the cerebrum.

In regard to this action of harmine on the cerebrum, it is of interest to observe that the minimum lethal dose per kilogramme for a series of animals is roughly in inverse proportion to the amount of grammes of brain per kilogramme of body weight in those animals. A somewhat similar relationship occurs with cocaine, which also produces cerebral convulsions.*

The clonic convulsions produced by harmine are not directly fatal to the animal, as they do not markedly interfere with respirations. When the dose is lethal, the convulsions are followed for a short time before death by a condition of motor paralysis due to a depressing action on the central nervous system. If the dose be not lethal, the convulsions are usually entirely recovered from within one or two hours.

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* Dixon, *Manual of Pharmacology*, 1906, p. 145.

D. ACTION ON SKELETAL MUSCLE.

To ascertain the effects produced by harmine on voluntary muscle, experiments were made on the isolated gastrocnemius muscles of the frog, one muscle being immersed in a solution of the alkaloid, the other muscle in Ringer's solution. A modified Wild's method was employed, and to stimulate the muscles the secondary current passed simultaneously through both muscles. Tracings were taken on a slowly revolving drum.

Experiment 21 (figs. 1 and 2).—Strength of solution, 1 in 2000. Normal twitches resulting from stimulation with break shocks are shown at 11.28, both muscles being in Ringer's solution. At 11.30 Ringer's solution was withdrawn from muscle B and replaced by a solution of harmine hydrochloride 1 in 2000 in Ringer's solution. Muscle twitches (generally three in succession) were thereafter taken at intervals of two minutes, with the secondary coil at 100 mm. throughout.

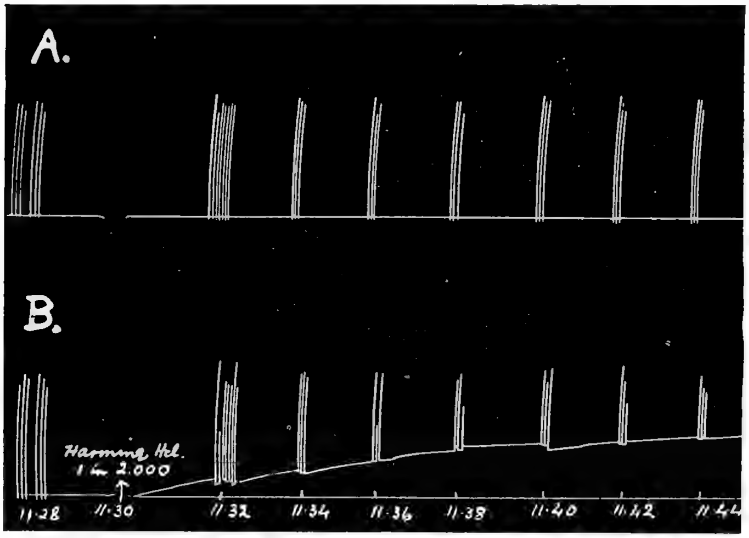

FIG. 1.

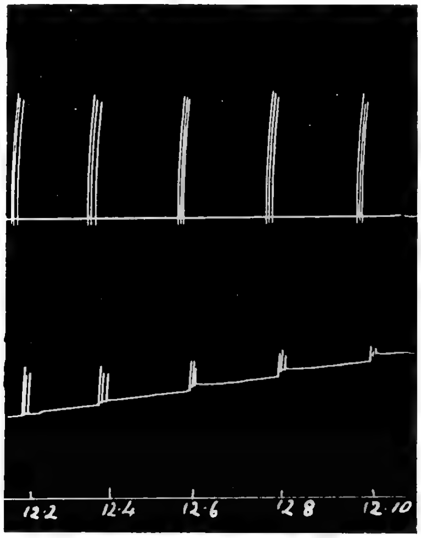

FIG. 2.

As the tracing shows, harmine causes the muscle gradually to pass into a condition of rigor with diminishing excitability and extent of contraction, so that in forty minutes the muscle had raised the lever above the level of the summit of a single twitch and no longer responded to the stimulus. The control muscle was unaffected.

This effect on muscle is always produced by solutions of harmine when not less dilute than 1 in 5000, sometimes even by solutions of 1 in 10,000. Results of this action on muscle are exemplified in the general effects of poisoning by harmine by the occurrence of rigidity and impaired excitability of the muscles round the seat of injection, and also by the unusually rapid onset of rigor mortis after lethal doses.

E. ACTION ON THE CIRCULATION.

(*a*) *Heart.*

A series of experiments was performed in which the isolated frog's ventricle was perfused by means of Schafer's frog-heart plethysmograph. A mixture of defibrinated ox-blood (one part) and Ringer's solution (two parts) was used as the nutrient solution and as the solvent for harmine. The bulb of the plethysmograph which contained the heart was filled with Ringer's solution, and the contractions of the ventricle were recorded by means of an air-piston recorder attached by a rubber tube to the brass cylinder.

Experiment 22 (figs. 3 to 5).—Strength of solution, 1 in 10,000. This strength of solution rapidly reduced both the rate of beat of the heart and also the amplitude of its excursus, the diminution of excursus being due mainly to less complete systole, but also to incomplete relaxation (fig. 3). Thus, in three minutes the rate fell from 18 to 6 contractions per minute, while the excursus was reduced from 9 to 2 millimetres. In six minutes the ventricle was arrested in a position of almost complete diastole, and the normal solution was thereupon substituted for the harmine solution (fig. 4). This so quickly restored the heart, that in ten minutes the rate and the excursus were practically the same as before harmine (fig. 5).

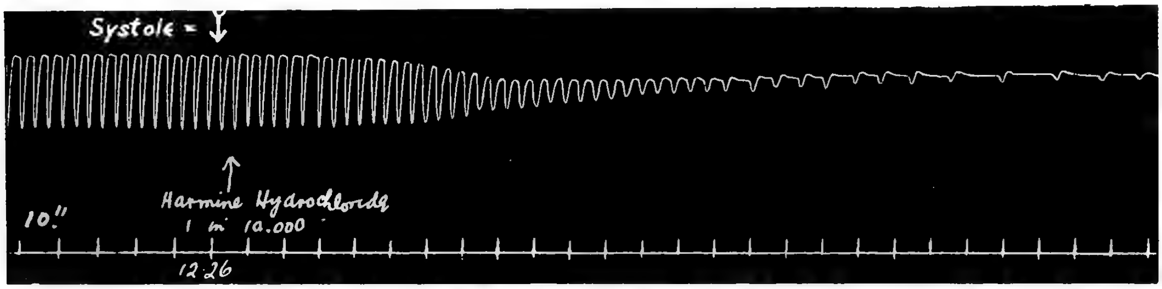

FIG. 3.

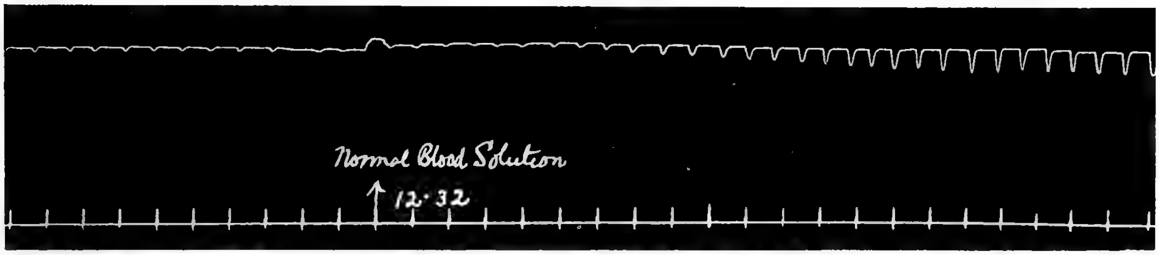

FIG. 4.

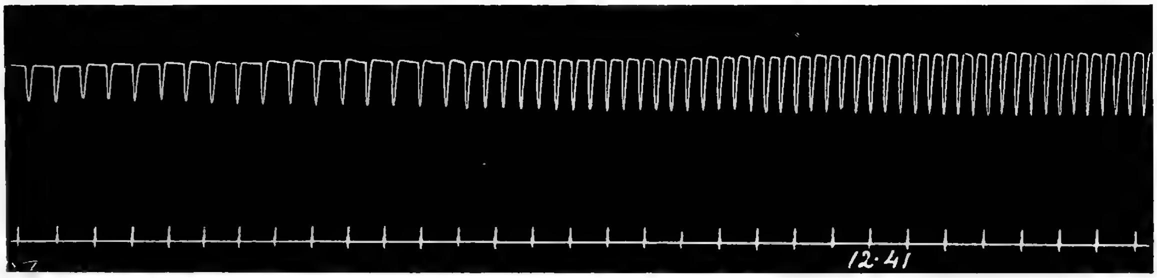

FIG. 5.

Experiment 23 (figs. 6, 7, and 8).—Strength of solution, 1 in 25,000. The conditions and result of this experiment are detailed in the following table :—

Table VI.—Experiment 23.

Time.	Rate per Minute.	Amplitude of Excursus.	Solution Perfused.
4.10	28	17 mm.	Normal solution.
4.20	30	16 ,,	
4.22	..	...	Harmine solution turned on (fig. 6).
4.25	17	11 mm.	
4.34	13	10 ,,	Fig. 7.
4.44	14	10 ,,	
5.4	11	14 ,,	Fig. 8.
5.11	...	...	Normal solution turned on.
5.13	20	17 mm.	
5.16	26	17 ,,	

This solution, therefore, produced considerable slowing and some weakening of the heart, but did not arrest it in fifty minutes. Recovery was rapid on reperfusion with the normal solution.

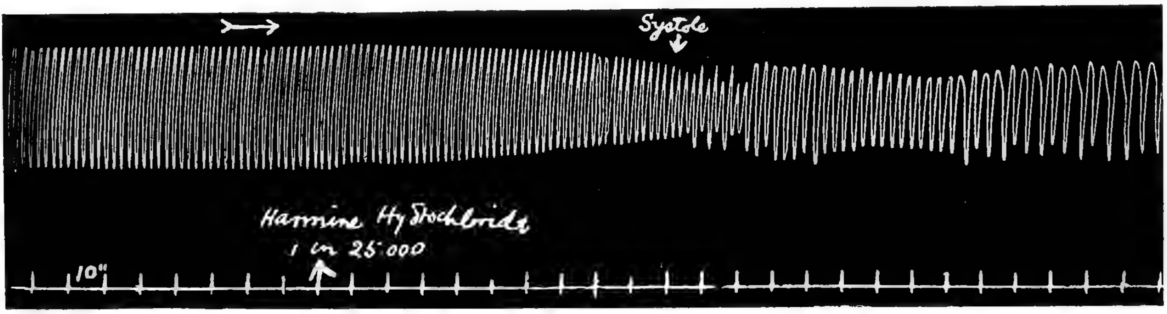

Fig. 6.

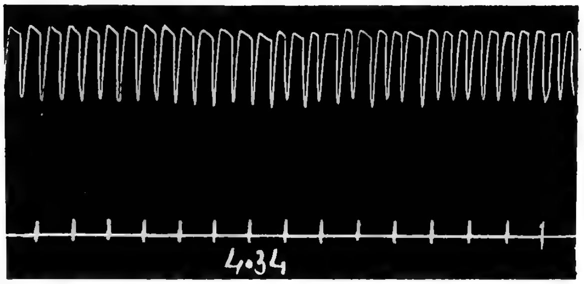

Fig. 7.

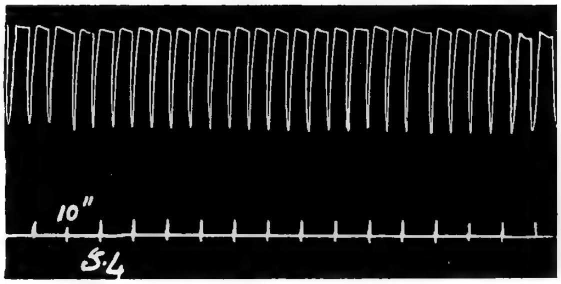

Fig. 8.

These two experiments illustrate the chief effects of harmine on the frog's heart, which may now be summarised. Solutions of 1 in 10,000 or more concentrated solutions rapidly slow the heart and arrest it in a position of complete, or almost complete, diastole. Solutions of 1 in 15,000 to 1 in 30,000 produce slowing of the heart, and also some reduction in the amplitude of its excursus due to less complete systolic contraction. Solutions of 1 in 50,000, or weaker solutions, have no effect on the heart.

A point of some interest, when taken into consideration with the effect of harmine on blood pressure in mammals, is the extreme readiness with which the heart recovers when the harmine is removed from the circulation.

Other experiments have shown that the slowing of the heart produced by harmine is not prevented by simultaneous perfusion with atropine sulphate, and is therefore due to an action on the cardiac muscle.

(*b*) *Blood-vessels.*

To ascertain any changes produced by harmine on the blood-vessels of the frog, the following method was used. After the frog was pithed and the heart exposed, the venæ cavæ were cut across, and a fine cannula was tied into the left aorta, the right aorta being ligatured. This cannula was connected with two Marriotte's flasks containing the fluids to be perfused. A record was taken of the amount of fluid exuding per minute from the cut venæ cavæ. Ringer's solution was used as the normal solution and as the solvent for harmine.

Perfusion of the vessels for thirty minutes with solutions of harmine of varying strengths gave the following results:—A solution of 1 in 1000 reduced the flow from 1·8 c.c. per minute to 0·9 c.c. per minute; a solution of 1 in 2500 reduced the flow from 2·4 c.c. per minute to 1·7 c.c. per minute; a solution of 1 in 5000 reduced the flow from 2·7 c.c. per minute to 2·0 c.c. per minute; while a solution of 1 in 7500 had no effect on the flow through the vessels. Harmine has therefore a slight constricting action on the frog's blood-vessels.

(*c*) *Heart and Blood-vessels.* (*Blood Pressure.*)

In all blood-pressure experiments the animals (rabbits or cats) were first anæsthetised with chloroform; the trachea was then exposed, and a cannula tied into it through which diluted ether was thereafter inhaled. A cannula in the left carotid artery was connected with the manometer. Respirations were recorded by means of a double stethograph attached by a band round the thorax and connected with a Marey's tambour. Injections were made into the right jugular vein. It was found in preliminary experiments that the minimum lethal dose of harmine injected in this way is about 0·03 gramme per kilo.

Experiment 24 (Table VII., figs. 9 and 10).—Rabbit, 2400 grammes. The first injection of 0·01 grm. per kilo, equivalent to one-third of the intravenous minimum lethal dose, produced a somewhat transient fall of blood pressure, the normal level being restored in about ten minutes. The fall of pressure was accompanied by a slowing of the heart, which was evidently, in part at least, a causal factor. Recovery of blood pressure occurred in spite of further slowing of the heart. It is noteworthy

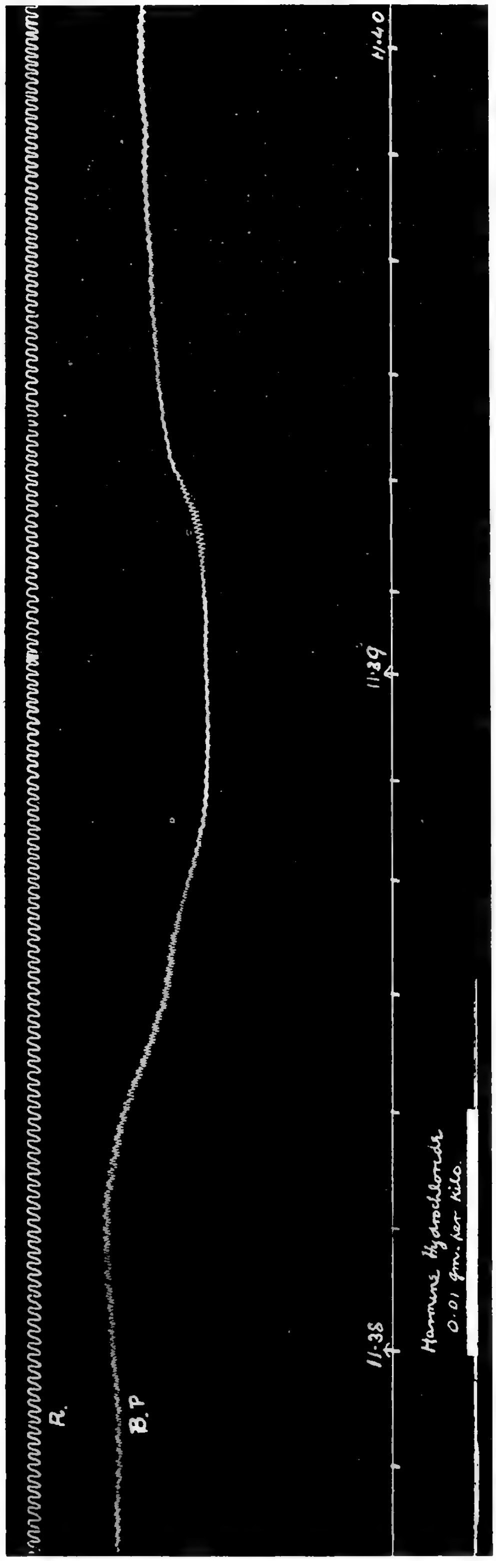
R.
B.P
11·38
11·39
11·40
Harmine Hydrochloride
0·01 gm. per Kilo.

FIG. 9.

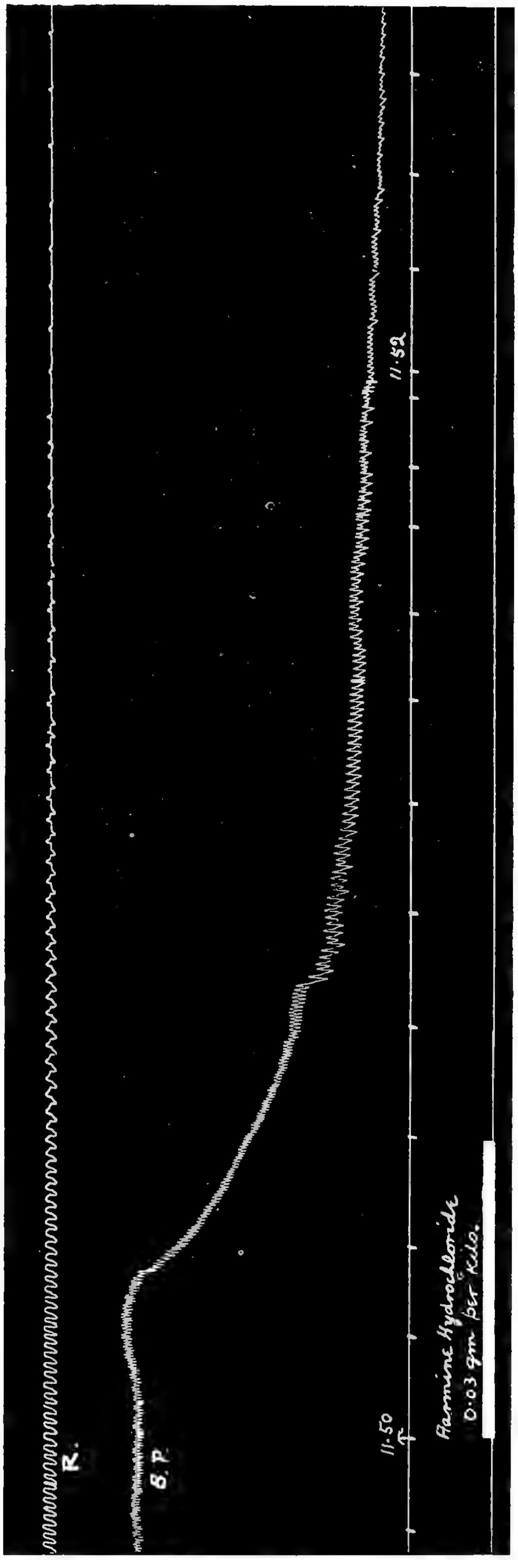
R.
B.P
11·50
11·52
Harmine Hydrochloride
0·03 gm per Kilo.

FIG. 10.

that, though the dose injected in this case was so large as one-third of the minimum lethal, no effect was produced on respiration.

The second injection produced a rapid decline of blood pressure, accompanied by slowing, and later by great feebleness, of the heart's contractions. Respiration was not much affected until the blood pressure reached a very low level. This, together with the facts that respirations continue as long as the heart beats and that respirations are unaffected except by doses which produce a grave fall of blood pressure, goes to show that death from intravenous injection of harmine is mainly, if not solely, due to cardiac failure.

Table VII.—Experiment 24.

Time.	Dose of Harmine intravenously.	Average B.P. in mm.	Pulse Rate per 10 seconds.	Rate of Respirations per 10 seconds.	Respiration Excursus.	Notes.
11.37	...	100	48	10	2 mm.	
11.38	0·01 grm. per kilo.	...	...	...	...	Fig. 9.
11.38.30″	...	82	42	10	2 mm.	
11.40	...	92	46	10	2 „	
11.48	...	98	40	10	2 „	
11.50	0·03 grm. per kilo.	...	...	...	...	Fig. 10.
11.50.30″	...	60	37	7	2 mm.	
11.51	...	50	14	5	1 „	
11.52	...	35	16	3	0·5 „	Pulse waves very small.
11.54	...	28	10	3	...	„
11.56	...	0	0	0	...	

The effects of harmine on blood pressure, as deduced from this and other experiments, may be briefly summarised. Apart from very small doses, which sometimes produce an insignificant rise of blood pressure, the chief action of harmine is to produce a fall of blood pressure, due to slowing of the heart, and, in the case of lethal doses, also to enfeeblement of the heart's contractions. The slowing of the heart is not prevented by previous administration of a dose of atropine sufficient to paralyse the vagal endings, so that it is due to an action on the cardiac muscle, as was found also in the case of the frog's heart.

The only point of importance which remains to be discussed is whether the fall of pressure is due solely to cardiac causes or is due partly to vascular dilatation. To determine this, several experiments were made in which a record was taken of the blood pressure and also of the volume of the kidney or of a loop of intestine.

Experiment 25 (fig. 11).—Cat, 2700 grammes. Blood pressure was recorded as in the previous experiment, and the kidney volume was recorded by an oncometer and air-piston recorder. An injection of 0·004 gramme per kilo was given, about one-eighth of the minimum lethal dose. This reduced the blood pressure in one minute from 120 mm. to 88 mm., and the pulse rate from 18 to 13 per ten seconds. There was meantime a considerable reduction in the volume of the kidney, showing that there was no dilatation of its blood-vessels. Similar results were obtained with the intestinal volume. It would appear, therefore, that the fall of blood pressure is due chiefly to diminished output from the heart, and not to dilatation of the abdominal vessels, though experiments on the intact animal gave indications of some dilatation of the vessels of the skin.

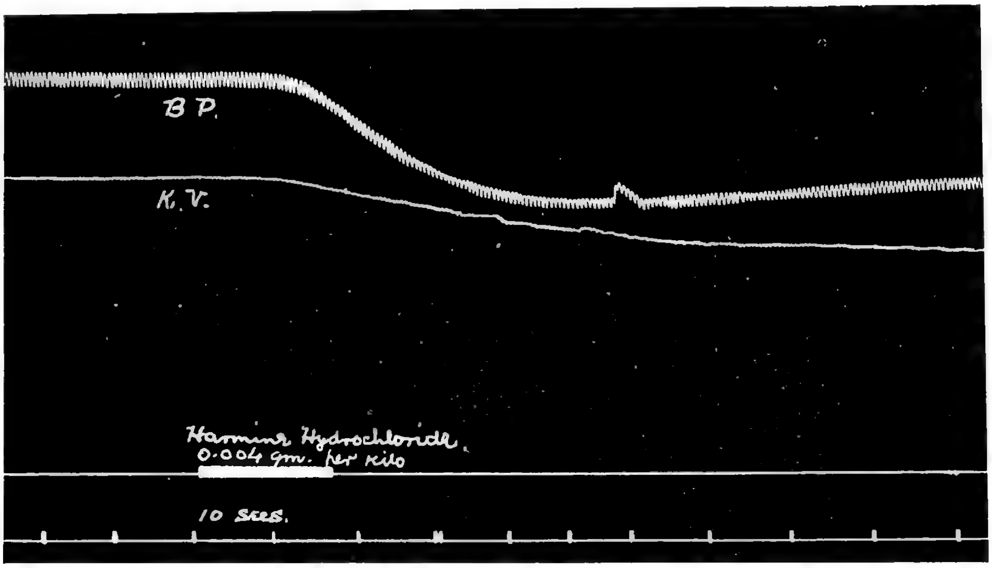

Fig. 11.

F. Action on the Respiration.

Lethal doses of harmine paralyse the respiration in frogs a short time before cessation of the heart beats, but at a time when there is great feebleness of the circulation. In mammals the same effect is obtained with small lethal doses; but with rapidly lethal doses, especially if intravenously injected, the heart beats and respirations cease at the same time. At the time of death the diaphragm reacts to weak stimulation of the phrenic nerve, and respiratory failure is probably partly due to a direct depressing action of harmine on the respiratory centre, and is partly consequent upon circulatory failure.

In the unanæsthetised mammal sublethal doses produce a distinct stimulation of respiration. This does not occur if the animal is anæsthetised with chloroform or ether, a very common phenomenon with respiratory stimulants.

G. Action on Temperature.

Large doses of harmine cause a fall of temperature in mammals, an effect which has been shown by Harnack * to be generally true of convulsant poisons. The fall of temperature is sometimes preceded by a slight transient rise.

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* Harnack, *Archiv für exper. Path. u. Pharmakol.*, 1897, Bd. xxxviii.

H. ACTION ON THE UTERUS.

Rabbits were used for these experiments. They were anæsthetised as for blood-pressure experiments and kept during the experiment in a bath of saline solution at 38° C., enough of the body being submerged to ensure that the uterus was never exposed to the air. The abdomen was then opened in the middle line, and the uterus, isolated from the surrounding viscera, was connected with a lever writing on a slowly revolving drum.

Experiment 26 (figs. 12 to 14).—Rabbit, 2350 grammes, parous, non-pregnant. Slight spontaneous contractions occurred regularly at the rate of about 2 per minute.

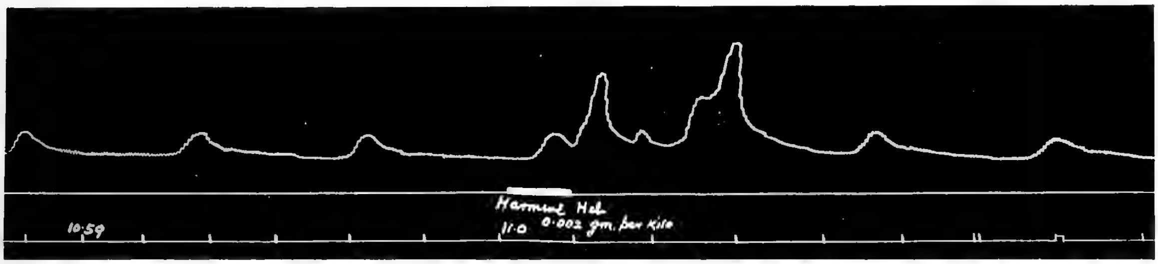

FIG. 12.

At 11.0, 0·002 gramme per kilogramme of harmine hydrochloride was injected intravenously, and this produced a marked augmentation of the uterine contractions, which, however, soon passed off. At 11.15 a second injection of twice the former amount was given, and this produced very powerful uterine contractions (fig. 13), which were repeated at intervals afterwards (fig. 14). The resting tone of the uterine muscle was also increased.

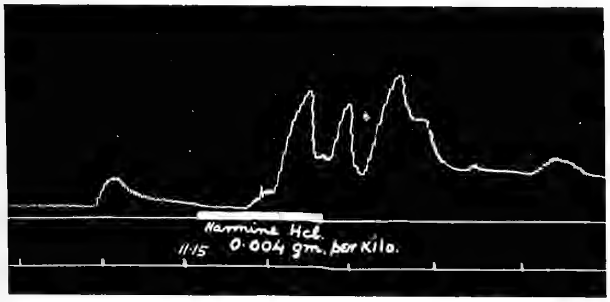

FIG. 13.

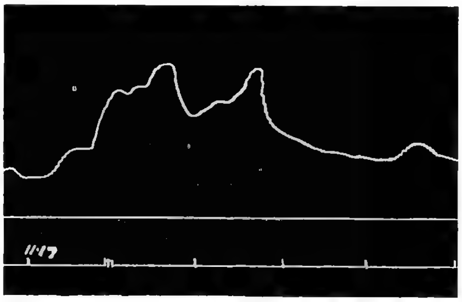

FIG. 14.

It is evident, therefore, that harmine exerts a decided stimulating effect on the uterine contractions.

GENERAL SUMMARY.

The minimum lethal dose of harmine hydrochloride per kilogramme by subcutaneous injection is, for the frog, 0·6 gramme; for the guinea-pig, 0·12 gramme; for the rabbit, 0·23 gramme; for the rat, 0·2 gramme; and for the pigeon, 0·15 gramme.

In frogs, lethal doses of harmine paralyse the mid-brain, medulla oblongata, and spinal cord. Abolition of reflex excitability occurs before arrest of the heart, and before paralysis of the voluntary muscles. In mammals large doses cause epileptiform convulsions, cerebral in origin. If the dose be non-lethal these are soon recovered from; if the dose be lethal, they give place to a condition of paralysis of the central nervous system, which endures for a short time before death.

Harmine produces rigor and inexcitability of an isolated muscle, but, even with lethal doses, the concentration of harmine in the blood is not sufficient to render this action of importance in the general effects of this alkaloid.

Strong solutions of harmine perfused through the frog's heart slow the heart and arrest it in a position of almost complete diastole; weaker solutions slow the heart and diminish the completeness of systolic contraction. The effects are due to an action on the cardiac muscle.

Harmine has a slight peripheral constricting action on the frog's blood-vessels.

In mammals, harmine, in doses which have any marked effect on blood pressure, produces a fall of blood pressure due chiefly to slowing, or, in the case of large doses, to slowing and weakening, of the heart's contractions. Cardiac failure is the chief cause of death from harmine poisoning.

Sublethal doses of harmine stimulate respiration; lethal doses paralyse respiration, partly from a direct action on the respiratory centre and partly as a consequence of circulatory failure.

Like many convulsant poisons, harmine in large doses produces a fall of temperature in mammals. Even in small doses it stimulates the contractions and augments the tone of uterine muscle.

COMPARISON OF THE ACTIONS OF HARMINE AND HARMALINE.

The pharmacological actions of harmine resemble very closely those of harmaline in so far as the symptoms produced in the intact animal and the effects produced on the various systems and on isolated tissues are qualitatively the same in the case of both alkaloids. For this reason the pharmacology of the former alkaloid has been discussed more briefly. Harmine is, however, only about half as toxic as harmaline; and probably the chief reason for the relatively lower toxicity of harmine is that the primary stimulating action on the central nervous system less readily gives place to paralysis, and hence respiratory paralysis plays a less important part in the production of its lethal effects than is the case with harmaline.

As the alkaloids can easily be obtained from the seeds in a mixed form, whereas their separation from one another is, I understand, a difficult and tedious process, this close similarity in their pharmacological actions possesses this importance, that the mixed alkaloids would apparently be as effective therapeutically as either alkaloid alone, should a therapeutic use for them be found.

V.—On the Resistance to Flow of Water through Pipes or Passages having Divergent Boundaries.

By Professor **A. H. Gibson**, D.Sc., University College, Dundee. *Communicated by* Professor W. Peddie, D.Sc.

(MS. received March 20, 1911. Read July 3, 1911. Issued separately August 30, 1911.)

CONTENTS.

§ 1. INTRODUCTION.

Some time ago the author published [*] the results of a series of experiments on the flow of water through tubes having uniformly diverging boundaries, in which the loss of energy corresponding to given angles of conicity of the tubes was determined. These pipes, some circular, others square or rectangular in cross section, had the same initial and the same final areas, these being respectively the same as those of circles of 1·5 inch and 3·0 inches diameter, the ratio of initial to final mean velocity of flow being in each case 4 to 1.

The present experiments were planned with a view of extending the investigation to cover a series of values of the ratio of enlargement, and also of ascertaining whether the loss in similar pipes having identical mean velocities of flow varies with or is independent of their dimensions.

In some cases where such divergent passages form an essential feature of a hydraulic machine it is the practice to project the boundaries of the smaller pipe for some distance into the space bounded by the divergent walls, and the work has been extended to investigate the effect of this method of construction on the efficiency of energy transformation.

The question as to the shape of pipe giving the least loss of energy with given initial and final areas and with a given length—a problem of much practical importance—was also touched upon in the former paper, and further investigation has been directed to this point.

Altogether upwards of ninety pipes have been examined. The experiments have been carried out in the engineering laboratories of University College, Dundee, the apparatus used and the methods of making measurements and of carrying out the work being substantially illustrated and described in the former paper.[†] Of the pipes examined those of rectangular section were of wood carefully made to template and

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[*] *Proc. Roy. Soc.*, A, vol. lxxxiii., 1910, p. 366.

[†] *Ibid.*, p. 368.

varnished. The circular pipes were of brass bored out to the correct taper, or, in the case of the pipes with varying curvature, carefully bored out to template. Calling θ the angle of conicity of a pipe (the angle contained between its opposite faces), the following table shows the range of uniformly tapering circular pipes experimented upon :—

Initial Diameter.	Final Diameter.	Ratio of Final to Initial Area.	Value of θ.
Inches.	Inches.		
·65	2·15	10·96	180° (sudden enlargement)
·50	1·50	9·0	10°, 20°, 40°, 60°, 90°, 180°
1·00	3·00	9·0	20°, 40°, 60°, 90°, 180°
* 1·50	3·00	4·0	3°, 4°, 5°, 7½°, 10°, 12½°, 15°, 17½°, 20°, 30°, 40°, 50°, 60°, 90°, 180°
2·00	3·00	2·25	10°, 20°, 40°, 60°, 90°, 180°

The mean velocities of flow in these experiments ranged from 1·83 feet per second to slightly over 21 feet per second. The results show that in any given pipe the loss of head, expressed as a percentage of the loss, $\frac{(v_1 - v_2)^2}{2g}$, theoretically obtained at a sudden enlargement between the same areas, does not vary in any definite manner with the velocity, and is, in fact, sensibly constant for all velocities above the critical; and in giving the results the losses have, in every case, been expressed as a percentage of this quantity.

§ 2. Experiments on Circular Pipes with Uniformly Diverging Boundaries.

The following table gives the mean of all experiments carried out on each pipe, while the results are shown graphically and are compared with those of the former experiments, in fig. 1 :—

Loss of Energy expressed as a Percentage of $\frac{(v_1 - v_2)^2}{2g}$, the Theoretical Loss at a Sudden Change of Velocity from v_1 to v_2.

Value of θ		180°.	90°.	60°.	40°.	20°.	10°.
Pipe diameters in inches.	·65 to 2·15	103·5	...	...	...	...	...
	·50 „ 1·50	102·8	102·6	102·8	82·0	45·0	16·6
	1·0 „ 3·0	102·1	104·1	101·3	80·8	44·0	...
	1·5 „ 3·0	101·7	111·1	120·5	101·7	42·5	17·5
	2·0 „ 3·0	99·2	112·1	...	88·7	41·9	18·6

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* These experiments are described in the former paper.

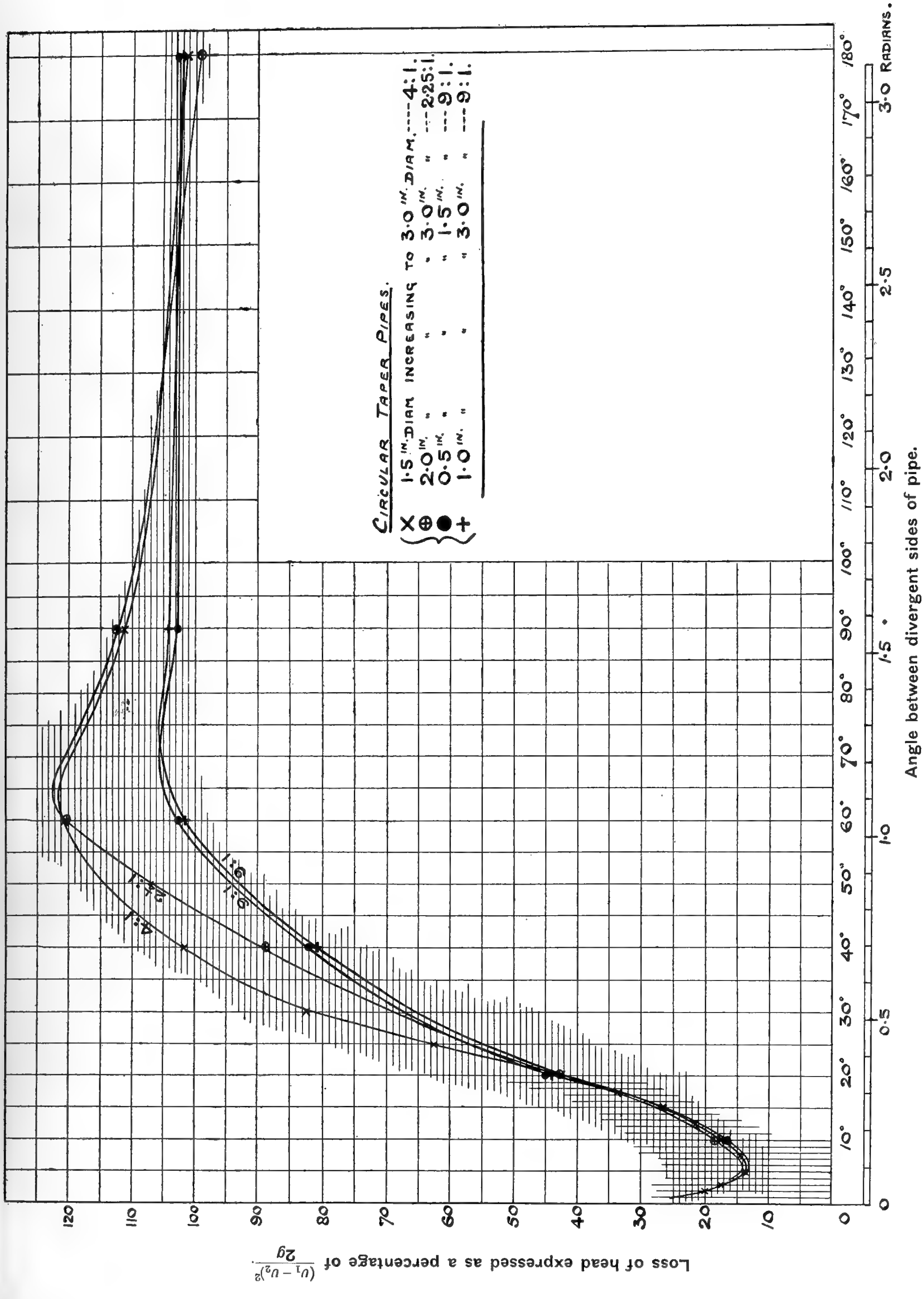
CIRCULAR TAPER PIPES.
× 1·5 IN. DIAM INCREASING TO 3·0 IN. DIAM. ----4:1.
⊕ 2·0 IN. " " " 3·0 IN. " ---2·25:1.
● 0·5 IN. " " " 1·5 IN. " ---9:1.
+ 1·0 IN. " " " 3·0 IN. " ---9:1.
4:1
2·25:1
9:1
9:1
0
10
20
30
40
50
60
70
80
90
100
110
120
Loss of head expressed as a percentage of $\frac{(U_1 - U_2)^2}{2g}$.
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
100°
110°
120°
130°
140°
150°
160°
170°
180°
0·5
1·0
1·5
2·0
2·5
3·0 RADIANS.
Angle between divergent sides of pipe.

FIG. 1.

From these results it appears that the total loss in the pipes having $\theta = 180^\circ$ is in every case in close agreement with that given by BOULANGER's formula, $\frac{(v_1 - v_2)^2}{2g}$. The actual loss is, in the majority of cases, slightly greater than that given by this formula. Experiments on larger pipes having a sudden change in diameter from 3 inches to 6 inches and from 4 inches to 6 inches respectively* show an experimental loss somewhat less than that given by the formula. The percentage loss increases slightly with the area-ratio, and in pipes with the same area-ratio is greater the smaller the pipe.

Denoting the ratio of enlargement by m, and the smaller diameter by d, the loss at a sudden enlargement for values of m between 2 and 12, and for pipe diameters ranging from ·50 inch to 6 inches, can be expressed, within narrow limits, by the relationship—

$$\text{loss of head} = \frac{102{\cdot}5 + {\cdot}25m - 2{\cdot}0d}{100} \left\{ \frac{(v_1 - v_2)^2}{2g} \right\} \text{ feet.}$$

The following table shows the results obtained by the use of the formula, against those experimentally obtained :—

Size of Pipes.	Value of m.	Loss expressed as Percentage of $\frac{(v_1 - v_2)^2}{2g}$.	
		Experimental.	By Formula.
·65 to 2·15 inches	10·96	103·5	103·9
·50 „ 1·5 „	9·0	102·8	103·7
1·0 „ 3·0 „	9·0	102·1	102·8
1·5 „ 3·0 „	4·0	101·7	100·5
2·0 „ 3·0 „	2·25	99·2	99·1
3·0 „ 6·0 „	4·0	97·5	97·5
4·0 „ 6·0 „	2·25	92 (approx.)	95·0

As θ is diminished from 180° the percentage loss in every case increases, attains a maximum value for some value of θ in the neighbourhood of 65°, and afterwards diminishes rapidly with θ until θ is about 5° 30′. This value gives a minimum loss of approximately 13·5 per cent. Any further diminution in θ is accompanied by an increased loss owing to the large value of the wall friction in pipes of the comparatively great length accompanying such small values of θ. The value of θ which coincides with the maximum loss, varies somewhat, both with the size of pipe and with the area-ratio, increasing slightly with the dimensions when the latter is constant, and with the area-ratio when the mean pipe diameter is constant. Over the range of pipe diameters and area-ratios examined in these experiments its value lies between 63° and 70°.

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* BRIGHTMORE, *Proc. Inst. Civil Engineers*, vol. clxix., 1906–7, Pt. iii. p. 322. Here the loss of head was 97·5 per cent. of the theoretical for an enlargement of area 1 to 4, and was about 92 per cent. of the theoretical for an enlargement of 1 to 2·25.

The maximum percentage loss varies in these experiments between 105 per cent. and 122 per cent. It increases with the mean diameter of the pipe for the same area-ratio, and also increases as the ratio of enlargement is reduced.

As θ is diminished below 60° the percentage loss curves rapidly converge, and for values of θ less than 25° these are very sensibly the same for all the pipes. With $\theta = 20°$ the percentage losses due essentially to the divergence of the walls, the friction losses being calculated as explained in the former paper,* are as follows :—

Pipe diameters (inches) . .	·50 to 1·50	1·0 to 3·0	1·5 to 3·0	2·0 to 3·0
Percentage loss . . .	41·0	41·7	40·5	40·3

For a given ratio of enlargement, for values of θ less than 60°, the percentage loss increases slightly as the mean diameter diminishes, and, for a given mean diameter, on the whole increases slightly although irregularly as the ratio enlargement is reduced. The value of θ giving rise to the same loss as is experienced with a sudden change of section, varies within fairly wide limits from 41° to 60°, being slightly greater, for a given area-ratio, the larger the pipes, and, for a given mean diameter, increasing in an irregular manner with the area-ratio. Its mean value over the range of ratios considered is approximately 50°, and where, in the design of hydraulic machinery, it is necessary for this value to be exceeded, a sudden enlargement of section will give a more efficient transformation of energy than will a uniformly tapering pipe. For values of θ between 7·5° and 35° the loss may be expressed with a fair degree of accuracy by the relationships—

$$\text{loss} = {\cdot}0110\ \theta^{1{\cdot}22} \frac{(v_1 - v_2)^2}{2g} \text{ feet, where } \theta \text{ is in degrees,}$$

or

$$\text{loss} = 3{\cdot}50 \left(\tan\frac{\theta}{2}\right)^{1{\cdot}22} \frac{(v_1 - v_3)^2}{2g} \text{ feet.}$$

This latter relationship becomes of importance in the design of trumpet-shaped pipes to give a minimum loss of energy. Values obtained by calculation from these formulæ are compared in the following table with those obtained experimentally :—

Percentage Loss.			
$\theta°$.	Mean of Experimental Values.	By Calculation.	
		$1{\cdot}10\ \theta^{1{\cdot}22}$.	$350\left(\tan\frac{\theta}{2}\right)^{1{\cdot}22}$.
7·5	14·5	12·8	12·8
10	17·5	18·2	18·1
15	28·0	29·7	29·9
20	43·5	42·5	42·4
25	58·0	55·5	56·2
30	71·0	70·5	73·0
35	80·8	83·8	85·7

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* *Ibid.*, p. 370.

§ 3. EFFECT OF PROJECTING SMALLER PIPE INTO SPACE BOUNDED BY DIVERGENT WALLS.

For the purpose of examining this effect, a thin sleeve of internal diameter ·90 inch and external diameter 1·0 inch was prepared and used inside the various 1-inch pipes, as shown in fig. 2.

The length l of the internal projection was varied by varying the thickness of the washer W. The pressure in the smaller pipe was measured at two points distant respectively 12 inches and 20 inches from the open end, and the pressure at this end was deduced from these readings on the assumption that the friction loss per unit length of the pipe is constant. The percentage losses in a conical pipe with initial and final diameters ·90 inch and 3·0 inches respectively are very sensibly the same as in one with initial and final diameters 1·0 inch and 3·0 inches, and the losses actually observed with the projecting pipes are therefore given, for comparison with those given by the latter pipes.

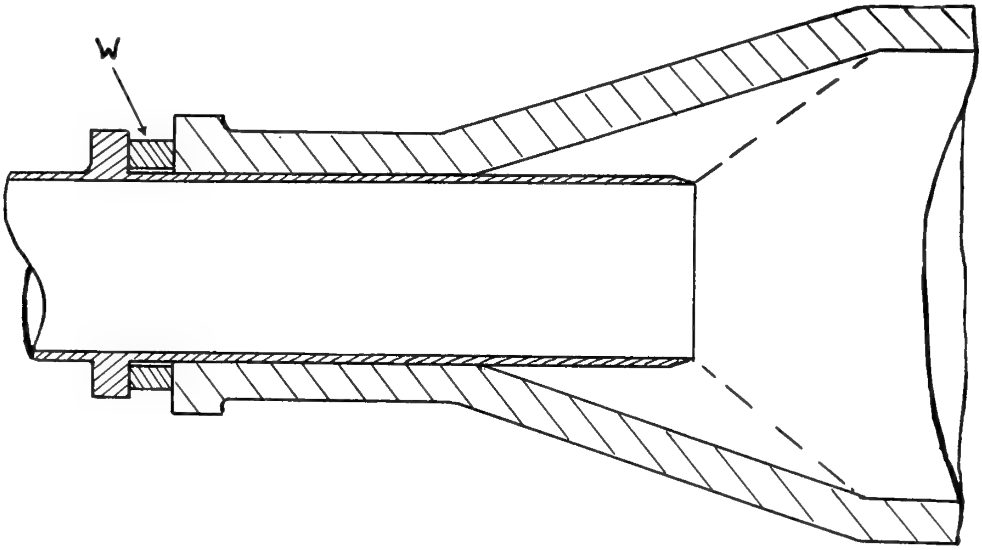

FIG. 2.

The results of the experiments are as follows :—

Percentage Loss of Head.			
Value of θ . . .	40°	60°	90°
Pipe with diameters 1 in. and 3 in. .	80·8%	101·3%	104·1%
Projecting pipe with diameters ·90 in. and 3 in. .	Pipe projecting— ·50 in. . . 98·0% 1·00 in. . . 108·0%	Pipe projecting— ·25 in. . . 104·5% ·50 in. . . 107·2% 1·00 in. . . 112·0%	Pipe projecting— ·25 in. . . 107·7%

In every case the effect of the projection is to increase the loss, the effect being greater the greater the length of the projection and also the less the angle of divergence of the conical sides. The loss is, in fact, greater in every case than would be experienced if the pipe walls were tapered off from the extremity of the projecting pipe, as shown by the dotted lines in fig. 2.

§ 4. Rectangular Pipes with Uniformly Diverging Boundaries.

Three sets of rectangular pipes were examined, these having one pair of sides parallel and 1·329 inch apart in every case. The areas of the small and of the large ends of these pipes were, in the case of the pipes having area-ratios of 4 : 1 and 9 : 1, identical with those of the circular taper pipes having the same ratios of enlargement. The details of the pipes are as follows :—

Dimensions of Pipes (inches).		Area-Ratio.	Values of θ.
Small End.	Large End.		
·590 × 1·329	5·315 × 1·329	9 : 1	10°, 15°, 20°, 26°, 40°, 60°, 90°
1·329 × 1·329	5·315 × 1·329	4 : 1	5°, 10°, 15°, 22° 42′, 30°, 40°
1·329 × 1·329	2·990 × 1·329	2·25 : 1	10°, 15°, 20° 30°

The results of the means of the experiments on these pipes are plotted in fig. 3. From these it appears that the percentage loss in such pipes is very approximately the same for all ratios of enlargement between 2·25 to 1 and 9 to 1 for values of θ between 10° and 40°, and that it varies but little with the dimensions of the pipe. The minimum loss is obtained when θ is approximately 11°, the percentage loss under these circumstances being about 17·5 per cent. As θ is increased the loss increases rapidly, and attains a value of 100 per cent. when θ is between 31° and 40°, the value of this critical angle being less with the smaller ratios of enlargement and with the pipes having the smaller mean sectional areas. For values of θ between 10° and 35°, the only values of any use in practice, the loss can be expressed with a fair degree of accuracy by the relationships—

$$\text{loss} = \cdot 0072\,\theta^{1\cdot 40}\frac{(v_1 - v_2)^2}{2g}\text{ feet, where }\theta\text{ is in degrees.}$$

$$= 5\cdot 30\left(\tan\frac{\theta}{2}\right)^{1\cdot 40}\frac{(v_1 - v_2)^2}{2g}\text{ feet.}$$

The following table shows a comparison between experimental results and values calculated from these relationships :—

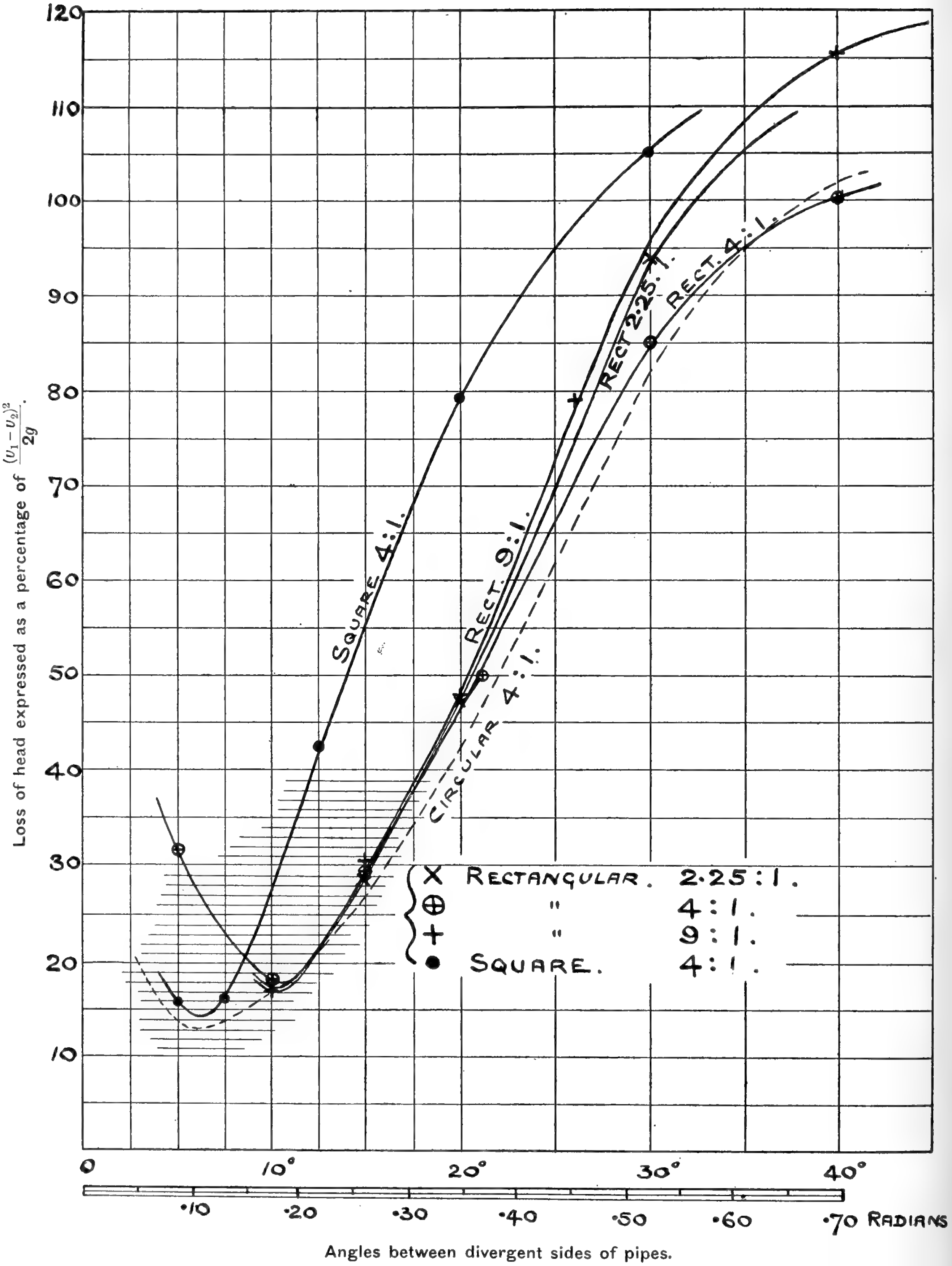

FIG. 3.—Percentage Loss of Head in Straight Taper Pipes of Square and Rectangular Section.

Percentage Loss of Head.			
θ.	Experimental (mean).	$\cdot 72\theta^{1\cdot 4}$.	$530\left(\tan\frac{\theta}{2}\right)^{1\cdot 4}$.
10°	17·6	18·0	17·8
15°	29·5	31·7	31·3
20°	47·5	47·5	46·7
25°	69·5	64·8	64·2
30°	90·0	85·0	83·5
35°	103·0	104·0	103·5

A comparison with circular taper pipes of the same initial and final areas and having the same values of θ shows, as indicated in the following table, that the rectangular pipe gives a greater loss of head, except for values of θ between 10° and 15° :—

Percentage Loss of Head.		
θ.	Circular Pipe (mean).	Rectangular Pipe (mean).
10°	17·5	17·6
20°	43·5	47·5
30°	71·0	90·0
40°	89·0	108·0

If pipes of the same length and same ratio of enlargement are compared, however, the rectangular pipe, having a greater value of θ than the circular pipe, is much less efficient except for such lengths as would make θ, in the rectangular pipe, approximately 11°.

Experiments on rectangular pipes having an enlargement ratio of 9 to 1, and having θ respectively 40°, 60°, and 90°, showed corresponding losses of 115, 122·3, and 119 per cent. This indicates a maximum loss when θ is approximately 70°, or when it has sensibly the same value as gives maximum loss in the corresponding circular pipe.

§ 5. Pipes of Square Section with Uniformly Divergent Boundaries.

Two pipes, having a smaller section 1·329 inch square and a larger section 2·658 inches square and with θ respectively 7·5° and 30° were examined, these completing the series examined in the preceding experiments. The results of the whole set of experiments are plotted in fig. 3. The percentage loss is a minimum for a value of θ in the neighbourhood of 6°, practically the same as for a circular pipe, and has a value of about 14·5 per cent.

For larger values of θ the loss in a square pipe is considerably greater—85 per cent.

greater when $\theta = 20^\circ$—than in the corresponding circular pipe, while for values of θ greater than 8° it is also greater than in a rectangular pipe with the same value of θ but having one pair of sides parallel.

§ 6. PIPES OF BEST FORM.

Where no restrictions are placed on the length of the pipe, a straight taper pipe having a divergent angle of about 6° in the case of a circular pipe and of a square pipe, and of about 11° in the case of a rectangular pipe, will give the minimum loss of energy between inlet and outlet.* The great length of such a pipe, however, renders its use impossible in many cases which occur in practice, and in such a case it becomes important to determine what form of passage will give the least loss for a given length and given ratio of enlargement. It would appear that such a pipe should be trumpet-shaped, the angle of divergence being least at the small end of the pipe where the velocity is greatest, and gradually increasing as the velocity diminishes.

While impossible to determine the best curve from purely *a priori* reasoning, it seemed reasonable to suppose that the loss might be least either

(1) with a pipe giving uniform retardation $\left(\frac{dv}{dt} = \text{constant}\right)$,

or

(2) ,, ,, ,, change of velocity per unit length of pipe $\left(\frac{dv}{dx} = \text{constant}\right)$,

or

(3) ,, ,, ,, loss of head per unit length of pipe.

In the former experiments pipes were prepared both of circular and of rectangular section for the purpose of testing the validity of the first two of these assumptions.† In the case of the rectangular pipes, which had the same initial and final areas and the same length as a straight taper pipe having $\theta = 22^\circ\ 42'$,‡ it appeared that the loss was reduced by 5·3 per cent. in the former case $\left(\frac{dv}{dt} = \text{constant}\right)$ and by 12·1 per cent. in the latter case $\left(\frac{dv}{dx} = \text{constant}\right)$. In the case of the circular pipe, however, the loss was actually greater in the pipe having $\frac{dv}{dx}$ constant than in the straight taper pipe. On this account it was decided to test the validity of the third of these assumptions, and the pipes referred to in the table opposite were prepared for comparison with straight taper pipes of the same length and same change of section.

The boundary curves for these pipes were set out from equations deduced as follows:—The loss in a straight taper pipe whose angle of divergence is θ is proportional to $\delta(v)^2$ and very sensibly to θ^n or to $\left(\tan\frac{\theta}{2}\right)^n$ where $n = 1{\cdot}40$ for a rectangular pipe. Hence in

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* This statement requires modification in view of considerations outlined at a later stage of the paper.

† *Ibid.*, pp. 367, 375, 376.

‡ Not 20° as stated in the former paper.

	Areas.		Ratio of Areas.	Length.	Angle of Corresponding Straight Taper Pipes.
	Initial.	Final.			
Rectangular Pipes.	·590 in. × 1·329 in.	5·315 in. × 1·329 in.	9 : 1	ins. 13·40	20°
	” ”	” ”	9 : 1	10·25	26°
	1·329 in. × 1·329 in.	5·315 in. × 1·329 in.	4 : 1	9·94	22° 42′
	” ”	” ”	4 : 1	7·45	30°
	” ”	” ”	4 : 1	5·49	40°
	1·329 in. × 1·329 in.	2·99 in. × 1·329 in.	2·25 : 1	4·70	20°
	” ”	” ”	2·25 : 1	3·10	30°
Circular Pipes.	·50 in. diam.	1·50 in. diam.	9 : 1	3·80	15°
	”	”	9 : 1	1·870	30°
	1·50 in. diam.	3·0 in. diam.	4 : 1	8·575	10°
	”	”	4 : 1	2·802	30°
	2·0 in. diam.	3·0 in. diam.	2·25 : 1	5·715	10°
	”	”	2·25 : 1	1·870	30°

a length δx of a trumpet-shaped rectangular pipe, over which the mean angle is θ, the loss is presumably proportional to $\delta(v)^2\left(\frac{dy}{dx}\right)^{1\cdot40}$ or to $\frac{d(v^2)}{dx}\cdot\left(\frac{dy}{dx}\right)^{1\cdot40}\cdot\delta x$ where y is the half-breadth of the pipe and where x measures the distance of the element under consideration from some datum point on the axis of the pipe.

But in such a pipe $v^2 \propto y^{-2}$,

$$\therefore \text{loss in length } \delta x = \frac{d}{dx}(y^{-2})\left(\frac{dy}{dx}\right)^{1\cdot4}\delta x .$$

For this to be constant per unit length

$$\frac{d}{dx}(y^{-2})\left(\frac{dy}{dx}\right)^{1\cdot4} = \text{constant},$$

or

$$y^{-3}\left(\frac{dy}{dx}\right)^{2\cdot4} = \text{constant},$$

$$\therefore \frac{dy}{dx} = ky^{1\cdot25},$$

$$\therefore \int_{y_1}^{y}\frac{dy}{y^{1\cdot25}} = \int_{x_1}^{x}kdx,$$

$$\therefore y_1^{-\cdot25} - y^{-\cdot25} = \mathrm{K}(x - x_1) \qquad \text{. . . . . . (1)}$$

If the origin from which x is measured be taken at the small end of the pipe where the half-breadth is y_1, $x_1 = 0$, and if l be the length of the pipe and if y_2 be the half-breadth at the larger end, $x_2 - x_1 = l$, and

$$\mathrm{K} = \frac{1}{l}\left\{ y_1^{-\cdot25} - y_2^{-\cdot25} \right\}$$

from which K can be calculated. Knowing K, the value of y corresponding to any value of x can be readily obtained from equation (1), and the rectangular pipes were made to templates representing curves calculated in this way.

In a circular pipe $n = 1{\cdot}22$, while $v^2 \propto y^{-4}$, so that

$$\frac{d}{dx}(y^{-4})\left(\frac{dy}{dx}\right)^{1\cdot22} = \text{constant.}$$

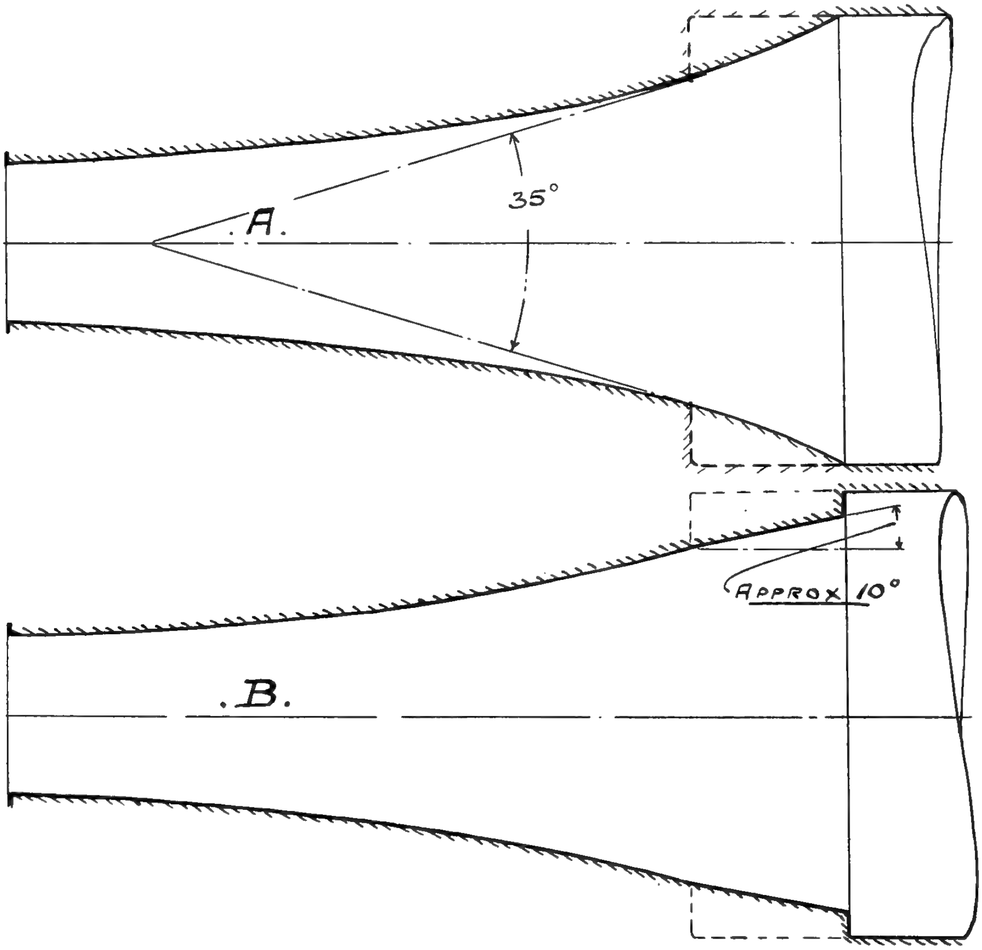

Fig. 4.

Proceeding as above, this gives

$$y_1^{-1\cdot25} - y^{-1\cdot25} = \text{K}(x - x_1) \qquad . \quad . \quad . \quad . \quad . \quad (2)$$

and on the same assumptions as before

$$\text{K} = \frac{1}{l}\left\{y_1^{-1\cdot25} - y_2^{-1\cdot25}\right\}$$

l being the length, and y_1 and y_2 the smaller and larger radii respectively. The circular pipes were made to templates set out from this equation.

Where the length of pipe is great, or the ratio of areas small, the curves thus formed may, at the smaller end of the pipe, diverge at an angle less than that (6° in a circular pipe and 11° in a rectangular pipe) giving minimum loss, and in such a case the pipe would be made to diverge uniformly at this best angle up to a point where its straight sides would intersect the calculated curved sides.

If, on the other hand, the length of pipe is small or the ratio of areas large, the calculated curves may, towards the larger end of the pipe, diverge at an angle greater than that (about 35° in a rectangular pipe) giving a loss equal to that at a sudden enlargement.

In such a case—as was confirmed by experiment—a more efficient pipe is obtained by enlarging the pipe to its final section by a sudden enlargement at the point at which the angle of divergence becomes equal to this critical value.

A still more efficient pipe is obtained if, from the point at which the angle of divergence becomes 35°, the section is enlarged gradually, the best angle of divergence being found to vary but slightly in such circumstances and in any cases likely to be found in practice, being approximately 20°.

All the pipes were first constructed with a continuous curve from inlet to outlet, and those pipes in which the angle at outlet exceeded the critical value were, after being used, modified as shown by the dotted lines in fig. 4, A. After further examination they were again modified as shown in fig. 4, B, with the results indicated in the following table :—

Percentage Loss in Trumpet-shaped Pipes.

	Ratio of Enlargement.	Value of θ in Straight Pipe of same Length as Curved Pipe.	Straight Pipe.	Curved Pipe.		
				Continuous Curve.	Modified as in "A."	Modified as in "B."
Rectangular Pipes.	9 : 1	20°	48·0	24·1	21·3	19·5
	9 : 1	26°	79·5	37·6	34·2	30·3
	4 : 1	22° 42′	50·5	47·6 * 44·4 † 26·4	...	...
	4 : 1	30°	85·1	38·0	35·9	33·9
	4 : 1	40°	100·0	48·9	42·7	41·5
	2·25 : 1	20°	47·4	28·1	...	...
	2·25 : 1	30°	94·0	53·0	...	...
Circular Pipes.	9 : 1	15°	28·0	23·4	...	...
	9 : 1	30°	67·0	39·4	38·0	...
	4 : 1	10°	17·5	13·9	...	...
	4 : 1	30°	82·5	38·8	35·5	...
	2·25 : 1	10°	18·5	14·5	...	..
	2·25 : 1	30°	69·0	40·9	...	...

* $\frac{dt}{dv}$=constant.

† $\frac{dx}{dv}$=constant.

From these results it appears that by the use of curved pipes of this form the loss with a given length of pipe may be reduced considerably as compared with the loss in a straight taper pipe between the same limits of area. The proportional saving is greater the greater the ratio of enlargement and also the shorter the pipe.

While no direct evidence that this is the best possible curve has been obtained, the great reduction in loss accompanying its use is evidence that no great improvement by a modification in its equation is probable, or indeed possible.

For values of θ less than about 15° in the case of a rectangular pipe and less than about 7·5° in the case of a circular pipe, evidently little is to be gained by introducing the curve. The proportional saving following on its introduction varies in these experiments from 62 per cent. in the case of a rectangular pipe having an enlargement ratio of 9 : 1 and corresponding to a straight taper pipe with $\theta = 26°$, to 22 per cent. in the case of a circular pipe with a ratio of 2·25 : 1 and corresponding to a straight pipe with $\theta = 10°$. As might be expected, the gain is more marked in a rectangular pipe, in which the enlargement of section takes place in one plane, than in a circular pipe. The effect of modifying the outlet end of the pipe as indicated in fig. 4 (A and B) is somewhat surprisingly large, the mere cutting away of the curved boundary to form a sudden enlargement reducing the percentage loss by about 7 per cent. on the average. The pipe as thus modified is, in effect, moreover, shorter than the original curved pipe giving the same change of section, and this led to the examination of a further series of pipes designed from considerations based on the following reasoning.

The loss of head in a pipe whose section increases gradually from A_1 to A_3, and which then suffers a sudden enlargement of area to A_2, might be expected, on theoretical grounds, to be equal to the sum of the separate losses which would be experienced in the taper portion of the pipe and at the sudden enlargement, if these were independent of each other. By reducing the angle of divergence of the first portion of such a tube, the sudden enlargement of section and the accompanying loss is made greater, but the loss in the diverging portion is reduced in a double degree, since not only is the numerical coefficient expressing such loss as a percentage of $(v_1 - v_3)^2/2g$ diminished, but A_3 is diminished at the same time, and thus the factor $v_1 - v_3$ is also diminished. A diminution in the angle of divergence therefore causes a rapid diminution in this portion of the loss, which may, or may not, be counterbalanced by the loss at the sudden enlargement of section. Owing to the comparatively low velocities at the large end of the pipe, however, except in pipes whose length is comparatively very short, and whose ratio of enlargement is small, this latter loss may be expected to be comparatively small and the total loss to be a minimum with a pipe—straight or curved—whose angle of divergence—actual or effective—is little greater than that giving minimum loss in the diverging portion of the pipe alone.

Furthermore it would appear possible, although at first sight paradoxical, that in a fairly long pipe having a uniform divergence from A_1 to A_2 at the best angle (about 11° in a rectangular pipe) the loss of head might even be reduced by reducing the angle of divergence still further without altering the length, thus introducing a sudden enlargement from A_3 to A_2 and a corresponding loss of head, but at the same time reducing the change of velocity, and therefore the loss, in spite of the increasing percentage coefficient, in the taper portion of the pipe. As will be seen from the experimental results, given at a later stage in the paper, these conclusions are justified, and it becomes possible to design a pipe—often with a considerable reduction in length—in which the boundaries are straight, and in which the loss is still appreciably less than in a straight taper pipe giving the full enlargement of section with the best possible value of θ.

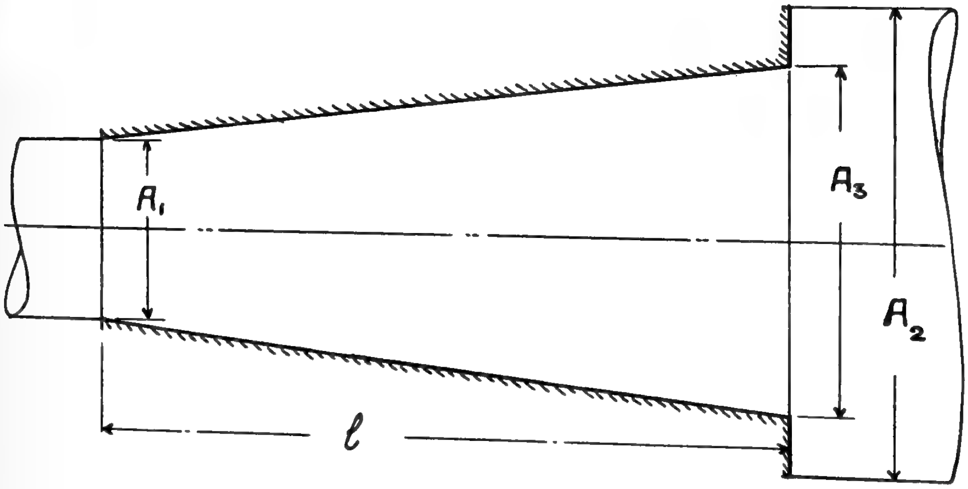

FIG. 5.

The total loss of head in such a pipe as shown in fig. 5, and consisting of a straight taper pipe terminating in a sudden enlargement of section, is theoretically equal to

$$K\frac{(v_1 - v_3)^2}{2g} + \frac{(v_3 - v_2)^2}{2g} \text{ feet}$$

where K is obtained from the curves of figs. 2 and 3. As $\frac{v_3}{v_1} = \frac{A_1}{A_3}$; while $\frac{v_2}{v_1} = \frac{A_1}{A_2}$, where A represents the corresponding area this becomes

$$\frac{v_1^2}{2g}\left\{K\left(1 - \frac{A_1}{A_3}\right)^2 + \left(\frac{A_1}{A_3} - \frac{A_1}{A_2}\right)^2\right\} \text{ feet}$$

or

$$\frac{(v_1 - v_2)^2}{2g}\left[\left(\frac{A_2}{A_2 - A_1}\right)^2\left\{K\left(1 - \frac{A_1}{A_3}\right)^2 + \left(\frac{A_1}{A_3} - \frac{A_1}{A_2}\right)^2\right\}\right] \text{ feet.}$$

In a rectangular pipe whose breadth increases uniformly from b_1 to b_3 in a length L,

$$b_3 = b_1 + 2\text{L} \tan\frac{\theta}{2}$$

$$= b_1 + \text{L}\theta \text{ (approximately) where } \theta \text{ is in angular measure,}$$

so that

$$A_3 = A_1 + \text{L}\theta,$$

and the above expression becomes

$$\text{loss} = \frac{(v_1 - v_2)^2}{2g}\left[\left(\frac{b_2}{b_2 - b_1}\right)^2 \left\{ \mathrm{K}\left(1 - \frac{b_1}{b_1 + \mathrm{L}\theta}\right)^2 + \left(\frac{b_1}{b_1 + \mathrm{L}\theta} + \frac{b_1}{b_2}\right)^2 \right\}\right] \quad . \quad . \quad . \quad . \quad (3)$$

The corresponding expression for circular pipes is

$$\text{loss} = \frac{(v_1 - v_2)^2}{2g}\left[\left(\frac{r_2^2}{r_2^2 - r_1^2}\right) \left\{ \mathrm{K}\left(1 - \frac{r_1^2}{\left(r_1 + \frac{\mathrm{L}\theta}{2}\right)^2}\right)^2 + \left(\frac{r_1^2}{\left(r_1 + \frac{\mathrm{L}\theta}{2}\right)^2} - \frac{r_1^2}{r_2^2}\right)^2 \right\}\right] \quad . \quad . \quad . \quad (4)$$

Differentiating these expressions with respect to θ, the value of θ and hence of b_3 or r_3, giving minimum loss of head, may be obtained. As, however, K varies with θ, the resulting expression becomes extremely cumbersome, and the best value is more easily obtained by trial of a few values of θ and the corresponding values of K. Handled in this way a solution is readily obtained.

To test the validity of equations (3) and (4), a series of experiments were carried out on rectangular pipes of width 1·329 inch and with an initial breadth of 1·329 inch, this increasing uniformly to 2·99 inches, after which the breadth suddenly increased to 5·315 inches, thus making $b_3 = 2{\cdot}25b_1$ and $b_2 = 4b_1$; on rectangular pipes of the same length and with the same initial and final areas, but with boundaries made to the curved templates already indicated; and on circular pipes having a gradual enlargement of section from ·50 inch diameter to 1·50 inch diameter, followed by a sudden enlargement to 3·0 inches diameter. In the latter pipes the full ratio of enlargement was thus 36 : 1. The results were as follow :—

	Length of Taper Pipe (inches).	Value of θ.	Value of θ Radians.	Percentage Loss of Head.	
				Experimental.	Calculated.
Rectangular Pipes.	9·50	10°	·1746	19·2	17·6
	6·30	15°	·2620	23·0	23·3
	3·10	30°	·3492	60·7	58·8
	4·70	Curved		23·4	22·6
	3·10	„		39·0	36·3
Circular Pipes.	3·80	Curved		21·2	21·1
	1·87	„		31·4	32·5

From these it appears that the experimental and calculated losses are in sufficiently close agreement to amply justify the general adoption of the formulæ, and these have been used to determine the value of θ giving the minimum loss of head in a number of typical cases. The following table shows how the loss in such a pipe compares with the loss in a straight taper pipe or in a curved pipe of the same length and of the same initial and final sections :—

	Ratio of Areas.	Value of θ giving Minimum Loss.	Length of Pipe (inches).	Value of θ in Straight Taper Pipe of same Length.	Percentage Loss of Head.	Loss of Head expressed as a Percentage of the Loss in	
						Straight Pipe.	Curved Pipe.
Rectangular Pipes.	9 : 1 Sections ·59 in. × 1·329 in. and 5·315 in. × 1·329 in.	10° 20′	17·95	15°	16·2	54·9	81·0
		10° 40′	8·81	30°	15·3	16·0	51·5
		11° 00	6·49	40°	16·2	14·2	...
		11° 45′	4·08	60°	20·3	...	...
	4 : 1 1·329 in. square to 1·329 in. × 5·315 in.	10° 20′	15·15	15°	15·6	53·8	...
		11° 00′	11·30	20°	15·3	32·6	60·5
		12° 00′	7·45	30°	18·2	22·0	53·6
		12° 45′	5·48	40°	22·0	21·1	53·0
		15° 30′	3·45	60°	29·4	...	...
	2·25 : 1 1·329 in. square to 1·329 in. × 2·99 in.	10° 40′	6·30	15°	15·2	51·5	...
		13° 20′	3·10	30°	22·8	26·8	43·0
		15° 40′	2·29	40°	28·2	25·2	...
Circular Pipes.	9 : 1 ·59 in. diam. to 1·50 in. diam.	7° 10′	3·80	15°	13·6	52·3	58·2
		11° 00′	1·870	30°	18·2	27·2	48·0
	4 : 1 1·50 in. diam. to 3·0 in. diam.	7° 00′	8·575	10°	12·7	73·5	...
		13° 30′	2·802	30°	20·8	22·2	58·5
	2·25 : 1 2·0 in. diam. to 3·0 in. diam.	7° 00′	5·715	10°	13·4	72·5	...
		15° 00′	1·870	30°	24·3	35·2	...

The loss may be still further reduced by replacing the straight taper portion of these pipes by curved pipes having the same initial and final areas and having boundaries calculated as already described. With pipes so designed the percentage losses become approximately as shown in the table on p. 114:—

From these results it appears that the effect of replacing the straight taper by a curve is proportionately greater in the pipes having the greater length, owing to the fact that as the pipe is lengthened the proportion of the total loss which takes place during the gradual enlargement is increased, while that taking place at the subsequent sudden enlargement is reduced.

Expressed as a percentage of the loss at a sudden enlargement, the effect of introducing the curve is approximately the same for all the pipes, being to reduce this loss by about 2·5 per cent. in the rectangular and 1·9 per cent. in the circular pipes.

§ 7. SUMMARY AND CONCLUSIONS.

The following are the chief conclusions to be drawn from the experiments:—

(*a*) In a circular pipe with uniformly diverging boundaries the loss of head expressed as a percentage of $(v_1 - v_2)^2/2g$ varies somewhat with the mean diameter of

	Area Ratio.	Value of θ in Straight Taper Pipe of same Length.	Percentage Loss of Head.
Rectangular Pipes.	9 : 1	15°	13·1
		30°	13·0
		40°	13·9
	4 : 1	15°	12·6
		30°	16·0
		40°	20·0
	2·25 : 1	15°	12·6
		30°	20·9
		40°	25·9
Circular Pipes.	9 : 1	15°	12·2
		30°	15·8
	4 : 1	10°	11·3
		30°	17·8
	2·25 : 1	10°	12·2
		30°	22·1

the pipe, and with the ratio of final to initial area, as well as with θ. An increase in the mean diameter slightly reduces the percentage loss, as does an increase in the ratio of enlargement. For values of θ between 6° and 35°, however, the differences are comparatively small and the loss of head can be expressed by the relationship

$$\text{loss} = \cdot 0110\ \theta^{1\cdot 22}\frac{(v_1 - v_2)^2}{2g}\text{feet}$$

where θ is in degrees. The minimum loss of head is attained with a value of θ in the neighbourhood of 5° 30′. The loss of head at a sudden enlargement of section also varies slightly with the smaller diameter d and with the ratio of enlargement m, and is given very nearly by the relationship

$$\text{loss} = \frac{102\cdot 5 + \cdot 25m - 2\cdot 0d}{100}\left\{\frac{(v_1 - v_2)^2}{2g}\right\}\text{feet.}$$

As θ is increased from 5° 30′ the loss rapidly increases to attain a maximum, greater in every case than 100 per cent., for a value of θ in the neighbourhood of 65°. The value of θ, which makes the loss equal 100 per cent., varies from 40° to 60°, and in practice a sudden enlargement of section is more efficient in the transformation of kinetic into pressure energy than is a gradual enlargement in which θ exceeds this critical value.

(*b*) By projecting the parallel portion of the pipe into the space bounded by the diverging walls (fig. 2) the loss is in every case increased, the difference increasing with the length of the projection.

(*c*) The percentage loss of head in rectangular pipes having one pair of sides parallel and the second pair uniformly diverging, varies little with the size of pipe and with the ratio of enlargement.

It can be expressed with fair accuracy for values of θ between 10° and 35° by the relationship

$$\text{loss} = {\cdot}0072\ \theta^{1{\cdot}40}\frac{(v_1 - v_2)^2}{2g}\text{feet}$$

where θ is in degrees. This loss is in general greater than in a circular pipe having the same value of θ, except where θ is between 10° and 15°. The minimum loss is obtained when θ is approximately 11°. The maximum loss is apparently obtained with values of θ in the neighbourhood of 70°.

(*d*) In pipes of square section the minimum loss of head is obtained with a value of θ in the neighbourhood of 6°, and has a value of about 14·5 per cent. As θ increases the loss becomes much greater—up to 85 per cent. greater—than in the corresponding circular pipe.

(*e*) By making the pipes trumpet-shaped, with curves designed so as to make $\frac{d(v^2)}{dx} = \text{constant}$, the loss of head in a pipe of given length may be considerably reduced. The proportional saving is greater as the length of pipe is less, and, in the pipes examined, varied from 20 per cent. to 60 per cent.

(*f*) A still greater saving, combined with great simplicity, may be effected by a design giving a gradual uniform enlargement in section from the initial section A_1 to one having an area A_3, and a sudden enlargement from A_3 to the final section A_2, as shown in fig. 5. The value of θ in the taper portion of the pipe, which gives a minimum loss of head, may be obtained from formulæ (3) or (4), p. 112, when the length of this pipe is settled. This value varies from 10° to 16° in the rectangular pipes and from 7° to 16° in the circular pipes, increasing, for a given length of pipe, as the ratio of enlargement is reduced, and, for a given ratio, increasing as the length is reduced. In any cases likely to occur in practice its value may be taken as follows, without any very great variation from conditions of maximum efficiency :—

Ratio of enlargement . .	9 : 1	4 : 1	2·25 : 1
Value of θ (rectangular pipe) .	11°	12° 30′	13° 30′
Value of θ (circular pipe) . .	9°	10° 30′	11° 30′

By this method of construction the loss may be reduced in favourable circumstances to about 90 per cent. (in rectangular pipes) and to about 96 per cent. (in circular pipes) of the minimum possible loss in a uniformly tapering pipe undergoing the full enlargement of section. By designing the pipe from A_1 to A_3 with curved boundaries giving $\frac{d(v^2)}{dx} = \text{constant}$, the loss may be still further reduced. In the majority of cases occurring in practice, however, the additional trouble of calculation and cost of template will not be counterbalanced by the slight increase in efficiency which they render possible.

In conclusion, the author would acknowledge his indebtedness to the Government Grant Committee, by whose grant in aid the provision of the pipes and apparatus used in these experiments has been made possible.

VI.—The Significance of Maximum Specific Electrical Conductivity in Chemistry.

By Professor **John Gibson**, Ph.D.

(Read July 13, 1908. MS. received June 13, 1911. Issued separately October 20, 1911.)

PHOTOCHEMICAL ACTION.

The first step made in this investigation was the recognition of increased specific electrical conductivity as a general characteristic of photochemical action. It was argued that if there be any common characteristic in photochemical changes it must be found in the simplest as well as in the more familiar and more complex reactions which are characteristic of the metabolism of plants.

No chemically simpler case suggested itself than the increase in electric conductivity of crystalline selenium under the influence of light.* This change might indeed be held almost to lie outside the range of chemistry proper, and to belong to the class of change often spoken of as merely physical change. But no sharp line can be drawn between physical and chemical changes, and the clue proved most useful.

The action of light on crystallised selenium seems to give evidence of a directive action of light rather than of an inherent tendency of the crystalline selenium itself towards increased conductivity, for the gain in conductivity persists only as long as the exposure to light. Placed in the dark, after exposure to light, crystallised selenium reverts to its initially lower conductivity. The same remark applies to all cases of photochemical changes which are not permanent. It is otherwise with changes which are permanent. A few instances of permanent photochemical change in homogeneous systems may be cited :—

(1) The conversion of yellow phosphorus, under the action of light, into red phosphorus.
(2) The gradual conversion of red amorphous selenium into the black crystalline form.
(3) The conversion of red crystalline mercuric sulphide into the black amorphous form.

These diverse instances of photochemical change are correlated by the fact that the change in each case is accompanied by a gain in specific conductivity.

An apparent exception to this rule is discussed in a very interesting paper by MEYER †) on the action of light on the chromo-gelatine film. The main reaction, viz. the photochemical reduction of potassium bichromate in presence of soluble organic

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* On Photochemical Action, *Proc. Roy. Soc. Edin.*, 1897, vol. xxi. p. 303.

† Comp. *Zeit. physik. Chemie*, lxvi. p. 58.

matter, is undoubtedly associated with increased conductivity,* and the decrease in the conductivity of the gelatine film observed is probably due to the heterogeneity resulting from the formation of insoluble gelatine. It is impossible without qualification to apply the rule to heterogeneous systems.

There is an apparent similarity between the action of the short-wave electro-magnetic vibrations called "light," in cases such as those above cited, and the action of the long-wave electro-magnetic vibrations on the coherers used in wireless telegraphy. In this case also there is a resultant increase in the conductivity of the system.

The Specific Electrolytic Conductivity of Good Electrolytes.

The line of argument developed in this paper will be greatly facilitated by frequent reference to the graphs in Fig. I., which are obtained by plotting as ordinates the specific conductivity at 18° C. (K_{18}) of a number of aqueous solutions of electrolytes in ohm^{-1} c.m.^{-1} against the concentration (Γ) in gram equivalents per kilo of solution as abscissæ. The advantages of this mode of representing the concentration have been discussed in a previous paper.†

The graph for HCl may be taken as typical. Starting at the origin with pure water, the specific conductivity rises as the concentration of HCl increases, but reaches a maximum ($K_{18\ \text{max.}} = 0{\cdot}7646$) at a concentration, according to Kohlrausch, of ($\Gamma = 5{\cdot}0$) 18·25 per cent., at 18° C. Beyond this concentration the specific electrolytic conductivity of the solutions falls off as the concentration increases.

The exact concentration corresponding to maximum conductivity is not easily determined, as in the neighbourhood of the maximum the conductivity varies but slightly with concentration.

For the sake of brevity, solutions of strong electrolytes will be referred to in what follows as being either maximal, ultramaximal, or premaximal, according as their concentrations are equal to, greater, or less than those having maximum specific conductivity.

Behaviour of Aqueous Solutions containing Hydrogen Chloride.

Of all known solutions none surpass hydrochloric acid, at comparable concentration, in specific conductivity, and none show a higher maximum of specific conductivity. It is probable that no other solution has a higher ionic concentration or a higher specific conductivity than hydrochloric acid of maximum conductivity.

The chemical properties of hydrochloric acid vary in a remarkable manner with the concentration. In dilute premaximal solutions hydrochloric acid behaves as a very stable acid. In concentrated ultramaximal solutions it is readily oxidised and acts as a reducing agent. In dilute premaximal solutions it favours hydrolysis. In highly

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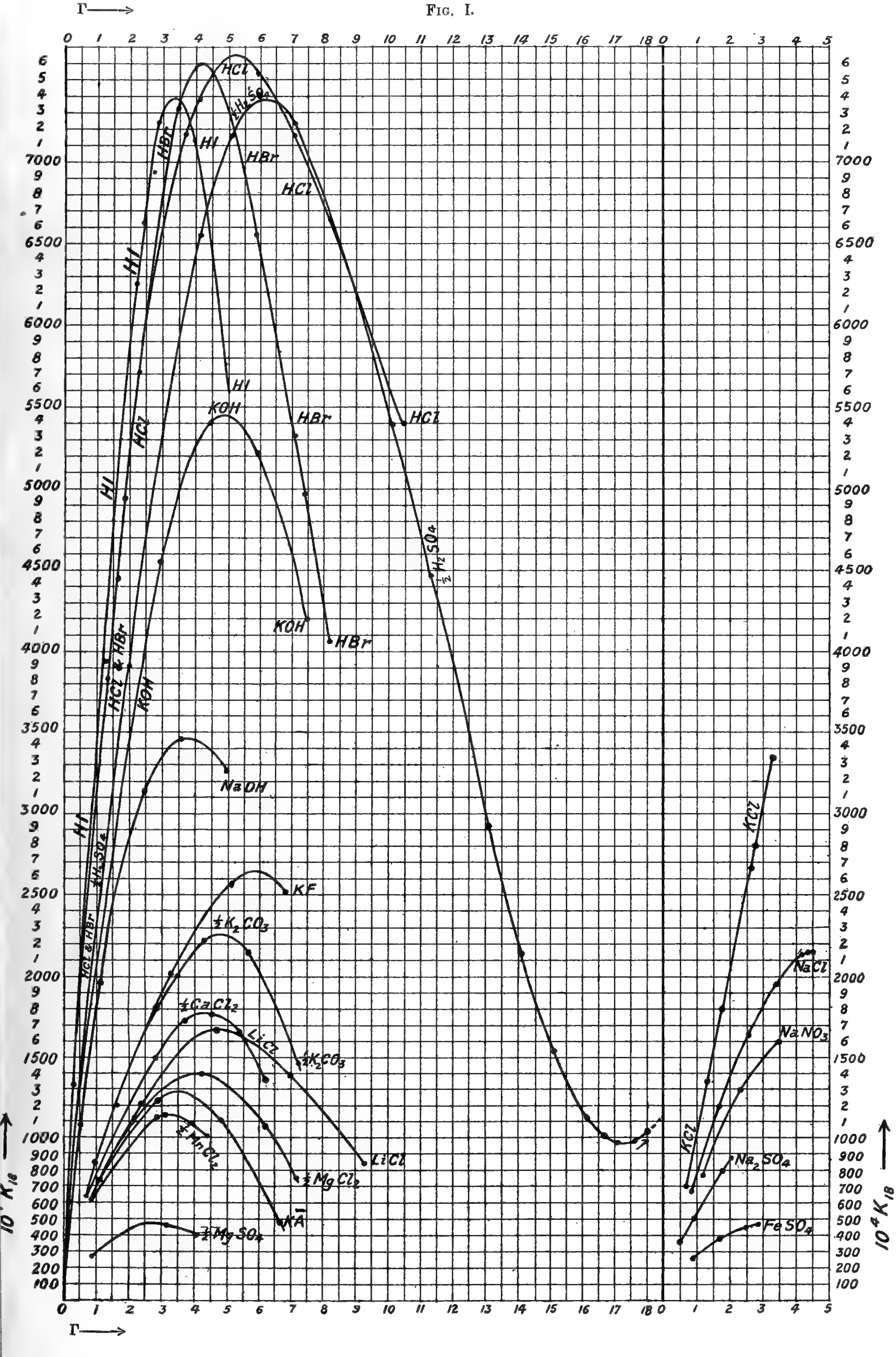
* This is clearly recognised by Meyer, *loc. cit.*

† J. Gibson, *Trans. Roy. Soc. Edin.*, 1905–6, vol. xli. p. 241.

Fig. I.



Γ = gram equivalents per kilogram = $m \div$ sp. gr. = $\frac{\text{per cent.} \times 10}{\text{gram equivalent}}$. The values for 10^4K_{18} are taken from KOHLRAUSCH and HOLBURN, *Leitvermögen der Electrolyte*, except those for HBr and HI, which were determined in this laboratory.

concentrated ultramaximal solutions it favours abstraction of water and changes which are accompanied by the formation of water, such as esterification. These different properties may all be summed up by simply stating that solutions of hydrochloric acid tend to gain in specific conductivity.

Saturated solutions of certain chlorides may be used as indicators of this tendency. If, for example, a small quantity of a solution of hydrogen chloride be added to a saturated solution of common salt containing a few minute crystals of salt in suspension, either some of the undissolved salt will dissolve, or else some salt will be thrown out of solution. It was found that precipitation occurs only when the hydrochloric acid added is in ultramaximal solution. The same condition holds for precipitation by hydrochloric acid of the chlorides of potassium, ammonium, and rubidium from their saturated solutions.* Premaximal solutions of hydrochloric acid may be distinguished in this way from ultramaximal solutions even when their concentration differs from the maximal solution by only ±1 per cent. HCl. Thus, precipitation was not observed with 17 per cent. HCl or less, and invariably observed with 19 per cent. and more.

THE BEHAVIOUR OF AQUEOUS SOLUTIONS OF HYDROGEN CHLORIDE TOWARDS DISSOLVED OXYGEN AND DISSOLVED CHLORINE RESPECTIVELY.

The behaviour of solutions of hydrogen chloride towards dissolved chlorine on the one hand, and towards dissolved oxygen on the other, presents another case in point.

Chlorine decomposes water, especially under the influence of light. The action is partially illustrated by the equation

$$2H_2O + 2Cl_2 \rightleftharpoons 4HCl + O_2.$$

This reaction is a reversible one, or, in other words, under certain conditions dissolved oxygen and hydrogen chloride react so as to produce free chlorine and water. Current theories do not enable us to predict the concentration at which equilibrium would be established. Assuming a tendency towards increased conductivity, the progress of the reaction in either direction should be associated with a gain in specific conductivity. It is owing to this tendency towards increased specific conductivity that concentrated ultramaximal solutions of hydrogen chloride, after long keeping in partially filled clear glass bottles, contain free chlorine, due to the oxidation of the hydrogen chloride. Numerous solutions were examined, but free chlorine was never found to persist in solutions which had been diluted to below 18 per cent. HCl, *i.e.* to below the concentration corresponding to maximum specific conductivity. So long as the solution is premaximal, free chlorine disappears from it, with formation of hydrogen chloride and free oxygen, the solution thereby gaining in specific conductivity. On the other hand, when the hydrochloric acid is in ultramaximal solution, hydrogen chloride is oxidised by the oxygen

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* GIBSON and DENISON, *Proc. Roy. Soc. Edin.*, vol. xxx. p. 562, 1909–10.

of the air into water and free chlorine, the solution here also gaining in specific conductivity.*

The equation for this reaction may be put in the following form—

$$(x+4)HCl+yH_2O+O_2 \rightleftharpoons xHCl+(y+2)H_2O+2Cl_2.$$

In this form the equation clearly indicates that the progress of the reaction in the direction indicated by reading from left to right involves a *dilution*, whereas its progress in the opposite direction involves a *concentration* of the hydrochloric acid. When the concentration of the free chlorine or of the dissolved oxygen is so small as to have only a negligible influence on the conductivity, the concentration of the maximal solution of hydrogen chloride coincides with the concentration at which equilibrium is established.

OXIDATION OF HYDROGEN CHLORIDE IN AQUEOUS SOLUTION BY CHROMIC ACID.

Experiments were made in order to determine the relationship between the specific conductivities of known solutions of hydrochloric acid of different concentrations and the time required to oxidise a small constant proportion of the hydrogen chloride contained in these solutions.

Chromic acid was chosen as the oxidising agent for this purpose, because it gives rise to a marked change of colour on reduction. A difficulty arises, however, owing to the fact that the addition of this oxidising agent, itself a strong electrolyte, affects the conductivity of the whole system. Practically nothing is known of the conductivity of such mixtures.

To obviate this difficulty, the quantity of chromic anhydride added was small. Further, the ratio of CrO_3 to HCl was kept the same for all the solutions. Under these conditions no serious error is incurred by regarding the conductivity in each case as being simply that of the aqueous solution of hydrogen chloride. It was found that the oxidation of the hydrogen chloride, as indicated by the change of colour due to the reduction of the chromic acid, proceeded more and more slowly the more closely the concentration of the solutions of hydrogen chloride taken approached that corresponding to maximum specific conductivity.

It was not found possible to determine the end points with accuracy in the diluter solutions, as in them the reaction is very slow. The results of one series of experiments are given in Table I.

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* Comp. BACKELANDT, *Bull. de l'Académie royale de Belgique*, 3^{me} série, t. xl., N^{r} 3, 1886.

TABLE I.

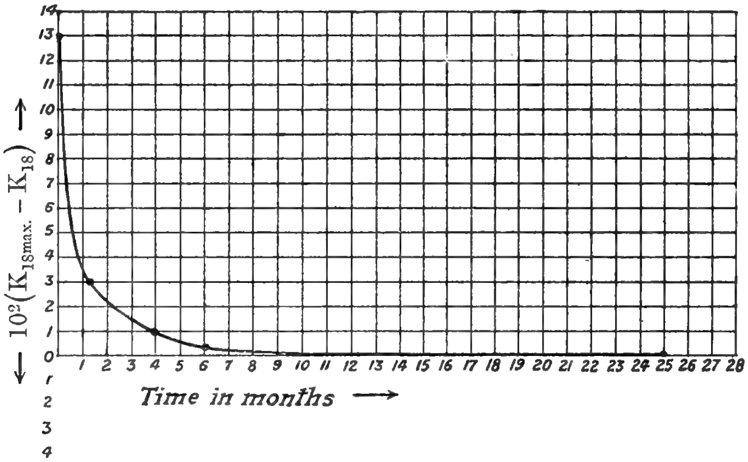
Hydrochloric Acid and Chromic Acid.

Per cent. HCl.	Γ.	$y = K_{max.} - K.$ $y \times 10^2.$	Time in days.	Time in months.
32	8·78	137	0·25	·008
30	8·23	101	0·3	·01
28	7·68	73	6	·2
24	6·58	25	38	1·3
21·7	5·95	8	118	3·9
20	5·49	1	174	5·9
18·22	5·00	0	>700	25 *circa*

N.B.—With 16 per cent. and 12 per cent. HCl the reduction was not nearly complete after four years' standing.

In the graph (Fig. II.) the times required for complete reduction of the CrO_3 are plotted as abscissæ against the specific conductivities of the respective solutions as ordinates. The maximum conductivity of hydrochloric acid is taken as origin, so that the ordinates indicate decrements of conductivity from the maximum, that is to say, they indicate the values for $y = K_{max.} - K$.

FIG. II.



From this series of experiments and from a number of other cases it appears that the tendency towards increased conductivity is greater the greater the possible gain in specific conductivity; or, in other words, the tendency increases with the value of $y = K_{max.} - K$. There is some reason to think that it may also increase with the value for $K_{max.}$.

HYDROCHLORIC ACID AS AN ESTERIFYING AGENT.

Consider a reaction such as that between oxalic acid and ethyl alcohol mixed in equivalent proportions

$$2C_2H_5OH + H_2C_2O_4 = (C_2H_5)_2C_2O_4.$$

The reaction from left to right is soon counterbalanced by the alteration in the concentration of the products, and equilibrium is reached long before the whole of the alcohol has been esterified. By constant withdrawal of the water formed during the process the esterification may approach completion. But the same end can be attained in another way, without the removal of the water, viz. by passing HCl gas into the mixture. By doing this, the chemist substitutes a system in which, as a result of the progress of the reaction from left to right, a great gain in specific conductivity is possible, for a system in which little or no such gain is possible. The tendency towards maximum specific conductivity is brought into play, and becomes the predominating factor, and the velocity of the reaction from left to right is therefore much greater. The possible gain in specific conductivity ($y = K_{max.} - K$) of the original mixture of alcohol and oxalic acid is very small, while that for the mixture containing HCl in addition is much greater. So long as the hydrochloric acid solution is ultramaximal, the dilution due to formation of water implies a gain in conductivity, but in premaximal solutions the case is reversed. Thus :—

(*a*) In dilute premaximal solutions hydrochloric acid accelerates catalytically the hydrolysis of esters.

(*b*) In concentrated ultramaximal solutions it favours the esterification of Alcohols by weak acids, instead of itself forming an ester.

In (*a*) there is a gain in conductivity due to the increase of the concentration of hydrogen ions. In (*b*) there is a gain in conductivity due to the decrease in the number of molecules which, being mostly associated and not split up into free ions, *e.g.* ($H_2C_2O_4$) and (C_2H_6O), lower the conductivity of the strong acid, while at the same time the water formed by the reaction greatly increases the specific conductivity, by diluting the highly concentrated ultramaximal acid solution. Were the strong acid itself to form an ester, there would not be this great increase in conductivity.

$$xH_2C_2O_4 + 2xC_2H_5OH + yHCl \rightleftharpoons x(C_2H_5)_2C_2O_4 + yHCl + 2xH_2O.$$

ACTION OF HYDROGEN CHLORIDE ON ETHYL ALDEHYDE, ALDOL, AND CROTONIC ALDEHYDE.

When acetaldehyde is treated with hydrochloric acid of the concentration of maximum conductivity, or with a rather more dilute solution, aldol is formed.

In this case water is neither abstracted from nor added to the aldehyde. The assumption of a tendency towards increased conductivity suggests that there should be an increase in specific conductivity accompanying the reaction. How can this be so?

Aldehyde is a non-electrolyte, and, when added to a solution of hydrochloric acid, it lowers the specific conductivity of the acid solution. This lowering of the specific conductivity is greater the greater the number of molecules of the non-electrolyte which are added. When molecules of aldehyde unite to form molecules of aldol, the number of molecules of non-electrolyte is halved, and the specific conductivity must, therefore, be increased. Further, so long as the reaction does not involve dehydration, the possible gain in specific conductivity thus brought about will probably be at a maximum when the acid has the concentration corresponding to maximum specific conductivity.

In order to demonstrate that a rise of specific conductivity does actually accompany this reaction, the following experiment was tried:—

The specific conductivity of a mixture of aldehyde and maximum conductivity hydrochloric acid (18 per cent. to 19 per cent.) was measured from time to time, the mixture being kept in a thermostat at 18° C. During the three days subsequent to the preparation of the mixed solution its conductivity rose steadily, and by the third day had risen 12·5 per cent., or from $10^3K_{18}=203$ to $10^3K_{18}=228$.

When aldol is treated with a solution of hydrochloric acid somewhat stronger than that having maximum specific conductivity, that is, with a slightly ultramaximal solution, it loses water and is converted into crotonic aldehyde.

On the other hand, crotonic aldehyde in presence of a much more dilute hydrochloric acid takes up water, re-forming aldol.

The aldol condensation, the dehydration of aldol, and the hydrolysis of crotonic aldehyde all take place in hydrochloric acid solutions, but the conditions in each case would appear to be such that an increase of specific conductivity accompanies the progress of the reaction.

Thus the tendency towards increased specific conductivity may show itself otherwise than by favouring dehydration or hydrolysis. The effect of adding molecules of a non-electrolyte to a conducting solution is in general to decrease the specific conductivity of the solution. This lowering of the specific conductivity depends primarily on the number of molecules of non-electrolyte added, so that a not inconsiderable increase in the specific conductivity of the solution may result from the polymerisation and consequent decrease in the number of such molecules. The polymerisation of molecules of the non-electrolyte present in a conducting solution may be regarded as favoured by the gain in conductivity which results from the removal or decrease in the number of such molecules.

Solutions which can be obtained by adding non-electrolytes, or relatively weak electrolytes, to solutions of strong electrolytes, may be conveniently distinguished by the prefix "sub." A solution obtained by adding a non-electrolyte to an ultramaximal solution may, on dilution, gain in conductivity, and may be converted into a submaximal solution, but it cannot be converted into a maximal solution by merely adding water. It is thus sub-ultramaximal.

Similarly, a solution may be sub-premaximal, in which case it will gain in conductivity on becoming more concentrated by loss of water, but cannot become a maximal solution by mere increase of concentration.

All such solutions may be expected to gain in conductivity as a result of the polymerisation * of the molecules of non-electrolytes or weak electrolytes which they contain.

The greater the concentration of the non-electrolyte present, the greater is the possible gain in conductivity due to its polymerisation, and accordingly the greater is the tendency, *cæteris paribus*, for such polymerisation to take place. The tendency towards polymerisation is not confined to solutions having a concentration of the electrolyte on one side only of maximum conductivity, but clearly belongs to sub-premaximal solutions as well as to sub-ultramaximal solutions.

In the synthesis of organic compounds, polymerisation or condensation without dehydration is often brought about by means of strong electrolytes. It is probable that these reagents will be found, as a rule, most effective for this purpose in the form of premaximal solutions. Where condensation or polymerisation accompanied by dehydration is desired, ultra-maximal solutions will prove, generally speaking, more effective.

Hydrochloric Acid and Cobalt Chloride.

Concentrated solutions of hydrogen chloride change the pink colour of hydrated cobalt chloride to a blue-green. A similar colour change is produced if the crystallised salt be heated so as to drive off water of crystallisation. Granting that the change of colour in the first case is also accompanied by dehydration, the assumption of a tendency towards increased specific conductivity suggests that premaximal solutions of hydrochloric acid should not cause the change of colour, because such solutions lose in conductivity by dilution. To test this, 50 c.c. each of a series of solutions of HCl of known concentration were severally mixed with two drops of a concentrated aqueous solution of cobalt chloride, and then arranged side by side, in order of concentration of HCl. It was then seen that in the weaker solutions up to 16 per cent. HCl, the pink colour was not altered. A solution of 18·2 per cent. HCl showed only a faint tinge of purple, but once past this latter concentration the change in colour was more and more marked. Using cobalt chloride as an indicator, it is quite easy in this way to make up a solution containing very nearly 19 per cent. HCl without any measurement or weighing.

Solutions of hydrobromic acid showed a similar behaviour with cobalt chloride.

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* The term "polymerisation" is here intended to include cases of condensation of the aldol type which are not accompanied by a permanent hydrolysis or dehydration.

No change of colour was observed with solutions weaker than 34 per cent. HBr, which is the concentration of maximal hydrobromic acid * ($K_{\text{max.}} = 0{\cdot}7590$; $\Gamma_{\text{max.}} = 4{\cdot}24$).

Behaviour of Aqueous Solutions of Hydrogen Iodide.

In Aqueous solutions of hydrogen iodide the tendency towards increased specific conductivity is frequently masked, owing to the strong affinity between dissolved oxygen and the hydrogen of hydrogen iodide.

Aqueous solutions of hydriodic acid do, however, exhibit the tendency to gain in specific conductivity.

A well-known method for the preparation of hydrogen iodide is to suspend iodine in water and pass in hydrogen sulphide. This reaction, however, cannot be used to obtain solutions of pure hydriodic acid of a higher concentration than that of the maximal solution which has a conductivity at 18° C. of $K_{\text{max.}} = {\cdot}740$, $\Gamma = 3{\cdot}4$,* for in ultramaximal solutions of hydrogen iodide an increase in the concentration of hydrogen iodide involves a decrease in specific conductivity. So long as the acid is premaximal the dissolved iodine is completely converted into hydrogen iodide, and the solution becomes colourless. Ultramaximal solutions remain coloured, however vigorous or long-continued the current of hydrogen sulphide may be.

In all these systems where the strong affinities are nearly balanced, the tendency towards a gain of specific conductivity becomes effective and determines the position of equilibrium.

The tendency of chlorine to unite with the hydrogen of water is of the same order as that of oxygen to unite with the hydrogen of hydrogen chloride, and similarly the tendency of iodine to unite with the hydrogen of hydrogen sulphide is of the same order as that of sulphur to unite with the hydrogen of hydrogen iodide.

The tendency towards increased conductivity is masked, in an aqueous solution containing hydrogen iodide and oxygen, because the affinity of the hydrogen of hydrogen iodide for oxygen is enormously greater than that of the free iodine for the hydrogen of water.

The addition of free iodine to a solution of hydrogen iodide lowers the conductivity of the solution. The resulting solution can decompose hydrogen sulphide only so long as there is a consequent gain in conductivity.

In an ultramaximal solution of hydriodic acid the tendency towards increased specific conductivity may even induce the action of hydrogen iodide on sulphur, with production of hydrogen sulphide, free iodine, and probably HI_3.

$$mH_2O + (n+2)HI + S \rightleftharpoons mH_2O + nHI + H_2S + I_2$$
$$mH_2O + (n+3)HI + S \rightleftharpoons mH_2O + nHI + H_2S + HI_3.$$

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* According to conductivity determinations made in this laboratory.

If the quantities of free iodine and hydrogen sulphide be kept small, the direction of the whole reaction appears to depend mainly, if not solely, on whether the solution of hydriodic acid be premaximal or ultramaximal, and the velocity of the reaction in either direction depends on the value for $y = \mathrm{K}_{\mathrm{max.}} - \mathrm{K}$. It is only from premaximal solutions of hydrogen iodide that the last traces of free iodine disappear altogether.

Behaviour of Nitric Acid.

Nitric acid and highly concentrated aqueous solutions of nitric acid undergo partial decomposition when exposed to light. The concentration of nitric acid corresponding to maximum conductivity lies between 28·5 and 29 per cent. HNO_3. At lower concentrations nitric acid is quite stable under the influence of light.

Peroxide of nitrogen and water are products of this photochemical decomposition. As this decomposition progresses there must be in such concentrated solutions a rise in conductivity, consequent upon the dilution of the acid.

In order to throw light on this behaviour of nitric acid, a number of solutions were prepared having known concentrations higher and lower than the maximum. Pure nitric oxide gas was passed into these solutions. With the solutions having concentrations higher than nitric acid of maximum conductivity colours were obtained passing from yellow-brown in the more concentrated solutions through green in less concentrated solutions, to pure blue in solutions only slightly more concentrated than the maximum acid. None of the solutions weaker than the maximum acid had any oxidising action on the nitric oxide, and they therefore remained perfectly colourless. Thus in nitric acid of 36 per cent. the blue colour was readily obtained, whereas an acid of 28 per cent. HNO_3 remained quite colourless. Decomposition of nitric acid in premaximal solutions could only imply a lowering in specific conductivity. They are not decomposed either by light or by nitric oxide.

The Action of Sulphuric Acid on Cane-Sugar.

According to its concentration sulphuric acid may be used either to hydrolyse or to dehydrate cane-sugar.

If to excess of concentrated sulphuric acid containing 84 per cent. H_2SO_4 a little of a concentrated solution of cane-sugar be added, charring sets in rapidly and is soon complete. On progressive dilution from this point onwards the time taken to char the sugar increases. When the acid has been diluted to about 30 per cent. H_2SO_4, it may be left for many days along with dissolved cane-sugar at the ordinary temperature, and the solution may even be boiled for several minutes without the slightest indication of charring.

Finally, in solutions of more dilute sulphuric acid, the chief reaction is of an opposite nature, for, instead of being dehydrated, the cane-sugar takes up water from the solution and is hydrolysed, forming ultimately a mixture of glucose and fructose.

84 per cent. sulphuric acid consists wholly, or almost wholly, of the monohydrate H_2SO_4,H_2O, and, according to the general rule that single substances are very poor conductors, there is a minimum of specific conductivity at this concentration ($K = 0{\cdot}0979$). From this point onwards a rapid increase in conductivity accompanies progressive dilution until a concentration of about 30 per cent. H_2SO_4 is reached, which is the concentration of the maximal acid.

$K_{max.}$ at 18° C. $= 0{\cdot}7388$. At 84 per cent. H_2SO_4 the value for $y = K_{max.} - K$ is $0{\cdot}7388 - 0{\cdot}0979 = 0{\cdot}6409$.

As the acid is progressively diluted from this point onwards the value for y falls, and with it the tendency of the acid solution to dilute itself by dehydrating the sugar decreases. When the maximum conductivity is reached, the tendency towards dilution disappears and the solution is relatively inert towards the sugar. At concentrations less than that corresponding to maximum conductivity the solution tends to concentrate itself by giving up water to the cane-sugar. Table II. and the corresponding graphs on Fig. III. show the results of two series of experiments made with solutions of sulphuric acid containing varying proportions of cane-sugar.

The times are those which elapsed between the date of mixing and the appearance of a brown tint, indicative of incipient charring.

TABLE II.

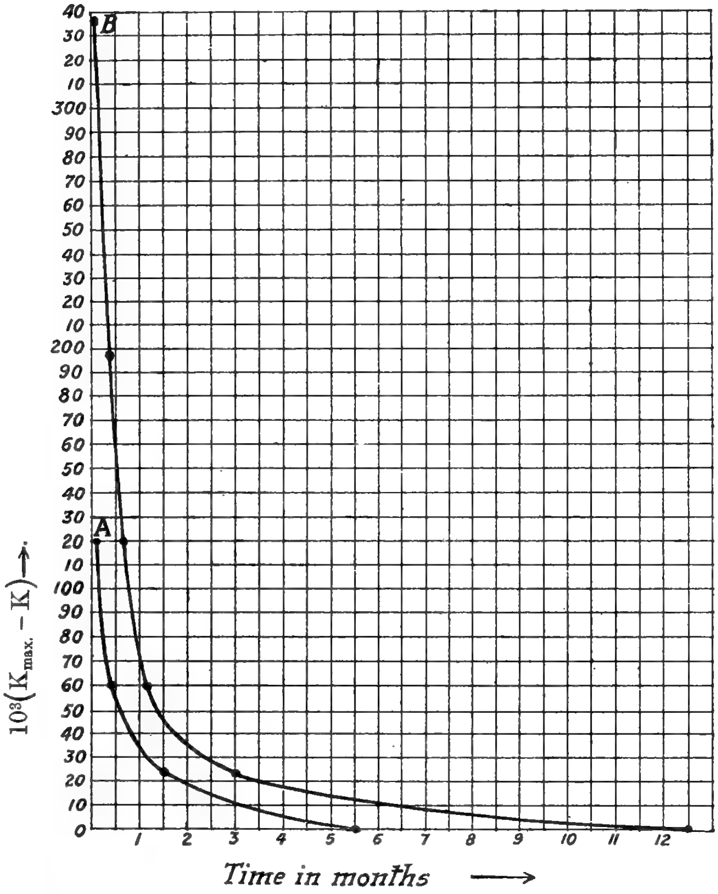
Cane-Sugar and Sulphuric Acid.

Per cent. H_2SO_4.	Γ.	10^3K.	10^3y_{18}.	*A.* Time in Months.	*B.* Time in Months.
60	12·23	373	366	...	·05
50	10·20	541	198	...	·37
45	9·18	616	123	·06	...
40	8·16	680	59	·40	1·1
36	7·34	715	24	1·6	2·9
33	6·73	733	6	5·6	7·7
30·5	6·22	739	0	11·9	12·4
26	5·30	722	...	uncertain (very long)	...

A refers to solutions containing 1 gram sugar to 50 c.c. acid.
B „ „ 0·3 „ „

When, as in Fig. III., the conductivities of the solution of the pure electrolyte are plotted instead of the conductivities of the actual solution (in this case sulphuric acid and sugar), then the influence of the presence of the non-electrolyte molecules shows itself by a distortion of the graph, such that it cuts the time axis. The greater the concentration of the non-electrolyte, the greater the distortion, and the greater will be the inclination of the graph towards the time axis. In Fig. III. two graphs for solutions of sulphuric acid containing respectively :

Fig. III.



(A) 1 gram cane-sugar per 50 c.c. of solution,
(B) 0·3 gram cane-sugar per 50 c.c. of solution,

are given. The graphs show clearly the effect of an increase in the concentration of the non-electrolyte.

In A the proportion of cane-sugar is sufficient to cause a marked distortion of the graph.

In B the distortion is much less, as the conductivities are comparatively little different from those of pure solutions of sulphuric acid.

SULPHURIC ACID AND FORMIC ACID.

The action of sulphuric acid on formic acid affords a striking example of the relationship between the value for y and the dehydrating power of sulphuric acid. Ultramaximal solutions of sulphuric acid of such concentration, that the value for y is considerable, readily effect the dehydration of formic acid, with production of carbonic oxide; but in solutions where the value for y is small this dehydrating power is also small, and ultimately disappears on progressive dilution as the value for y approaches zero, that is, as the concentration of the ultramaximal solution approaches that of the maximal solution, *i.e.* 30 per cent. H_2SO_4.

The following experiments were tried: In each experiment a small quantity, 5 c.c., in volume of anhydrous formic acid was mixed with 100 c.c. of one of a series of standard solutions of sulphuric acid having the concentrations given in Table II. The mixture was heated in a distilling flask, and when necessary a slow current of carbonic anhydride was used to sweep out the last portion of carbonic oxide evolved, this gas being collected and measured over a strong solution of caustic soda. With the more highly concentrated acid solutions carbonic oxide was given off freely, but when the concentration fell to $\Gamma = 8\cdot1$ ($y = 0\cdot123$ ohm^{-1} c.m.$^{-1}$), only a few cubic centimetres of carbonic oxide were given off. With $\Gamma = 7\cdot3$ ($y = 0\cdot025$), still less, and with $\Gamma = 6\cdot1$, or lower, no carbonic oxide was obtained. (See Fig. I.) Evidently the sulphuric acid does not dehydrate formic acid in premaximal solutions.

SUMMARY.

The examples discussed so far point to a remarkable relationship between the velocity of very many reactions and one particular quality of the media in which they occur, viz. their tendency towards increase of specific conductivity, this tendency being measured by the value for $y = K_{\text{max.}} - K$.

These examples may be summarised and correlated in the following manner:—

Homogeneous chemical systems which undergo change either of themselves or under the influence of the electro-magnetic vibrations which we call "light," change so that their specific electrical conductivity is increased, unless when coerced in an opposite direction by stronger chemical affinities.

The justification for such an hypothesis must lie in its usefulness. It must make it possible to predict correctly the results of hitherto untried experiments which it suggests, and lead to the correlation of hitherto uncorrelated phenomena. The proof offered in this paper is a cumulative proof. It is drawn from a great variety of instances widely different in character.

Apparent exceptions are capable of classification and correlation.

For instance, owing to strong chemical affinities, it is impossible to prepare a solution containing any considerable concentration of hydrogen ions along with a corresponding concentration of hydroxyl ions. A solution containing a concentration of hydrogen ions such as is found in hydrochloric acid of maximum specific conductivity (*circa* 18 per cent. HCl), along with a concentration of hydroxyl ions such as is found in aqueous caustic potash of maximum specific conductivity (*circa* 27·5 per cent. KOH), would be a far better conductor than any known solution, as these two ions have greater mobility than any others; but the strong affinity which determines their immediate association and the formation of water brings about a solution having a specific conductivity lower than that of either solution taken separately. Thus, on mixing the best conducting acid solution known with an equivalent quantity, that is, with a nearly equal volume, of the best conducting alkaline solution known, *i.e.* maximal caustic potash, the tendency for the hydrogen ions of the acid and the hydroxyl ions of the alkali to associate overcomes and masks the tendency towards an increase in specific conductivity, so that only the much less mobile potassium and chlorine ions are left as the chief carriers of electricity in the neutral and less highly conducting solution of potassium chloride.

The hypothesis is applicable to homogeneous, *i.e.* single-phase systems. It cannot even be formulated for heterogeneous systems, since the term "specific conductivity" applied to a heterogeneous system has no meaning. There are, however, many cases where it is possible to apply the hypothesis usefully, and to predict the course of events correctly, although the system is, or becomes, heterogeneous. Thus, in cases where a rearrangement resulting in alteration of specific conductivity brings about the separation of a non-electrolyte from a highly conducting solution, the system no doubt becomes heterogeneous, but its heterogeneity may be disregarded whenever the actual change of conductivity would not have been materially affected had the non-electrolyte remained in supersaturated solution. Heterogeneity confuses the issue only when marked changes in conductivity are the direct result of the appearance of the new phase or phases.

The separation of the non-electrolyte sulphur, in the action of hydrogen sulphide on a solution of iodine in hydriodic acid, is a case where heterogeneity may be disregarded.

The precipitation of barium sulphate and silver chloride, on mixing equivalent solutions of silver sulphate and barium chloride, is a case where the hypothesis is clearly not applicable. In this and similar cases of the double decomposition of salts the removal of electrolytes from the solutions necessarily implies a lowering of its conductivity, while at the same time the system becomes heterogeneous.

APPLICATION OF THE HYPOTHESIS TO PLANT CHEMISTRY.

This investigation was originally undertaken with the special object of throwing further light upon the chemistry of plant metabolism. With the exception of the first-cited instances of photochemical action, the examples and reactions discussed so far have all been reactions in which strong mineral acids play an essential part. This is not a matter of choice, the reason being that the tendency towards increased conductivity depends on the value for $y = K_{\max.} - K$, which is necessarily small when

$K_{max.}$ is small. It is therefore in solutions where $K_{max.}$ is greatest, that is, in concentrated solutions of the strongest acids, that the clearest evidence of the existence of the tendency towards increased conductivity is to be found. At first sight this would seem to lead far away from the chemistry of plant life, where mineral acids, and more particularly concentrated solutions of free mineral acids, are characteristically absent.

When the strong chemical affinities are not balanced, but directly brought into play as in the action of acids on bases, and generally wherever the strong tendency of the charged ions $\overset{+}{H}$ and $\overset{-}{OH}$ to neutralise each other predominates, there the weaker tendency towards increased conductivity is masked. Although the systems hitherto discussed comprised strong mineral acids, strong chemical affinities were uniformly more or less completely counterbalanced. Thus the examples discussed have comprised, among others, the action of nitric acid on nitric oxide; the action of hydrochloric acid on chromic acid and on aldehyde; the action of iodine on hydrogen sulphide, and the action of sulphuric acid on formic acid and on cane-sugar. Chemical systems in which the tendency towards increased conductivity is very marked and clearly recognisable resemble the chemical systems characteristic of plant life in this, that they are conducting systems containing good electrolytes, but with the strong affinities in abeyance. In plant chemistry the place of strong acids is taken by salts derived from the soil or, in the case of marine plants, from sea water. There is this further resemblance, that the solutions of many of the salts specially useful to plants, show maxima of specific conductivity, as do the strong acids. The conductivity of solutions of such salts have a specific conductivity of the same order as those of the strong mineral acids of corresponding concentration, their conductivities ranging in general from about one-third to one-sixth of those of the strong acids. So far as the insufficient data permit, it would appear that by merely selecting those salts which give the best conducting solutions and exhibit maxima of specific conductivity, we obtain an indication of the kind of salts most generally useful in plant chemistry. From the salts whose conductivities are given by **Kohlrausch** and **Holburn**, calcium, magnesium, lithium, and manganese chlorides, potassium carbonate, fluoride and acetate, are thus singled out. (See Fig. I.)

Reactions characteristic of plant chemistry are generally represented by equations which do not include good electrolytes. The fact that in plant metabolism the presence of good electrolytes, *i.e.* metallic salts, is indispensable has not hitherto been explained. The suggestion is here made that the tendency towards increased specific conductivity is an essential and determining factor in plant chemistry. It is not easy to obtain experimental evidence in favour of this suggestion in respect of foliage leaves, owing to the structural complexity of the tissues in which the reactions take place. The chemical reactions occurring in plants must be associated with changes in the local concentration of the sap solutions, which constitute the medium in which they occur, and consequently they must be associated with local changes in specific conductivity.

There is in foliage leaves a striking periodic alternation between dehydration and hydrolysis, namely, the diurnal change from sugar to starch, and again from starch to sugar.* Foliage leaves favour evaporation and sap concentration during insolation, by exposing a great surface, and by opening their stomata. They not less surely favour subsequent sap dilution by a checked evaporation, due to closure of the stomata when insolation ceases. Thus sunlight, evaporation, sap concentration, and conversion of sugar into starch, alternate with darkness, checked evaporation by closure of stomata, dilution with fresh sap, and consequent reversal of the reaction, and reconversion of starch into sugar. To increase the concentration of a premaximal solution, and to dilute an ultramaximal solution, is in both cases to bring about an increased conductivity. Bearing this in mind, we are able to correlate these two apparently opposed reactions as both tending towards increased conductivity.

Local sap concentration must surely occur in the intracellular regions of the mesophile where the sunlight is concentrated by the cell lenses of the epidermis on the light-absorbing chloroplasts congregated together close to the opened guard cells, which permit a free escape of water vapour. It is here that metabolism is most active and it is very probably here that sugar is chiefly formed.

Applying the hypothesis, it follows that when the sap concentration increases, and the solution becomes ultramaximal, the sap should tend to dilute itself by converting the sugar into starch. Accordingly, it is here that the formation of starch granules from the sugar is first noticed. When night falls or insolation ceases, the stomata close, the rate of evaporation slackens greatly, and then the concentrated sap, bathing the starch granules accumulated during the daytime, must become diluted by admixture with the dilute sap which continues to circulate owing to root pressure. This results in the solution becoming premaximal, so that the tendency towards increased conductivity determines the hydrolysis of the starch and its reconversion into sugar.

To such speculation, unaccompanied by direct experimental evidence, a greater or less degree of plausibility can at best be conceded. More is not claimed for it at present. It is advanced here, in the hope of drawing the attention of botanists and physiological chemists to a line of investigation which, being based on a recognition of the importance of the actually occurring local variations in sap concentration, promises to be very fruitful.

If we turn from the consideration of the metabolism in foliage leaves and other green parts of the higher plants to the processes belonging to the filling and ripening of seeds, we find analogous reversible reactions, but under conditions more amenable to direct experimental investigation, for here the reversals are not of diurnal, but are, as a rule, of annual occurrence. Anabolic polymerisations, condensations, and dehydrations characterise the filling and ripening of seeds, and these changes are certainly accompanied by the drying up and concentration of the sap. In presence of the

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[*] Brown and Morris, "The Chemistry and Physiology of Foliage Leaves," *Chem. Soc. Jour.*, 1893, p. 637.

necessary water, such reactions give place, during the germination of seeds, to catabolic hydrolysis, as in food digestion generally, both by plants and animals.

In this direction the author has obtained what he regards as conclusive experimental evidence of the usefulness of the hypothesis of a tendency towards increased specific conductivity in relation to plant chemistry. This evidence bears upon the two classical examples of catabolic enzymatic reactions in seeds which are afforded by the splitting up of the glucosides, amygdaline and potassium myronate. By the use of the hypothesis the following simple experiments were suggested, and their results correctly predicted. The experiments consisted simply in mixing ordinary mustard powder and crushed bitter almonds respectively with the salt solutions which are given in Table III., some of which are premaximal and some ultramaximal, and then observing whether the characteristic pungency of allyl sulphocyanate or the smell of benzaldehyde became perceptible, and in what time.

TABLE III.

Relation to Maximal Solution.	Electrolyte.	Per cent.	Γ.	$10^3 K_{max.}$*	$10^3 K$.	$10^3 y$.
Ultra	Lithium chloride	23·90	5·6	168	161	7
Pre	,, ,,	12·62	3·0	...	140	...
Pre	Sodium chloride (saturated)	26·40	4·5	...	216	...
Pre	,, ,,	14·40	2·5	...	161	...
Pre	Potassium chloride (saturated)	24·86	3·3	...	330	...
Pre	,, ,,	13·41	1·8	...	180	...
Pre	Potassium bromide (saturated)	40·28	3·4	...	392 ?	...
Pre	,, ,,	23·21	1·9	...	220 ?	...
Pre	Potassium iodide (saturated)	58·24	3·5	...	460 ?	...
Pre	,, ,,	36·74	2·2	...	260 ?	...
Ultra	Potassium acetate	46·74	5·4	130	90	40
Pre	,, ,,	26·05	3·0	...	128	...
Ultra	Magnesium chloride	23·81	5·0	140	134	6
Pre	,, ,,	12·98	2·7	...	124	...
Ultra	Calcium chloride	28·84	5·2	178	171	16
Pre	,, ,,	14·85	2·7	...	150	...

* Approximate values from graphical interpolation.

The splitting up of amygdaline is certainly hydrolytic, and so probably is the splitting up of potassium myronate, although it is often represented by an equation which does not indicate hydrolysis. Certainly the presence of water is essential to both reactions. In each and every experiment the necessary water was present in large excess.

The following question now arises: Which, if any, of these solutions should allow, and which of them should prevent or greatly retard, the interaction of the two glucosides with their corresponding enzymes, emulsin and myrosin?

Applying the hypothesis, the various solutions may be arranged into two groups: (A) Premaximal solutions and (B) Ultramaximal solutions, the concentration of the solutions in group (A) being somewhat less, and that of those in group (B) somewhat greater, than the concentrations corresponding to maximum conductivity.

It was predicted that the premaximal solutions would permit the hydrolysis of the amygdaline and of the potassium myronate, but that the ultramaximal solutions would inhibit or greatly retard the hydrolysis and consequent splitting up of the glucosides. The results actually obtained justified the hypothesis in a very satisfactory manner. With crushed bitter almonds all the premaximal solutions gave the smell of benzaldehyde quite distinctly within five minutes or less after mixing; and also gave, with ordinary English mustard powder, a distinct pungency.* Conversely, none of the ultramaximal solutions gave rise, on mixing, to the smell of benzaldehyde, or to any distinct pungency, on standing ten minutes. When the mixtures are allowed to stand in loosely covered vessels for twelve hours or so, the difference between the two sets becomes very marked.

Without the hypothesis of a tendency towards increased conductivity as a directing factor it does not appear possible to predict the behaviour of the various systems. When the mixtures made with solutions belonging to group (B)—and in which the reactions were inhibited—were mixed with sufficient water to bring the solutions to a concentration distinctly lower than that corresponding to maximum conductivity the reactions were found to proceed readily, even after long standing. This demonstrates that the enzymes are not rendered permanently inactive, and completes the proof that the tendency towards increased conductivity is a real directing factor in these cases.

Another interesting observation bearing on the behaviour of sulphuric acid may be cited here.

Professor A. J. Brown has discovered that the covering of the seeds of *Hordeum vulgare* acts as a peculiar semi-permeable membrane. He finds, for instance, that it is possible to concentrate dilute sulphuric acid by soaking the barley grain in the dilute acid, for the membrane, when undamaged, permits the passage of water, but not of sulphuric acid, into the interior of the grain.

The preceding examples suggest an answer to the following question: What is the maximum concentration of sulphuric acid which can possibly be reached in this way? The answer is: Not beyond the concentration corresponding to maximum conductivity, *i.e.* 30 per cent. H_2SO_4, for, as has been seen, the sulphuric acid tends towards increased conductivity, so that when the concentration reaches that corresponding to maximum conductivity, the tendency will oppose further concentration, as that would imply a decrease in the specific conductivity of the solution, which would thereby become ultra-

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* This statement requires modification in one case only, viz. so far as mustard and saturated solution of potassium iodide are concerned, for this solution has a marked disintegrative effect and appears to produce a deeper-going change which masks the tendency of the premaximal system.

maximal. Professor Brown states further[*] that "it was found that sulphuric acid could not penetrate into the grain, not only from volume normal solutions, but also from solutions containing 9, 18, or even 36 grammes of acid per 100 c.c. In the case of the seeds immersed in the strongest acid, however, the interior remained dry, presumably because the power of the seed contents of imbibing water was insufficient to overcome the osmotic pressure of the liquid."

"The vitality of the embryos was not destroyed by steeping the seeds in the acid solutions; when placed under suitable conditions they all germinated."

Now, 36 grams of sulphuric acid per 100 c.c. corresponds to a percentage of 29·7 H_2SO_4, which is only 0·3 per cent. below that corresponding to maximum conductivity.

It is suggested that in plant metabolism the tendency towards increased specific conductivity is a directing factor, both in the case of foliage leaves and of seeds. Increased specific conductivity results from the progress of the reactions in the one direction or in the other, according as the sap has the character of an ultramaximal, or of a premaximal solution. It is important in this connection to note that increase in specific conductivity does not solely result from the actual addition or removal of water from the sap solutions, but that it also results from polymerisations or condensations especially of the aldol type in submaximal, sub-premaximal, and sub-ultramaximal solutions.[†]

It is hoped in a subsequent paper to develop the application of the hypothesis to chemical systems generally, and especially to those occurring in plant and animal metabolism.

Several conjoint papers have been, or will shortly be, published bearing on different points related to the inquiry which is summarised in this paper.

I take this opportunity of thanking those who in one way or another have given me kind assistance. My thanks are very specially due to Mr Andrew King, F.C.S., for long-continued and invaluable analytical assistance. I also gratefully acknowledge the receipt of a Research Grant from the Carnegie Trust.

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[*] *Proc. Roy. Soc.*, 1909, vol. lxxxi. p. 82.

[†] See page 124 *et seq.*

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VII.—Nuclear Osmosis as a Factor in Mitosis. By A. Anstruther Lawson, Ph.D., D.Sc., F.L.S., F.R.S.E., Lecturer in Botany, University of Glasgow. (With Four Plates.)

(Read June 19, 1911. MS. received July 25, 1911. Issued separately November 7, 1911.)

The recent important work of Farmer and Digby (1910) on the cytology of certain varietal and hybrid ferns has raised again the interesting and absorbing question of the mechanism of mitosis. This paper constitutes a valuable addition to the literature* which has bulked so largely during the last few years, and which has been instrumental in establishing many interesting and important facts regarding the greatest of all cytological problems—namely, nuclear division. The interest of this later contribution lies, not so much in the actual observations which these writers have jointly recorded—although the facts revealed are important in that they confirm the work of other writers and extend the range of observation,—but rather in the theory which they have deduced from their results and which they have put forward to account for the factors at work in the living cell,—factors which they believe to be concerned in the formation of the achromatic spindle.

The observations made in this more recent paper confirm the generally accepted view that the achromatic spindle is formed from a differentiation of the cytoplasm—a differentiation which, on account of the active rôle it is believed to play in mitosis, has been called *kinoplasm* by Strasburger. They also confirm the view that—with the exception of some unessential variations in the distribution and orientation of the kinoplasm in the prophase—the process of spindle development is fairly uniform throughout the vascular plants. The establishment of such uniformity is valuable, because it follows that the factors concerned in the process would also be uniform, and any theory accounting for such factors would necessarily be far-reaching in its application.

From the facts and views expressed in the above literature we may briefly summarise the mitotic process as follows:—It seems that with the change of the spireme into definite bivalent chromosomes, the cytoplasm in the immediate vicinity of the nuclear membrane becomes differentiated into a series of delicate fibrils (kinoplasm), forming a weft which more or less completely surrounds the nucleus. In somatic cells this weft becomes raised up from the nuclear membrane at opposite points in such a fashion as to form conical-shaped caps of kinoplasm, which, on account of their position, are known as polar caps. The fibrils composing the caps converge at

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* Strasburger (1882, 1895, 1905, 1907); Belajeff (1894); Farmer (1893, 1895, 1905, 1910); Osterhout (1897); Juel (1897); Sargant (1897); Lawson (1898, 1900, 1903); Debski (1897); Williams (1899); Byxbee (1900); Smith (1900); Němec (1899); Mottier (1897, 1898, 1907); Miyake (1905); Allen (1903, 1905); Overton (1905, 1909); Berghs (1904, 1905); Grégoire (1903); Davis (1899, 1909).

points which are directly opposite one another, so that the spindle is bipolar from its inception. This is also true in some cases for the heterotype spindle, but as a rule in the latter, the weft of kinoplasm pushes out at a number of places and the fibrils converge at several points which are not necessarily opposite one another. The result is that a number of fibril sheaves are developed which are of conical shape, and the spindle at this prophase may be tripolar, quadripolar, or multipolar. By the coalescence of these cones, however, the spindle eventually becomes bipolar and has the same symmetrical form as the somatic spindle. With the organisation of the cones in the prophase—whether the spindle is bipolar or multipolar—it is believed that the nuclear membrane breaks down and disappears. The fibrils of the spindle now push into the nuclear area, and with their free ends become attached to the chromosomes. The latter become arranged at the equator, forming the characteristic equatorial plate, and we now have what is known as the metaphase. Each bivalent chromosome separates into two daughter chromosomes, each of which moves to opposite poles of the spindle. It is believed by some cytologists that it is the contraction of the fibrils attached to the chromosomes which accomplishes not only the separation of these bodies, but also the migration of the two halves to the poles.

These, in brief, are the conclusions reached by many investigators whose observations have extended over a wide range of types of vascular plants. They are the views that are commonly held at the present time, and they have in the main been sustained by the recent work of FARMER and DIGBY (1910). These writers, however, have done more. They have drawn some theoretical conclusions from their observations in an attempt to account for the factors concerned in the various changes and movements in the cell expressed in the achromatic figure. Following the work of Professor MARCUS HARTOG, they have come to the conclusion that an explanation of these changes and movements may be found in the electrical conditions of the cell. They point out the remarkable manner in which the sheaves of fibrils, during the prophase, diverge in the proximity of the chromatin-charged linin, and that these are so repelled by each other that they press out equidistantly at the periphery of the cytoplasm. This condition appeals to them as convincing evidence in support of their hypothesis that the linin, with its contained chromatin, by virtue of the chemical changes involved in its metabolism, has brought about an electrical condition of opposite sign, similar in each of the spindle cones. This hypothesis seems to them to be in harmony with the fact that the disappearance of the nuclear membrane is closely associated with the spreading of the chromosomes beneath it just before their retrogressive movement to the equator, whilst the spindle poles have shifted away from the nuclear surface. For these and other reasons Professor FARMER lends his support to the view that electrical conditions in the cell are not only responsible for the form of the spindle, but for its very existence —a view frequently put forward, but not generally accepted.

Without attempting an analysis of this hypothesis, I should like to point out some difficulties which I have experienced in interpreting the observations which have been recorded in the process of spindle development as ordinarily accepted, and which I have briefly outlined above.

In the first place, the cytoplasm—presumably in the form of a reticulum—in the immediate vicinity of the nuclear membrane becomes transformed into a series of delicate threads or fibrils, which forms a dense weft about the nucleus. There seems not much doubt that these threads are really transformed cytoplasm, and this is the generally accepted view. It is believed that these kinoplasmic threads eventually become the fibrils of the mature spindle. But just how that transformation has been brought about and the factors responsible for the changes are questions which have never been satisfactorily answered. The kinoplasmic idea of Strasburger offers no explanation—it is simply descriptive. The hypothesis of electrical conditions and phenomena of induction as being factors in these changes is vague and difficult to comprehend. This idea, which has again been advocated by HARTOG (1910), is no doubt very suggestive, but unfortunately it is based more upon appearances than upon knowledge of such electrical conditions in the living cell or upon the knowledge of the effect of such conditions upon living protoplasm.

Another difficulty—and in my opinion the greatest difficulty in the whole process of mitosis—that requires some explanation is the breaking down, collapse, and disappearance of the nuclear membrane. Many investigators (including the present writer) have either described or figured the breaking down of the nuclear membrane at a time when the multipolar stage has been reached, or in somatic cells when the polar caps have been completely formed. This stage has been so frequently described that its actual occurrence has never been questioned. Now it is a fact of general acceptance that the nuclear membrane is cytoplasmic in nature (PEIRCE, 1903)—it is, in fact, the inner limiting layer of cytoplasm, and it is a membrane in virtue of its having come in contact with the karyolymph (PFEFFER, 1890; GRÉGOIRE, 1903; LAWSON, 1903; YAMANOUCHI, 1906). It is not only a plasmatic membrane, it is permeable and consequently osmotic. The nucleus itself is an osmotic system, and its membrane is the main essential element in that system. It should be remembered that at the time the membrane is supposed to break down, the nuclear cavity, while considerably under its maximum size, is nevertheless very large, and the membrane is under considerable tension, due to the high osmotic pressure of the karyolymph. Furthermore, it is well known (LAWSON, 1903; GATES, 1908; FARMER and DIGBY, 1910) that the membrane is capable of increasing or diminishing its surface area. This is clearly demonstrated in any spore mother-cell where changes in the size of the nuclear cavity may be easily observed. So that, in this sense, the membrane is both stretchable and elastic. The point that I am endeavouring to make is, that it is difficult to understand why a membrane with these properties should break down under the conditions of spindle formation. During the prophase the karyolymph is undoubtedly exerting a considerable pressure upon the membrane. This is clearly indicated by the almost spherical form and turgid appearance of the nucleus at this time. One would expect a less violent process than breaking down and collapse under such circumstances. Nevertheless, the actual breaking down has been described and figured by several close and accurate observers. Without attempting to question the accuracy of these records, I should like to point out a fact which will become more obvious later in this paper. It is, namely, that at the time when the membrane is reported to break down, the nuclear cavity has diminished considerably in size—that there is less karyolymph than formerly. A rational explanation for this change is a variation in the osmotic relations—that a part of the karyolymph has diffused into the cytoplasm by exosmosis. Under such circumstances it is not difficult to understand the collapse of the nuclear membrane upon the sudden application of fixing reagents. After a careful re-examination of my own preparations, I have not only been convinced that this is really the cause of the breaking down of the nuclear membrane, but also that in the normal living cell the membrane does not break down. What would happen if such a breaking down were possible in the living cell? Clearly the surrounding cytoplasm would be at once exposed to the large remaining body of karyolymph, which is a watery fluid. By the very reason of that exposure and contact one would expect a new membrane to be precipitated immediately. The new membrane would be precipitated so simultaneously with the break that the latter could not be detected. For does not the nuclear membrane exist as a membrane by virtue of its contact with the karyolymph? (PFEFFER, 1890; LAWSON, 1903; GATES, 1907, YAMANOUCHI, 1906). The killing of the cytoplasm by the application of fixing reagents would prevent the precipitation of a new membrane, so that any rupture caused by such reagents would show in fixed material.

The growing or pushing in of the fibrils from the base of the cones into the nuclear area when the nuclear membrane is supposed to have vanished has also offered some difficulties. It is generally admitted that these fibrils are nothing but modified cytoplasm, and as such they are viscous and semi-fluid. It seems improbable that such fine, delicate cytoplasmic threads should traverse the clear remaining body of nuclear fluid—threads which at one moment are reported to be elongating towards the periphery of the cell, and in the next, upon the disappearance of the nuclear membrane, are observed to traverse or elongate in the opposite direction. Surely something more than the vague mystery of "electrical conditions" is needed to account for such extraordinary changes. But, as Professor FARMER admits, "the time has not yet arrived when it will be possible to give an explanation of these cellular changes that will prove satisfactory from a physical point of view."

These threads seem not only endowed with the power of traversing the clear watery fluid of the nuclear area, but it is reported that they become attached to the chromosomes by their free ends. Now it is a fact that all of the chromosomes become attached to fibrils—none of them escape. It seems also that the distribution of the fibrils is fairly uniform among the chromosomes. That is to say, the number of fibrils that become attached to the various chromosomes is approximately the same, there being no striking difference in the size of the fibril sheaves attach to each chromosome as we see them in the mature spindle. Moreover, these fibrils attach themselves to opposite sides of each bivalent chromosome, and the sheaf on one side is approximately equal to that on the other. The difficulties here presented are quite obvious. In the first place, an explanation is needed to account for the actual attachment of the free ends of these fine, delicate, in-growing fibrils to the chromosomes, and if they do so attach themselves, this implies a selective power either on the part of the fibrils or of the chromosomes both in regard to numbers and position of attachment.

Another series of difficult interpretations is to be found in reference to the coalescence of the cones of the multipolar stage which results in the bipolar figure. It will be remembered that the apices of the cones may be some distance apart, but it is believed that they eventually approach one another at opposite points. Such approachment and coalescence implies a movement. Such a movement would necessarily be through the undifferentiated reticulum of the cytoplasm. It should be remembered that certain of the apices of the cones are so far apart that they pass through an angle of 45° in the accomplishment of this fusion. In this connection Professor FARMER calls attention to the aggregation of the nuclein-charged linin beneath the points of origin of the cones, and he sees in this an indication that there exists a causal connection between the two phenomena; and just as the chromatin at this early stage appears to determine the formation of the four or more poles, so now the chromosomes again appear to be the active agents in effecting the resolution of the quadripolar into a bipolar arrangement. But just how this is brought about Professor FARMER does not explain. The fact is, the idea of approachment and eventual coalescence of the cones has been based upon appearances only. A careful search of the literature and of my own preparations has failed to reveal the slightest indication that the cytoplasmic reticulum has been in any way disturbed by such a coalescence. No real evidence has been recorded to show that an approachment of the cones really occurs. I shall attempt to prove in the following pages that the idea of a lateral movement and coalescence of the cones is a misconception.

Perhaps the most striking feature of the whole mitotic process is the constancy and uniformity of the equatorial plate in the metaphase. Here the chromosomes always arrange themselves in the same plane at the equator of the spindle. This plane constitutes a dividing line between two series of fibril-sheaves which extend in opposite directions and generally converge at the poles. It is this constant position of the chromosomes which gives the spindle its character. Up to the present no adequate explanation has been offered to account for the factors concerned in the arrangement of the chromosomes in this peculiar fashion which results in so striking a feature of mitosis. To say that the equatorial plate is due to electrical conditions only confuses the issue, at least until more is known of such electrical conditions and their influence upon protoplasmic bodies. It is just as profitable to say that it is due to cell-polarity, the determining factors of which are unknown so far as the vascular plants are concerned.

It is believed by some that the meaning and function of the achromatic figure is to accomplish the separation of the chromatin substance of the mother nucleus into two equal portions. It is believed that by the contraction of the fibrils which undoubtedly become attached, the daughter chromosomes are not only separated from one another, but are actually pulled to opposite poles of the spindle. Here again I find some difficulties. In the first place, the poles of the bipolar spindle rarely extend as far as the cell-wall, and consequently if such actual pulling of the chromosomes takes place, there appears to be no stationary resistance to pull against. And then again, from an examination of many preparations I find that the daughter chromosomes invariably pass beyond the region of the pole of the spindle. These and other facts do not lend support to the idea that this movement is accomplished by the contractility of the connected fibrils.

And finally the question presents itself: If these fibrils of the achromatic spindle have no concern in the separation of the daughter chromosomes, what is the reason for the existence of such a complicated mechanism?

In view of the many difficulties and inconsistencies mentioned above, is it not possible that the development and function of the achromatic figure have been misinterpreted? Is it not possible that the so-called "mechanism of mitosis" represents the passive results and effects of movements rather than an active agent in such movements? After a careful, comprehensive study of a wide range of types, I am forced to answer these questions in the affirmative. I have also been convinced that the cause of so many difficulties lies in the fact that a series of important and critical stages in spindle formation has been overlooked—stages which throw an entirely new light on the problem, and which will necessitate a revision of the accepted views and interpretations of nuclear phenomena.

These stages are to be found in the later prophase, preceding the organisation of the equatorial plate. They are stages concerning the fate of the nuclear membrane. Contrary to my earlier observations, as well as to the observations of the majority of cytologists, I find that the nuclear membrane does not break down, but, on the contrary, behaves as a permeable plasmatic membrane should behave under varying osmotic relations. The discovery of these stages not only clears up a doubtful point which I mentioned above in regard to the prophase, but is far-reaching in its importance. It goes to prove that osmotic conditions rather than electrical conditions are active factors concerned in the formation of the achromatic spindle. This I shall attempt to demonstrate from a study of the spore mother-cell of *Disporum*, *Gladiolus*, *Yucca*, and *Hedera*, also the vegetative cells in the root tip of *Allium*.

DISPORUM.

In fig. 1 we have represented a median section of a microspore mother-cell of *Disporum Hookeri*. It is taken at a time when the nuclear cavity is just about its maximum size, soon after the growth period, which up till recently was known as "synapsis."[*] Within the nucleus there are five bivalent chromosomes almost completely organised, and a large spherical nucleolus. Surrounding the enlarged nuclear cavity there is a very distinct membrane, which shows every indication of being under pressure of the karyolymph. The surrounding cytoplasm, which appears as a relatively narrow zone in section, is densely but finely granular and of a reticulate structure. Enveloping the whole is a fairly thick and apparently firm cell-wall. It will be seen that the nucleus occupies more than half the cubical volume of the cell. At this time the cytoplasm is perfectly uniform, with no indication of kinoplasm[†] having been differentiated.

In fig. 2 we have represented a little later stage. Here it will at once be noticed that the nuclear volume has diminished considerably in size, that the amount of karyolymph present is not so great as that represented in the first figure. It will also be noticed that the width of the cytoplasmic zone has correspondingly increased. There is also to be seen a distinct modification in the structure of the cytoplasm, especially in the immediate vicinity of the nucleus. The cytoplasm in this region has taken on the form of fine, delicate threads which appear to radiate out a short distance from the nuclear membrane towards the periphery of the cell. In fig. 3 we represent a cell where the diminution of the karyolymph has continued to such an extent that its cubical volume is less than half that shown in fig. 1. Here also we see the cytoplasm in the form of radiating threads; but these latter are much more sharply defined and longer than those shown in fig. 2. This is really the stage where the nuclear membrane is reported to break down in other types. But, as shown in figs. 4 and 5, this certainly does not occur in *Disporum*. It should be noted in passing that in these cells the characteristic multipolar arrangement is not so sharply defined as in many other plants, the kinoplasm taking on the form of radiations which form small tuft-like sheaves. The nuclear membrane remains intact, and, as indicated in figs. 4, 5, and 6, it gradually closes in the nuclear cavity with the diminution of the karyolymph. This latter, although now very much reduced in quantity, apparently still exerts a considerable pressure on the enveloping membrane, for the nuclear cavity is still spherical and turgid.

These changes in the dimensions of the nuclear cavity are evidently gradual, but the point of interest is that they are always accompanied by a corresponding increase in the differentiation of the surrounding cytoplasm; for it is evident from figs. 3, 4, 5, and 6 that, as the nucleus becomes smaller and smaller, the cytoplasmic radiations become longer and more sharply defined. In fig. 7 we have a most interesting stage. Here the karyolymph has diminished to such an extent that the chromosomes appear crowded about the nucleolus and the clear nuclear sap is hardly visible. The nuclear membrane is in close touch with the chromosomes for the greater part of its surface.

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[*] LAWSON, A. A. (1911).

[†] I intend using the word "kinoplasm" throughout this paper as a convenient term, but not, however in the sense in which it was first applied by STRASBURGER.

We have here, from figs. 3 to 7, a series of stages which, as far as I know, has never before been described. That it represents early phases in the development of the spindle is, I think, quite obvious. It also demonstrates that with the gradual decrease in the nuclear volume there is a corresponding increase in the cytoplasmic volume. It should be remembered that throughout these stages, as well as those immediately preceding, the cell is surrounded by a firm cell-wall of considerable thickness, to which the peripheral cytoplasm is closely associated, and that a perceptible diminution in the volume of the *cell*-cavity is inconceivable. It should also be remembered that the nuclear membrane is part of the cytoplasm. With these facts in mind it is quite clear that in the stage represented by fig. 7 the cytoplasm fills a cubical space which is more than double that shown in fig. 1, but there is no change in the dimensions of the cell as a whole. That varying osmotic relations constitute a causal factor in these transformations seems to me a safe and rational assumption. Everything necessary to promote osmotic diffusion is present. There is a permeable membrane and substances of different chemical composition and presumably of different density on either side of it. It is therefore not difficult to understand the gradual diminution of the karyolymph, as shown in these figures, on the basis of osmotic diffusion. The karyolymph has passed out into the cytoplasm by exosmosis.

All of these circumstances bring about a condition where a limited amount of cytoplasm of reticulate structure is obliged to occupy a cubical space which is gradually increased by reason of the diminution of the large nuclear space. This necessarily sets up a state of tension in the cytoplasm—a tension sufficient to cause a readjustment and changed configuration in the reticulate form of the cytoplasm; a change to the form of threads or fibrils which are drawn out from the reticulum by the receding nuclear membrane. With the closing in of the nuclear membrane about the chromosomes the cytoplasm must follow the membrane, and the changed configuration of the cytoplasm would first make itself evident in the region of the membrane. On examination of the serial stages represented in figs. 1 to 7, the conclusion is irresistible that this is really what has happened. The kinoplasmic fibrils are drawn-out threads of cytoplasm—drawn out by reason of the inward movement of the membrane.

But now, what follows the stage represented in fig. 7? In fig. 8 we have a later condition, where the karyolymph and membrane are no longer visible. This invisibility, however, does not prove that these elements of the nucleus no longer exist. They are both present—the one very much reduced and saturating the chromosomes, and the other completely enveloping each chromosome. So that we now have, not a single osmotic system as formerly, but as many osmotic systems as there are bivalent chromosomes; and in this case there are five.

This closing in of the membrane about each bivalent chromosome is doubly interesting. It not only establishes a number of osmotic systems which are more or less independent of one another, but it clears up a doubtful matter, mentioned above, as to the manner in which the kinoplasmic threads become attached to the chromosomes.

These threads from their very first appearance are moored to the membrane—being a continuation of the same cytoplasmic substance—and that association continues throughout all of these stages. As the membrane recedes, the threads are drawn in with it, and so it comes about that as the membrane becomes closely applied to the surface of the chromosomes, each of these bodies is furnished with its own system of fibrils, which to all intents and purposes are attached, as shown in fig. 9. This seems to me a much more rational method of attachment than the commonly accepted view that the threads push into the nuclear area and attach themselves individually to the chromosomes with their free ends. It also accounts for the more or less equal distribution of the fibrils among the chromosomes; for these threads would continue their fairly uniform occurrence over the osmotic surfaces, that is, over the membranes enveloping each chromosome, and as these latter are approximately the same size and shape, the amount of fibrils furnished to each chromosome would be about equal.

It is obvious that as osomotic diffusion progresses and the nuclear vacuole becomes smaller and smaller, there will follow not only a corresponding shifting of the lines of tension as expressed in the kinoplasmic threads, but also an acceleration of the changes occasioned by such a shifting. So that the interval between the stages represented in figs. 6 and 9 would be a very brief one, and such critical periods would not be very frequently observed. It is also obvious that, as the karyolymph becomes gradually exhausted by the continued osmotic diffusion, it eventually becomes no longer visible as a clear nuclear sap. This transition is illustrated in figs. 7 and 8. As the condition shown in fig. 8 is approached there naturally follows a further readjustment of the lines of tension. In the earlier stages, as shown in figs. 3, 4, 5, and 6, these lines of tension radiate out from the nuclear membrane with the nucleus itself as a centre; but when we reach the stage represented in figs. 8 and 9, this condition no longer prevails. The lines of tension have readjusted themselves to meet the new condition. Each bivalent chromosome becomes the centre of a system of fibrils, but on account of the crowded position of the chromosomes (fig. 8) at this time, the radiations are not so regularly disposed as in the earlier stages. Now, I do not for a moment believe that these radiating threads—which merely express lines of tension—move individually or collectively through the cytoplasm. The apparent change in their position is due to the relaxing of the tensions along certain lines and establishment of new tensions along others. In other words, while the lines of tension do shift, the actual threads of cytoplasm do not. These latter withdraw or reappear, according to the shifting of the position of the osmotic surfaces, that is, the membrane enveloping each chromosome.

Another point of great interest in this connection, and revealed in the stage shown in fig. 8, is the distribution of the fibrils over the surface of the chromosomes. Here it will be seen that the chromosomes are longer than broad, and the line of division between the two daughter chromosomes is parallel with the long axis. If the chromosomes were perfectly spherical, one would expect a uniform and symmetrical radiation of the fibrils, but, as seen in fig. 8, the lateral surface of each chromosome is furnished with many more fibrils than the end surface, and for this reason the disposition of the fibrils is not symmetrical. Also, the close juxtaposition of the chromosomes would aid in the prevention of symmetry. This unsymmetrical arrangement, however, is of very short duration. The greater surface from which project the larger number of fibrils apparently dominates the direction of the lines of tension, and in this readjustment the bivalent chromosomes become less crowded and each one becomes suspended between two sheaves of fibrils, as shown in fig. 9.

The state of tension set up in the cytoplasm by the gradual diminution and final vanishing of the nuclear vacuole now finds an expression in two conical-shaped sheaves of kinoplasmic threads which appear on opposite sides of each bivalent chromosome, so that, as shown in fig. 9, each of these bodies is provided with an independent miniature spindle, and these lie parallel to one another. Now, as the surfaces which form the base of attachment for the fibrils are equal, so the two sheaves on the opposite sides of each chromosome are also equal, and the chromosome is thus suspended at the equator. Applying this to all five chromosomes, and taking into consideration the more or less parallel arrangement of the main lines of tension, we have here an exceedingly suggestive explanation for the organisation of the equatorial plate. But in this connection it should be remembered that we know little or nothing in regard to the problem of cell polarity in the vascular plants, and the plane occupied by the chromosomes during the metaphase is too closely involved in this problem to justify my offering the above as an adequate explanation. I have no hesitation, however, in expressing my belief that the osmotic surfaces enveloping each chromosome are determining factors in the suspension of these bodies between two sets of fibril sheaves of fairly equal size.

From a study of dividing cells in *Disporum* and other types which I will mention later, no evidence was found to support the view, held by Strasburger and others, that the daughter chromosomes are drawn to the poles by the contraction of the spindle fibrils. That these fibrils shorten and thicken with the movement of the chromosomes towards the poles is no doubt quite true, but this is not sufficient proof that they are actually engaged in the pulling of these bodies to opposite ends of the spindle. I believe that this shortening and thickening is due to the relaxing of the tension in these fibrils as the chromosomes move to the poles, and the fibrils merely act as guide lines with no pulling force. Although the tension in the fibrils between the daughter chromosomes and the poles of the spindle is thus relaxed, as shown in fig. 10, the tension in the cytoplasm as a whole has not been relaxed, for we see new lines of tension expressed in the fibrils stretching between the pairs of daughter chromosomes. This is quite clear in figs. 10 and 11. There has merely been a shifting of the lines of tension caused by the movement of the chromosomes to the poles. It should be noted in passing that the daughter chromosomes move beyond the actual poles of the spindle. This feature was observed not only in *Disporum*, but in many other types, and it supports the statement made above that the contractility of the fibrils is not the cause of the separation of the daughter chromosomes.

In the stage represented in fig. 11 we see the two groups of daughter chromosomes lying at opposite ends of the cell, with a series of cytoplasmic threads stretching between them. My interpretation of these fibrils at the close of the anaphase is that they represent the same state of tension by the spindle in the metaphase and the radiating kinoplasm of the prophase—a tension caused in the first place by the diminution and final vanishing of the nuclear vacuole.

The daughter chromosomes forming the two groups now become more or less intimately united—a condition in which it is difficult to distinguish the individuals. With this massing together each chromosome loses its compact and homogeneous appearance by becoming vacuolated. This vacuolation of the daughter chromosomes was first described by the writer in the case of *Passiflora* and *Equisetum* (LAWSON, 1903), and was later confirmed by other writers (GRÉGOIRE et WYGAERTS, 1903; YAMANOUCHI, 1906 and 1910; GATES, 1907). It would seem that this is a constant and normal occurrence in the organisation of daughter nuclei. YAMANOUCHI (1910) regards this vacuolisation as either a secretion from the chromosomes or a dissolution of portions of them into liquid. In the light of the present researches I am inclined to regard the presence of these lacunæ or vacuoles within the chromatin as due to the diffusion of endosmosis. In this connection I see no reason why the chromosomes should not still possess the plasmatic membrane with which they were enveloped in the later prophase (see p. 144 above). This vacuolisation proceeds until the membrane extends beyond the limits of the chromatin, as shown in fig. 12, and eventually each daughter nucleus consists mainly of a single large vacuole filled with karyolymph. As these two nuclear vacuoles increase in size there naturally follows a general relaxation of the tension set up in the cytoplasm at the prophase, and this relaxation is expressed in the loose curved appearance of the threads stretching between the daughter nuclei, as shown in fig. 13.

GLADIOLUS.

In contrast to the conditions found in *Disporum*, the spore mother-cells in *Gladiolus* are very large; and they have the additional interest of passing through a series of typical multipolar stages in the course of spindle formation, which has been described as occurring so frequently in the vascular plants.

In fig. 14 we have represented a median section of a miscrospore mother-cell of the common garden species of *Gladiolus*. The large spherical nucleus occupies about half the volume of the cell-cavity. It is apparently at or near its maximum size, and, judging from its turgid appearance, it is evidently under high osmotic pressure. The chromosomes appear as curved or bent rods many times longer than broad. A large globular nucleolus is also suspended in the karyolymph. The nuclear membrane stands out in sharp contrast as the inner limiting layer of cytoplasm against the clear nuclear sap.

Within the meshes of the cytoplasm there are numerous oil globules and other food granules. In other respects the cytoplasmic reticulum is quite uniform. The peripheral cytoplasm is in close association with a firm cell-wall of considerable thickness.

In fig. 15 we represent a condition which shows unmistakable evidence of a diminution in the volume of the nuclear vacuole. Accompanying this diminution we find the first indication of the transformation of the cytoplasmic reticulum into kinoplasmic threads. Here it will be seen that the cytoplasm in the region of the nuclear membrane has undergone a modification which takes the form of a narrow weft of delicate threads. This weft does not appear to be uniform in its distribution about the nucleus, and differs from the early kinoplasmic zone described above for *Disporum* in that the threads do not form a system of radiations. It appears that as the nuclear membrane recedes with the diminishing of the karyolymph, the drawing out of the threads from the cytoplasmic reticulum is more marked at certain places than at others (figs. 15 and 16). At such places there are conical-shaped sheaves of threads produced, which impart an irregular and unsymmetrical form to the kinoplasm. The beginning of these sheaves is shown in fig. 15, and later stages are shown in figs. 16 and 17, where we have a typical multipolar arrangement. In the stages shown in figs. 16, 17, and 18, we find in each cell several large conical-shaped sheaves of fibrils whose wide bases are evidently continuous with the nuclear membrane, and whose outer or distal extremities taper out into more or less sharp points. The drawings are, of course, made from sections, and consequently the figures do not represent all of the cones developed in each cell. In fig. 16 there are three of these cone-shaped sheaves to be seen; in fig. 17 there are four; in fig. 18 three; and in fig. 19 two. A study and compilation of serial sections convinces me that the number of sheaves developed in these early stages is not an essential feature. In the matter of numbers they seemed to vary considerably in the different cells I have examined. The form and position of the kinoplasmic sheaves seem likewise a matter of no great importance, for, as I shall point out later, they are constantly changing during the prophase. The feature of these early stages that is of great importance, and one that should be noted as having an essential bearing on all the changes of the prophase, is that as these kinoplasmic sheaves develop and increase in size there is a corresponding gradual decrease in the volume of the nuclear vacuole. It will be seen that as the nuclear vacuole becomes smaller and smaller, the kinoplasmic threads become longer and more sharply defined. That there exists a causal relation between these two sets of changes I have no doubt whatever. If measurements be taken of the volume of the nucleus as indicated in the sections shown in figs. 20 and 21, it will be found that there has taken place a great reduction in the karyolymph—that its volume is now only about one-eighth of that shown in nucleus in fig. 14. As I pointed out above in the case of *Disporum*, we have here a limited amount of cytoplasm now occupying a cubical space which has been very much increased by reason of the diffusion of the karyolymph from the nuclear vacuole. The state of tension that necessarily follows finds an expression in the drawing out from the cytoplasmic reticulum a series of fine, delicate threads. If we now examine closely the kinoplasm which has been thus differentiated, we will find that the changed configuration of the cytoplasm is much more sharply defined near the nuclear membrane, and as we follow the threads outward to the periphery, they gradually fade out and become lost in the reticulum. From this it would seem that the tension expressed in these fibrils decreases in proportion with the distance from the nuclear membrane. This is obviously beyond actual proof, but if it is true, as appearances seem to indicate, it may account for the conical shape of the groups or sheaves of fibrils, for these clearly show a like tendency to attenuate as they approach the periphery.

A comparison of the serial stages shown in figs. 14 to 21 is sufficiently convincing that while there is a marked but gradual decrease in the volume of karyolymph there is no evidence whatever that the nuclear membrane breaks down, collapses, or disappears. On the contrary, the membrane remains intact throughout all of these stages. As indicated in figs. 19, 20, 21, and 22, the nuclear vacuole may not always retain its spherical form, and the shape of the membrane may vary accordingly, but even in such extreme cases as shown in fig. 22 the contour of the membrane in section may easily be followed. It has simply receded with the gradual diffusion of the nuclear sap.

Now, the nuclear membrane not only remains intact throughout the prophase, but it continues to form the base of the lines of tension expressed in the drawn-out threads, for it is in reality a continuation of the same cytoplasmic substance as the kinoplasm. It would therefore naturally follow that, as the membrane receded with the diminution of the nuclear vacuole, the lines of tension would shift accordingly. Such a shifting does not mean the changing of the threads bodily from one position to another. It means the relaxing of the tension along certain threads, which would consequently fall back into the form of the original reticulum, and the setting up of new lines of tension, with the drawing out of new threads from the hitherto undifferentiated reticulum. In this fashion not only individual threads, but entire sheaves or cones may appear to assume different positions. I believe the conditions shown in figs. 20 and 21 represent transition stages in the shifting of the lines of tension, and consequently the apparent shifting in the position of certain cones or sheaves in this way. In both these figures there are portions of the cytoplasm which can be interpreted in no other way than transitions between a reticulum and kinoplasmic threads. I regard such demonstrations as very important, because I believe they suggest a rational explanation not only for the apparent changes in the position of the fibril sheaves, but also for the ultimate resolution of the multipolar into a bipolar arrangement. In figs. 17, 18, 23, and 24, it will be seen that the apices of the cones may be a considerable distance apart. It is generally believed that the apices approach one another and the cones ultimately coalesce in two groups. Such a movement of the cones bodily seems to me not only improbable but impossible, without some disturbance of the cytoplasmic reticulum. In the series of stages shown in figs. 16 to

25 there is no trace whatever of such a disturbance in the cytoplasm. There is no evidence of any sort to support the view that a movement and coalescence of the cones really occurs, except the fact that we eventually have a bipolar figure in place of one which was previously multipolar. Throughout all of these stages it will be seen that the nuclear membrane, which in reality constitutes the bases of the cones, is constantly moving inward as it closes in about the chromosomes, and as the nuclear vacuole becomes smaller and smaller the area of the membrane becomes less and less. With these changes there necessarily follows a corresponding shifting in the lines of tension; so that during the entire prophase there is a constant changing in the distribution of the kinoplasm. The ultimate bipolarity of the spindle is therefore not brought about by the approachment and coalescence of the cones in two groups, but by the shifting of the osmotic surfaces which form the bases of the lines of tension represented in the threads of kinoplasm.

In fig. 22 we have a condition where the karyolymph has been reduced by diffusion to such an extent that the chromosomes have become crowded together around the nucleolus. The nuclear membrane is now in close touch with several of the chromosomes. In the lower part of the figure one of the chromosomes seems to be already partly enfolded by the membrane. That this enveloping process continues until the membrane becomes closely applied to the entire surface of each chromosome is in my opinion beyond much doubt. To make an actual demonstration of the plasmatic membrane during its close application to the surface of the chromosomes is obviously out of the question. We are, therefore, obliged to accept less convincing evidence. In fig. 22, however, we have undoubtedly the beginning of such a process. If we compare figs. 22 and 23, and examine them in the light of the evidence obtained in similar stages in the case of *Disporum*, there is really only one rational conclusion to come to. It is, namely, that each chromosome has not only been completely and closely enveloped by a membrane, but each of these bodies, as a result of that enveloping process, has been furnished with a system of kinoplasmic fibrils. With the establishment of as many osmotic systems as there are chromosomes—systems which are to a great extent quite independent of one another—there will naturally follow a new and rapid readjustment of the lines of tension expressed in the kinoplasm. Such a readjustment is probably taking place in the stage represented in fig. 24.

As stated above, the chromosomes in *Gladiolus* are very long, being many times longer than broad. It would therefore follow that as the nuclear membrane became closely applied to the chromosomes, the broad sides of these bodies, offering the greater osmotic surfaces, would naturally be thus furnished with many more kinoplasmic threads than the short end surfaces. This condition may be seen quite clearly in figs. 23 and 24. And so with the final readjustment, the main lines of kinoplasm would find themselves exerting a tension on opposite sides and at right angles to the long axis of each chromosome, and these latter bodies would thus be suspended at the equator, as shown in fig. 25.

YUCCA.

A perfect series of stages was obtained in the microspore mother-cells of *Yucca*, which furnished convincing evidence that the nuclear membrane neither breaks down nor collapses during the period of spindle formation. In fig. 26 we have represented a median section of a mother-cell with the bivalent chromosomes just about completely organised. The nuclear vacuole has reached its maximum size and occupies a space nearly equal to the volume occupied by the cytoplasm. That the nuclear vacuole is under high osmotic pressure seems evident from its spherical form and the distended condition of the enveloping membrane. The cytoplasm is finely and densely granular, but perfectly uniform in its reticulate structure. The peripheral cytoplasm is in close touch with the inner surface of the thick cell-wall.

Fig. 27 represents a similar section at a somewhat later stage. It will at once be seen that the nuclear vacuole is now less than half the original volume shown in fig. 26. It will also be seen that this reduction is accompanied by a differentiation or rather a changed configuration of the cytoplasm. With the nuclear membrane as a base there appear numerous long radiating threads or fibrils which show every indication of having been drawn out from the cytoplasmic reticulum. Many of these threads are so fine that they can only be seen with difficulty, being more or less obscured by food granules. Others, again, are well defined and extend for some distance towards the periphery. In the stage shown in fig. 28 we find the nuclear vacuole has diminished still further and the kinoplasmic threads have increased in number. Fig. 29 represents a little later stage, where the nuclear vacuole has been reduced to such an extent that the chromosomes have become crowded together by the enclosing nuclear membrane. The kinoplasmic threads are still more numerous and much more sharply defined. The lines of tension represented in the threads or fibrils seem to shift when the stage represented in fig. 30 has been reached. As indicated in this figure, the threads appear to arrange themselves in conical-shaped sheaves or groups, until, as shown in fig. 31, there is a distinct tendency to the multipolar arrangement. It should also be noted in this last figure that the nuclear membrane is now in close touch with the majority of the chromosomes.

A comparative study of these serial stages (figs. 26 to 31) establishes a number of facts in regard to spindle development that are of vital importance. In the first place, it becomes obvious that there has been a gradual and progressive diminution in the amount of karyolymph. In the second place, there is no doubt whatever that the nuclear membrane persists throughout all of these stages. In the third place, these figures demonstrate quite clearly that the differentiation of the cytoplasmic reticulum into the kinoplasmic threads or fibrils progresses with the diminution in the volume of the nuclear vacuole.

I have already stated my interpretation of these facts in the case of *Disporum* and *Gladiolus*. The diminishing of the karyolymph I believe to be due to osmotic diffusion, and the presence of the plasmatic nuclear membrane makes such a diffusion possible. As this gradual diffusion progresses and the volume of the nuclear vacuole decreases, the reticulate cytoplasm finds itself under tension in being obliged to occupy a greatly increased cubical space (compare fig. 31 with fig. 26). This tension finds an expression in a changed configuration of the reticulum. This latter becomes drawn out in the form of threads by the diminishing and receding plasmatic membrane.

A comparison of such stages represented in figs. 31 and 32 convinces me that the reduction of the karyolymph by diffusion does not cease when it becomes no longer visible as a clear nuclear sap, but continues until each chromosome becomes closely enveloped by the nuclear membrane. It will be seen from fig. 32 that each chromosome is not only thus furnished with a system of fibrils which become closely applied to its surface, but osmotic diffusion continues for some time, establishing new lines of tension. As in the case of *Disporum* and *Gladiolus*, the main lines of kinoplasm extend from the broad sides of the chromosomes, and the tension thus becomes exerted on opposite sides, and at right angles to the long axis of each bivalent chromosome. These latter bodies thus find themselves suspended at the equator, as shown in fig. 33.

HEDERA.

With the object of extending the range of my observations into the Dicotyledons, I have selected the common ivy—*Hedera helix*—as a type for study. In the microspore mother-cells of this plant I find also a series of stages showing the persistence of the nuclear membrane throughout the prophase—stages which can only be interpreted in the manner for the monocotyledonous types, *Disporum*, *Gladiolus*, and *Yucca*. The nucleus, at the time the chromosomes are nearly formed from the spireme, occupies more than half the volume of the cell-cavity, as shown in fig. 34. In section the cytoplasm appears as a narrow zone filling the space between the nuclear membrane and the cell-wall. Its reticulate structure is uniform throughout. The chromosomes are small, oval-shaped bodies, and for the most part occupy a position in touch with the nuclear membrane. The large nuclear vacuole is evidently under high osmotic pressure. It is almost spherical in form and in a state of turgescence.

Fig. 35 represents a similar section at a somewhat later stage. It will be seen that the nuclear vacuole is much smaller than that shown in fig. 34. A certain amount of the karyolymph has evidently diffused into the cytoplasm, and this has been carried still further in the stage shown in fig. 36. The conditions shown in figs. 35 and 36 are quite similar to corresponding stages in the mother-cells of *Disporum*. Accompanying the decrease in volume of the nuclear vacuole there is a change in the form of the cytoplasmic reticulum. It will be seen (fig. 35) that the reticulum, at one side of the nucleus, has been drawn out into a broad tuft of short threads or fibrils. It will also be seen that as the nucleus becomes smaller and smaller (fig. 36), the kinoplasmic threads become longer and more radial in their distribution; they also become more numerous and more sharply defined.

My interpretation of these kinoplasmic threads in *Hedera* is the same as that for the types mentioned above. These threads simply express lines of tension in the cytoplasm—a tension caused by the increased cytoplasmic area, and which is sufficient to change the configuration of the reticulum, and the threads are therefore the passive results of nuclear osmotic changes.

In fig. 37 we have a typical multipolar stage with the numerous chromosomes crowded together in the small remaining vacuole of karyolymph. Nearly all of the chromosomes are now in close touch with the nuclear membrane. The closing in of the membrane continues until it completely envelops each separate bivalent chromosome in the manner above described for *Disporum.* The large number of chromosomes in *Hedera*, however, complicates matters, and we have the confused appearance represented in fig. 38. I have not the slightest doubt, however, that the fibrils become attached to the individual chromosomes in this manner. With the establishment of so many smaller osmotic systems there would naturally follow a final readjustment of the lines of tension expressed in the achromatic figure. This readjustment would be mainly controlled by the osmotic surfaces enveloping each chromosome. There was no indication whatever to suggest the bodily shifting and ultimate coalescence of the sheaves of the multipolar figure. The establishment of the equatorial plate and the symmetrical bipolar arrangement of the lines of tension represented in the fibrils is evidently brought about in the manner already described above in the case of *Disporum* and *Gladiolus.*

ALLIUM.

It is well known that spindle development in somatic cells is somewhat different from that occurring in spore mother-cells. This fact was established by NĚMEC (1899) and others, who found that as the kinoplasmic weft becomes differentiated about the nuclear membrane, it takes the form of two conical-shaped caps which project from opposite sides of the nuclear cavity. These kinoplasmic projections, on account of their position, are commonly referred to as polar caps. The threads of which they are composed eventually become the main fibrils, and their apices become the poles of the spindle. So that in vegetative cells there is nothing in the nature of the multipolar arrangement which is so characteristic of the heterotype mitosis. It seems that the mitotic spindle in somatic cells is always bipolar from the beginning.

Because of this striking difference between the somatic and heterotype mitosis, and in view of the new facts and interpretations recorded above in the cases of *Disporum*, *Gladiolus*, *Yucca*, and *Hedera*, I have considered it advisable to re-examine the nuclear changes leading to the formation of the achromatic spindle in the root tip of *Allium cepa*, a plant which has become a classic for nuclear study.

The first indication of approaching mitosis is a decided enlargement of the nuclear vacuole in which the chromatin reticulum lies suspended in the karyolymph. This enlargement is not so great as that which occurs at a similar time in the heterotype mitosis, but nevertheless sufficient to make these nuclei very conspicuous. The chromatin now changes from the finely divided reticulate condition to long, rather stout threads, and ultimately into the compact definite chromosomes, as shown in fig. 40. This figure represents a section of a somatic cell taken at a time when the chromosomes are nearly organised. The nuclear vacuole, it will be seen, is perfectly spherical and obviously under high osmotic pressure. It should be noted in passing that, unlike sporogenous cells, there are several large vacuoles in the cytoplasm.

In the following stages, namely, those represented in figs. 41, 42, 43, and 44, I was able to confirm the main observations of NĚMEC (1899) and others in regard to the development of the two polar caps at opposite sides of the nucleus. The beginning of these kinoplasmic caps is shown in fig. 41, where they appear in section as shallow crescent-shaped groups of threads. As indicated in figs. 42, 43, and 44, these crescent-shaped caps appear to elongate and become decidedly conical in form. These features do not differ essentially from what is commonly known in this connection. Unfortunately, however, a very interesting and important fact has been overlooked. It is, namely, that as these kinoplasmic structures known as the polar caps develop, there is a corresponding diminution in the volume of the nuclear vacuole. This is so clearly illustrated in figs. 41, 42, 43, 44, and 45, that actual measurements are not necessary. The decrease in the amount of karyolymph is gradual but unmistakable. It will also be noticed from these figures that as the karyolymph diminishes the outline of the nucleus becomes less spherical. As shown in figs. 43, 44, and 45, the nuclear vacuole becomes decidedly flattened on the sides that form the bases of the polar caps.

There is no doubt whatever in my mind that the factors responsible for the formation of the polar caps are the same as those which we have described above as being concerned in the formation of the kinoplasm during the heterotype mitosis. They are, namely, that a state of tension has been created in the cytoplasm by the reduction in the volume of the nuclear vacuole, and the cytoplasm thus finds itself obliged to occupy a greatly increased cubical space. This tension finds an expression in the drawing out of threads from the cytoplasmic reticulum by the receding nuclear membrane.

It is curious that somatic mitosis should be characterised by the drawing out of only two conical-shaped sheaves of kinoplasm. This feature, however, becomes less difficult to understand when we remember that the numerous vacuoles which are always present in the cytoplasm would render a radial or a multipolar arrangement of the kinoplasm impossible. In sporogenous cells these cytoplasmic vacuoles do not occur.

The developmental stages that now follow are practically the same as those described above for the heterotype spindle. The diffusion of the karyolymph continues until the nuclear membrane completely envelops each individual chromosome (figs. 46 and 47), thus providing each of these bodies with a series of fibrils. On account of the great length of the chromosomes, the greater number of fibrils—and consequently the dominating lines of tension—would be drawn to the broad sides of the chromosomes, and in this fashion the equatorial plate would be established, and the mature spindle presents the appearance shown in fig. 48.

An examination of fig. 48 will convince one that the poles of the spindle are not very remotely situated from the equator. It will also be seen without any doubt in figs. 49 and 50 that the daughter chromosomes move in opposite directions beyond the positions of the actual poles of the spindle. From this fact alone it would seem that the attached fibrils are not actively concerned in this movement. As I have stated elsewhere, they may possibly act as guide lines.

The organisation of the daughter nuclei, as illustrated in figs. 50, 51, 52, and 53, is important and interesting, because it shows how the tension originally set up in the cytoplasm during the prophase and expressed in the spindle fibrils eventually becomes relaxed. In fig. 50, for instance, we see the daughter chromosomes arranged in two groups at opposite sides of the cell. The state of tension in the cytoplasm is still evident by the drawn-out threads of cytoplasm stretching between the two groups. This same condition is still shown in fig. 51, where the chromosomes in each group are closely massed together. In fig. 52 we have a stage where each chromosome has become more or less vacuolated, clearly indicating that a considerable amount of karyolymph has been taken in by endosmosis. This would necessarily release the tension in the cytoplasm to a considerable extent. When, finally, as shown in fig. 53, the combined volumes of the two daughter nuclei approximates the original mother nucleus, all tension is relaxed and all fibrils disappear.

The interpretations which I have given above for these new stages in spindle formation in the various types mentioned are quite in harmony with certain well-known facts concerning important changes which take place in the nucleus both before and after mitosis. In the first place, it is an established fact that in the re-organisation of the daughter nuclei there is an accumulation of karyolymph within the chromosomes. This nuclear sap first appears in the form of minute lacunæ which increase in size and flow together, giving the chromosomes a vacuolated appearance. With the accumulation of the karyolymph the chromosomes become very finely divided, and the chromatin eventually appears as a fine reticulum suspended in a large vacuole of nuclear sap. It is also well known that out of this finely divided condition there is developed a stage commonly called the spireme, where the chromatin assumes the form of long, fairly thick threads, and not so finely divided as in the reticulum. And, finally, the spireme threads give rise to the more compact chromosomes. Now, the point of interest is that during this transition period between the finely divided condition of the reticulum and the more compact condition of the chromosomes there always occurs an enlargement of the nuclear vacuole, that during this period there is an increase in the amount of contained karyolymph. In spore mother-cells this enlargement is very great indeed, and constitutes a conspicuous growth period (LAWSON, 1911), while in somatic cells it is not so great. Now, coupling these facts with the building up of new chromatin substance with each nuclear generation, there is a suggestion that the condition of the chromatin has an influence on the varying osmotic relations. For now, again, it would seem that as soon as the chromatin assumes the compact form of the chromosomes there immediately follows a diminution in the volume of the karyolymph, and this continues until the nuclear sap is completely diffused into the cytoplasm.

This investigation, however, is not intended to cover all the phenomena of mitosis; its only object has been to throw some light on the problem of the achromatic spindle and the factors responsible for its formation in vascular plants.

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SUMMARY.

A study of the microspore mother-cells of *Disporum*, *Gladiolus*, *Yucca*, *Hedera*, and the vegetative cells in the root tip of *Allium* has revealed a series of stages in the development of the mitotic spindle which have never before been described.

The new stages that have been discovered are to be found in the prophase immediately preceding the organisation of the equatorial plate, and concern the fate of the nuclear membrane.

The interpretation of these stages has thrown a new light on the process of mitosis, and necessitates a revision of the accepted views of nuclear phenomena.

Contrary to the generally accepted view, it has been found that the nuclear membrane does not break down or collapse at any period during spindle development, but behaves as one would expect a permeable plasmatic membrane to behave under varying osmotic relations.

The nucleus is regarded as an osmotic system, and its membrane constitutes an essential element in that system.

It is a fact of common knowledge that the chromatin changes both in quantity and form sometime before the metaphase. The chromatin must increase in quantity, because the same amount is present for each mitosis. It changes in form from the finely divided condition represented in the reticulum and spireme to the more compact and homogeneous form of the chromosomes.

It would seem that these changes are in some way responsible for a variation in the osmotic relations of the karyolymph: at any rate, a gradual diffusion of the nuclear sap immediately follows these changes in the form of the chromatin.

A series of stages has been found showing beyond doubt that, closely following the organisation of the bivalent chromosomes, there is a gradual diminution in the volume of the nuclear vacuole. It is believed that the karyolymph gradually diffuses by exosmosis into the cytoplasm.

Throughout the entire prophase the nuclear membrane is functional in this osmotic transfer.

As the nuclear vacuole becomes smaller and smaller, the membrane gradually closes in about the chromosomes. These latter become crowded together about the nucleolus.

When the karyolymph becomes so much reduced that it is no longer visible as a clear nuclear sap, the membrane becomes closely applied to, and completely envelops, the surface of each chromosome.

The result is that, instead of a single osmotic system represented in the nucleus, we now have established as many independent osmotic systems as there are chromosomes.

For some time previous to the diffusion of the karyolymph the nuclear vacuole occupies a space that may approach or even exceed half the volume of the cell-cavity. So that all of these circumstances bring about a condition where a limited amount of cytoplasm of reticulate structure is obliged to occupy a cubical space which has greatly increased by the reduction in the volume of the nuclear vacuole.

This necessarily sets up a tension in the cell—a tension sufficient to cause a re-adjustment and changed configuration in the reticulate form of the cytoplasm.

As the nuclear vacuole becomes smaller and smaller, the cytoplasm in the region of the nuclear membrane becomes changed to the form of fine threads or fibrils which are drawn out from the reticulum by the receding membrane.

The state of tension set up in the cytoplasm thus finds an expression in these drawn-out threads of "kinoplasm."

From the different plants studied it seems that the lines of tension as expressed in the fibrils may group themselves in various ways at first. Thus we may have a weft of kinoplasm surrounding the nucleus; or a system of kinoplasmic radiations; or, more commonly, a number of conical-shaped sheaves of fibrils.

But whichever form the kinoplasm may appear to take, the lines of tension are constantly shifting throughout the prophase.

Such a shifting does not mean the changing of the threads bodily from one position to another. It means the relaxing of the tension along certain threads, which would consequently fall back into the reticulum form, and the setting up of new lines of tension by the drawing out of threads from the hitherto undifferentiated reticulum.

In this fashion not only individual threads, but entire sheaves or cones of fibrils may appear to assume different positions.

For these and other reasons the generally accepted view that the sheaves or cones of fibrils in the multipolar figure approach one another and eventually coalesce into two groups should no longer be retained.

There was no evidence to support the generally accepted view that the spindle fibrils grow into the nuclear area and attach themselves to the chromosomes.

This attachment is undoubtedly brought about by the enveloping of each bivalent chromosome by the receding nuclear membrane. This membrane, which is really the base of the drawn-out threads, upon being closely applied to the surface of each bivalent chromosome, furnishes each of these bodies with its own system of kinoplasm.

No evidence was found to support the view that the contraction of the attached fibrils draws the daughter chromosomes to the poles of the spindle. Such fibrils may serve as guide lines, but take no active part in the movement.

Taking all of the facts into consideration, I am forced to the conclusion that the achromatic spindle in vascular plants is simply an expression of a state of tension in the cytoplasm, and that this tension is caused in the first place by nuclear osmotic changes which create a condition where a limited amount of cytoplasm is obliged to occupy an increased cubical space.

As a result of this investigation, I can no longer regard the achromatic figure as an *active* factor in mitosis. It seems to be nothing more than a *passive* effect of nuclear osmotic changes.

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EXPLANATION OF FIGURES.

All the figures were drawn with the aid of the camera lucida, with Zeiss compensating oculars and oil immersion objective one-twelfth at the magnifications indicated.

Figures 1 to 13 × 1900.
Figures 14 to 25 × 1400.
Figures 26 to 53 × 1900.

DISPORUM.

Fig. 1. A section of a microspore mother-cell when the nuclear cavity has reached its maximum size. Five bivalent chromosomes are to be seen and a large nucleolus. The cytoplasmic reticulum shows a uniformity of structure.

Fig. 2. The same at a later stage. A considerable diminution in the size of the nuclear cavity is to be seen. The cytoplasm in the vicinity of the nuclear membrane has lost its reticulate structure and takes the form of a series of delicate threads which appear to radiate from the membrane.

Fig. 3. The same at a still later stage, with a further diminution in the size of the nuclear cavity. The cytoplasmic radiations have become longer and more sharply defined.

Fig. 4. The same, showing that the nuclear cavity has diminished to less than half the cubical area shown in fig. 1. The membrane is still intact, but a great reduction in the amount of karyolymph has taken place. The kinoplasmic radiations are more sharply defined.

Fig. 5. Another cell showing about the same conditions, but with the nucleus more centrally situated.

Fig. 6. A still later stage of the same, showing the crowding together of the chromosomes as the nuclear membrane closes in about them.

Fig. 7. The amount of karyolymph has been so much reduced that the nuclear membrane is in close touch with the chromosomes for the greater part of its surface.

Fig. 8. The karyolymph can no longer be seen as a clear nuclear sap, and the nuclear membrane has enveloped each individual chromosome.

Fig. 9. As the nuclear membrane has enveloped each bivalent chromosome, each of these bodies becomes provided with a sheaf of fibrils which to all intents and purposes are attached. As these sheaves of fibrils appear on opposite sides, there is a small spindle for each bivalent chromosome.

Fig. 10. The metaphase with the daughter chromosomes separating, and have begun their movement to the poles of the spindle.

Fig. 11. The daughter chromosomes at the poles.

Fig. 12. Showing the vacuolisation of the daughter chromosomes by the accumulation of karyolymph and the organisation of a membrane about each daughter nucleus.

Fig. 13. The daughter nuclei completely organised.

GLADIOLUS.

Fig. 14. A section of a microspore mother-cell with the nucleus at its maximum size.

Fig. 15. A slight diminution in the size of the nuclear cavity is shown, and a narrow weft of kinoplasmic threads appears about the nuclear membrane. This weft is not uniform, being much more prominent at intervals.

Fig. 16. A typical multipolar condition of the kinoplasm.

Fig. 17. The same a little later, showing four cones in the multipolar condition. The nuclear vacuole has decreased to less than half its original dimension.

Fig. 18. The same, showing three cones in the section.

Fig. 19. Another example of the same stage, showing two cones.

Fig. 20. A little later stage, showing the nuclear membrane still intact.

Fig. 21. Another example about the same stage.

Fig. 22. The nuclear vacuole has so much reduced that the membrane is seen closing in about the chromosomes.

Fig. 23. The nuclear membrane has now enveloped each chromosome.

Fig. 24. The same a little later.

Fig. 25. The mature spindle with the chromosomes at the equator.

YUCCA.

Fig. 26. A median section of a microspore mother-cell, showing the nuclear vacuole at its maximum size.

Fig. 27. The same, showing a considerable reduction in the volume of the nuclear vacuole and an indication of radiating kinoplasmic threads in the surrounding cytoplasm.

Fig. 28. The same at a slightly later stage, with the kinoplasmic threads much more sharply defined. The nuclear vacuole is considerably less than a fourth of its original volume, and the nuclear wall is still intact.

Fig. 29. Another example of the same condition, but slightly older.

Fig. 30. The nuclear membrane still intact, and the kinoplasmic threads appear in groups or sheaves.

Fig. 31. The chromosomes are crowded together by the enclosing of the nuclear membrane about them. An irregular multipolar condition has been reached.

Fig. 32. The nuclear membrane has completely enveloped each chromosome, so that each of these bodies is now provided with a system of kinoplasmic threads.

Fig. 33. The mature spindle with the chromosomes at the equator.

HEDERA.

Fig. 34. A median section of a microspore mother-cell showing the nuclear vacuole at its maximum size.

Fig. 35. The same, showing a considerable decrease in the volume of the nuclear vacuole and the appearance of an incomplete zone of kinoplasm.

Fig. 36. The same, showing the kinoplasmic threads radiating from the nuclear membrane and much more sharply defined. There is a still further decrease in the nuclear vacuole, and the nuclear membrane is intact.

Fig. 37. A distinct but irregular multipolar condition. The karyolymph in the nuclear vacuole has almost completely diffused, and the chromosomes are consequently crowded together by the receding nuclear membrane.

Fig. 38. Each chromosome has become enveloped by the nuclear membrane and consequently furnished with a system of kinoplasmic fibrils.

Fig. 39. The mature spindle with the chromosomes at the equator.

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Fig. 40. A median section of a vegetative cell in the root tip. The nucleus is quite large and prepared for mitosis. The chromosomes are almost organised.

Fig. 41. A slightly later stage of the same. The kinoplasm appears in the section as narrow crescents of threads which appear at opposite sides of the nucleus. There has been a slight decrease in the size of the nucleus.

Fig. 42. A further decrease in the volume of the nucleus, and a corresponding increase in the differentiation of the kinoplasm.

Fig. 43. The same a little later, showing the polar caps.

Fig. 44. Another section of the same.

Fig. 45. The polar caps completely organised, with a very obvious diminution in the volume of the nuclear vacuole. The nuclear membrane is still intact.

Fig. 46. The nuclear membrane has closed in about each chromosome.

Fig. 47. Showing the connection of the kinoplasmic fibrils to the membrane enveloping each chromosome.

Fig. 48. The mature spindle with the chromosomes at the equator.

Fig. 49. The daughter chromosomes have moved to the poles of the spindle. Numerous threads of kinoplasm stretch between the chromosomes at opposite ends of the spindle.

Fig. 50. The grouping together of the daughter chromosomes at the poles.

Fig. 51. The same a little later.

Fig. 52. The vacuolisation of the daughter chromosomes, accompanied by a relaxation of the tension in the cell. This relaxation is expressed in the loose curvature of the kinoplasmic threads.

Fig. 53. The daughter nuclei fully developed. The development of the large nuclear vacuoles has relaxed the tension in the cytoplasm completely, and all kinoplasmic threads have vanished.

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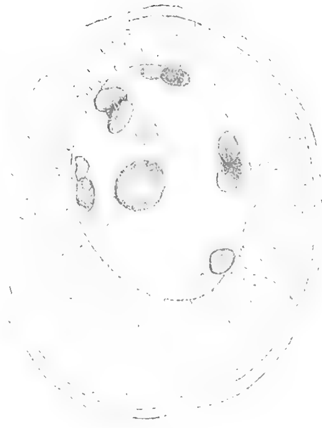

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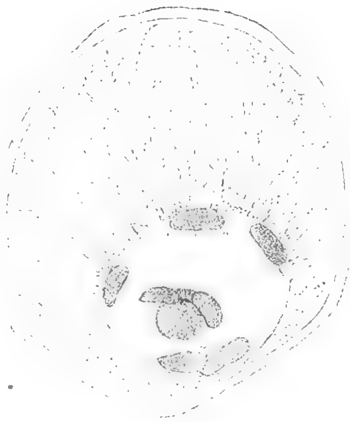

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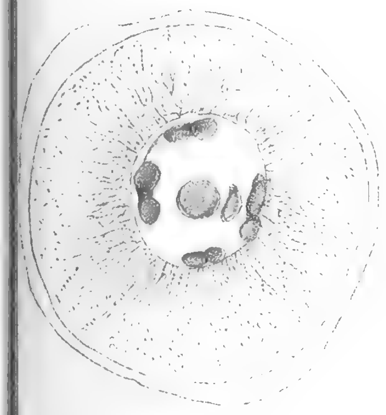

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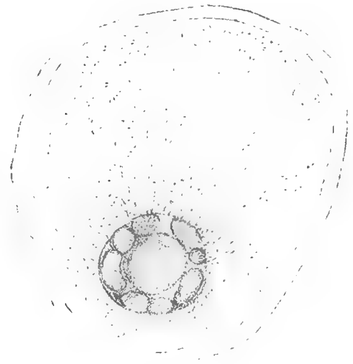

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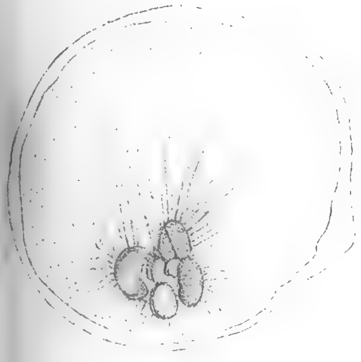

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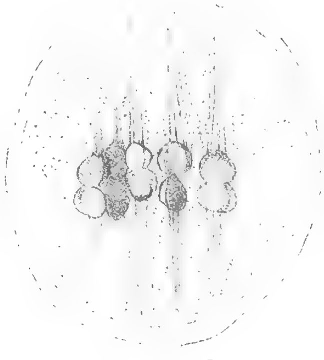

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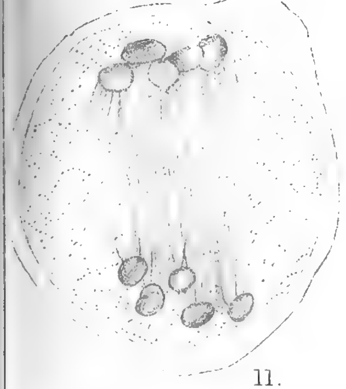

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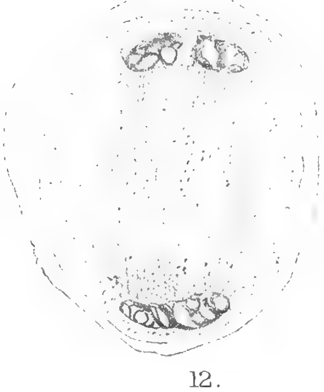

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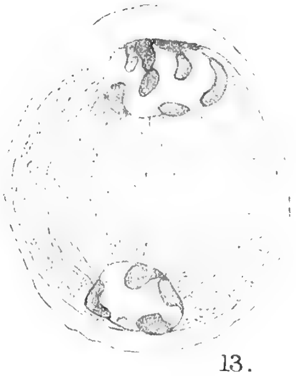

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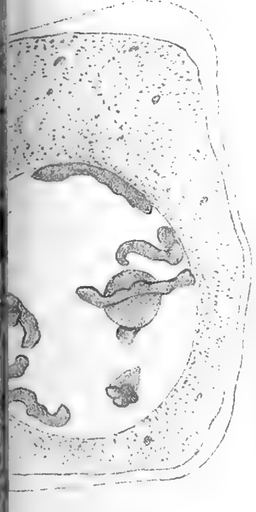
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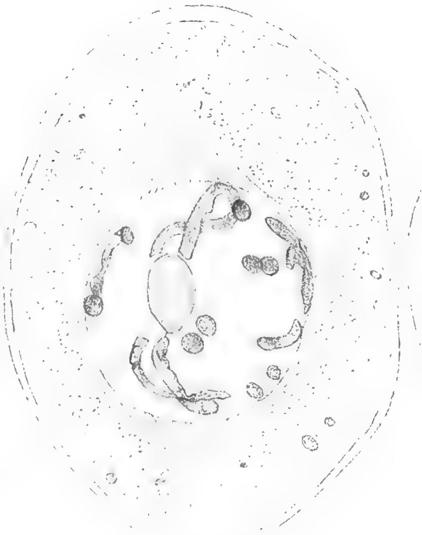
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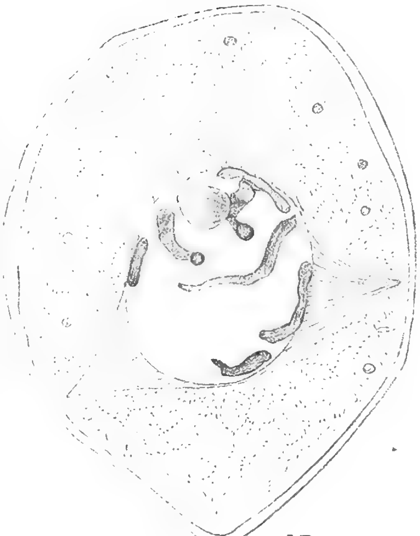
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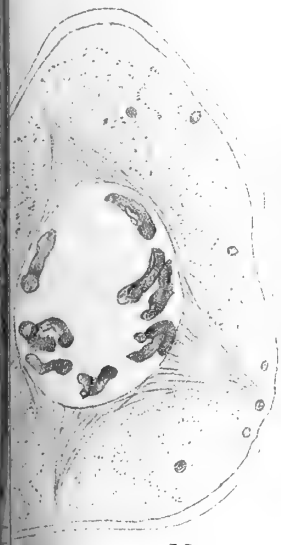
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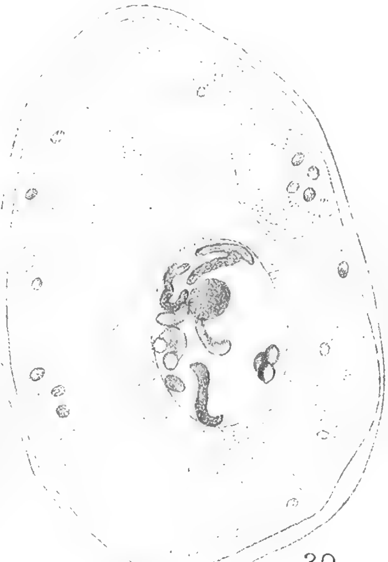
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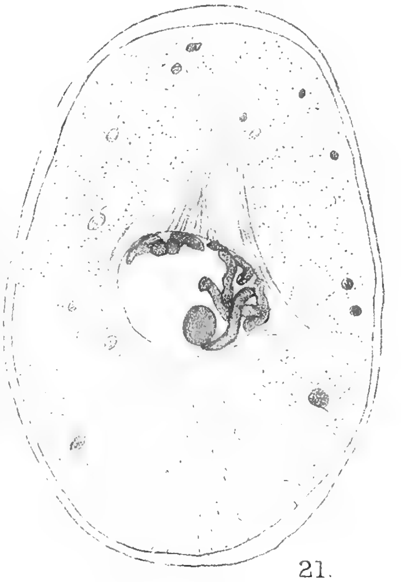
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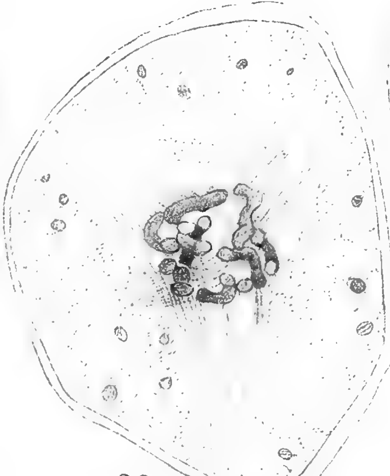
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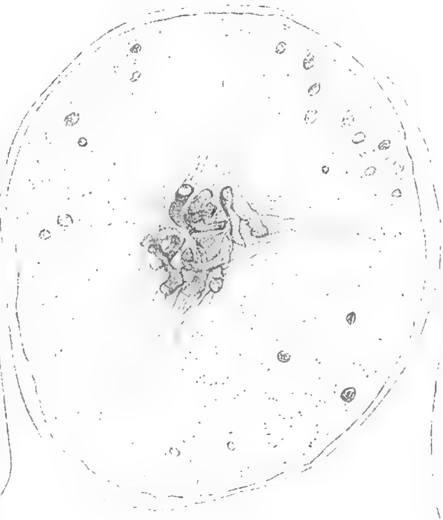
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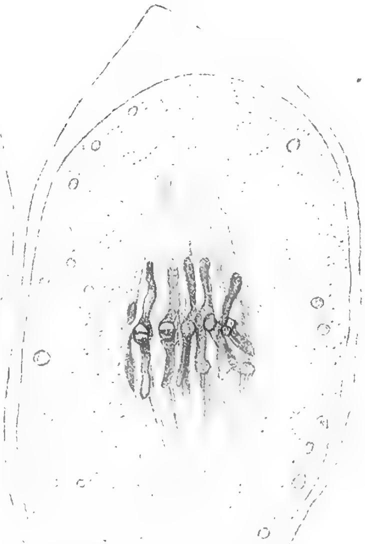
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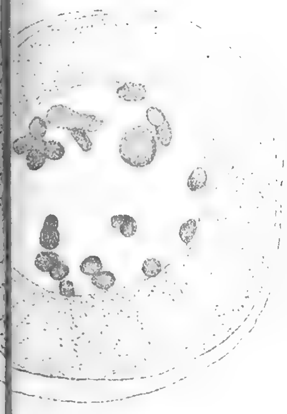
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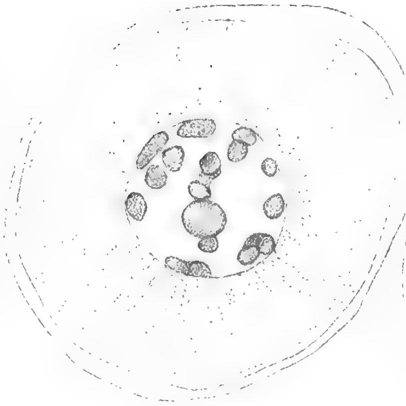
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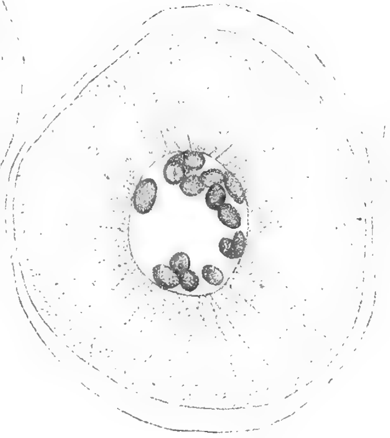
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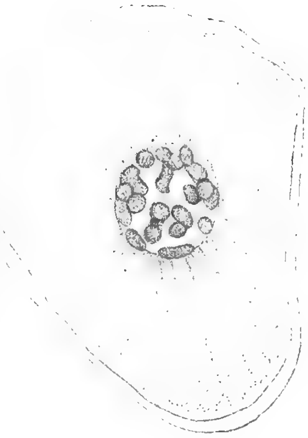
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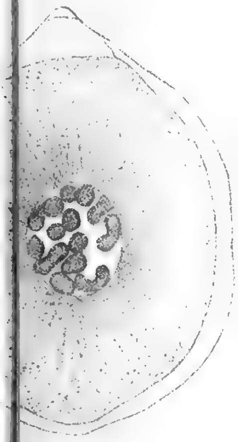
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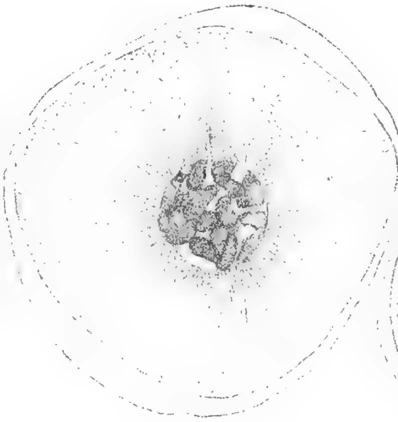
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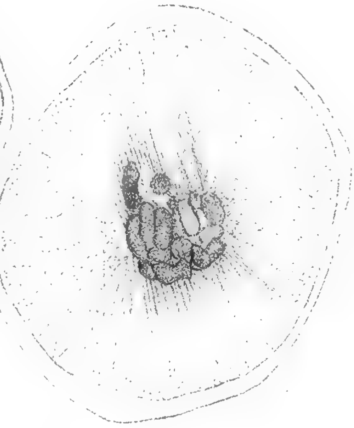
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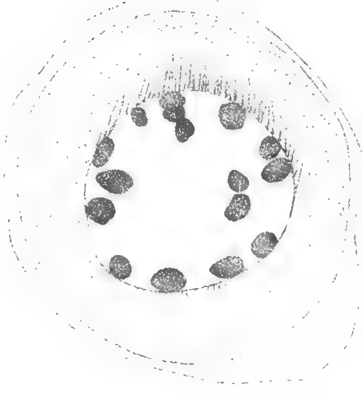
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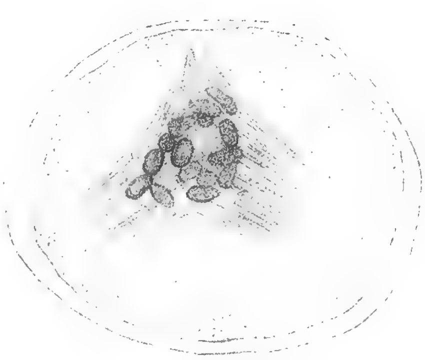
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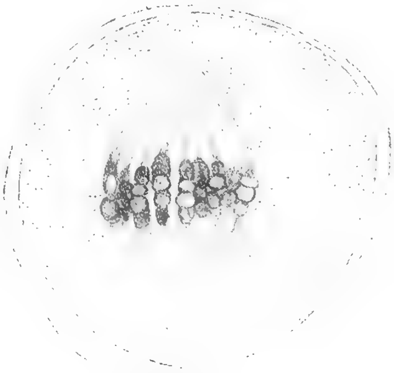
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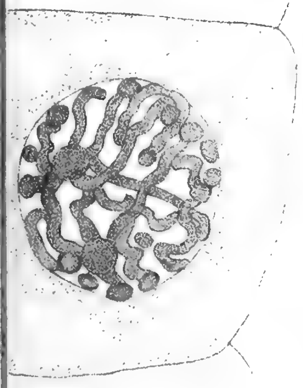

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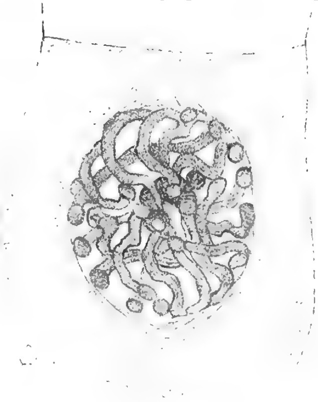

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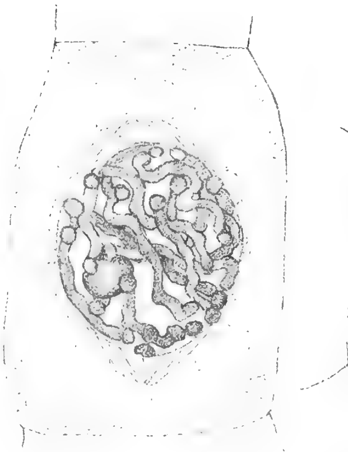

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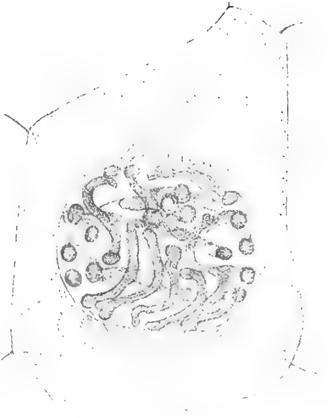

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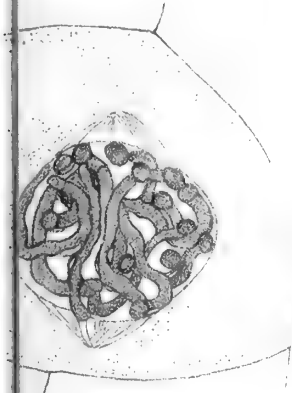

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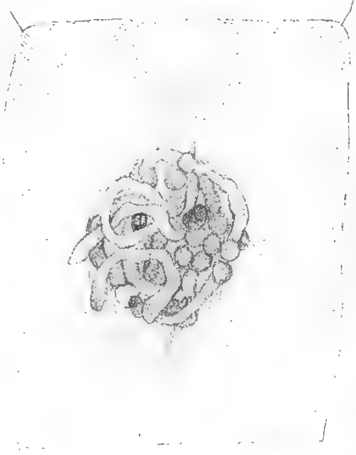

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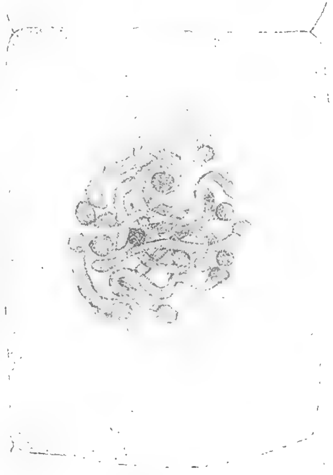

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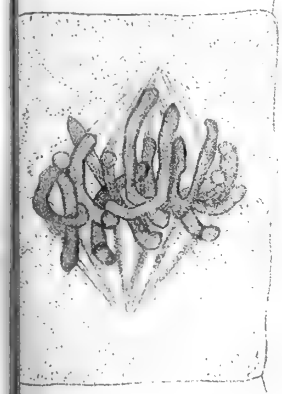

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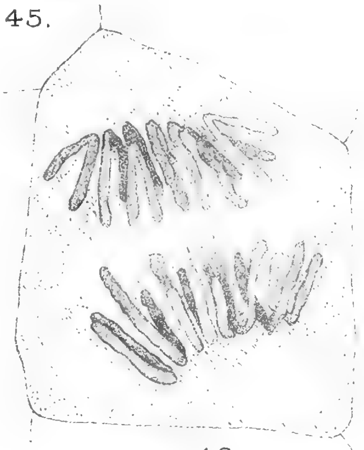

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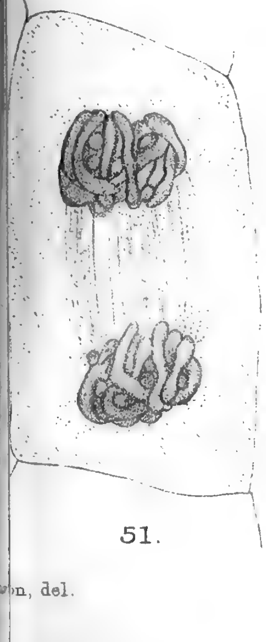

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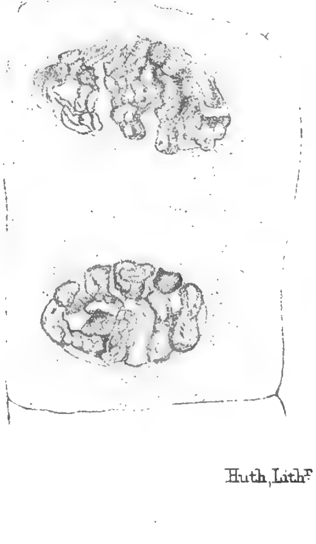

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VIII.—On the Structure and Affinities of Metaclepsydropsis duplex (Williamson). By W. T. Gordon, M.A., B.A., D.Sc., Falconer Fellow of Edinburgh University, Lecturer in Palæontology, Edinburgh University. *Communicated by* Professor JAMES GEIKIE, D.C.L., LL.D., etc. (With Four Plates.)

(Read July 3, 1911. MS. received July 28, 1911. Issued separately December 18, 1911.)

INTRODUCTION.

While collecting specimens of *Diplolabis römeri* (Solms) at Pettycur about three years ago, I discovered several blocks of stone containing numerous petrified fragments of another Zygopterid fern—*Metaclepsydropsis duplex* (Williamson). Two of the blocks were found to be parts of one large mass, and the petrifactions could be traced from the one block into the other. In size the complete mass must have been about 3 feet × 2 feet × 2 feet. The larger portion had to be broken into two before it was possible to remove it. Another block containing similar specimens was obtained later, but the preservation was so poor that the whole of the material was discarded.

The Pettycur plants are usually preserved by an infiltration of calcareous material, chiefly carbonate of lime, but in these blocks the petrifying material was siliceous. This silica was present in two forms—chalcedony and crystalline quartz. (As a result, hollow stems had the appearance of agates, generally with a crystalline centre.) The exterior had been more or less weathered, and the specimens stood out on the surface, their tissues being perfectly visible, and giving a lace-like appearance to the surface of the blocks.

As the occurrence of *Diplolabis römeri* was a new record from a British source, and as the specimens could be more easily examined (since thin sections are more readily prepared from calcareous than from siliceous material), I decided to finish my work on that genus before proceeding with a systematic investigation of the silicified specimens of *Metaclepsydropsis duplex*.

On looking over the specimens, however, about a year after they had been collected, I noticed, among the petioles, a fragment of what appeared to be a fern stem. Two sections were prepared from it, and the length was ascertained by cutting that part of the block into pieces $\frac{1}{2}$ to $\frac{3}{4}$ inch thick. The same stem was followed into another part of the block, and its extent in that direction also determined. The total length of this stem fragment was about 8 inches; it was hollow in the centre, and throughout its length no petioles or roots were emitted.

When this part of the block was cut up it was found to be so dark that no structure could be observed; in the hope that exposure to the atmosphere would soon weather the surfaces and so render the specimens visible, another part was sawn into pieces

3 inches thick and the slabs placed out-of-doors for about nine months. Silica, however, takes a considerable time to weather, and even after all these months there was no appreciable difference. On experimenting with hydrofluoric acid I found that in a few minutes the surfaces could be etched, and after this treatment the petrifactions were even more clearly seen than when they had been naturally weathered. The alteration also was a mere surface one, and the specimens were not destroyed. So clearly did the specimens appear that the surface could be examined with a fairly high power—a $\frac{1}{4}$-inch objective—and even the thickenings on the walls of the tracheides could be made out by reflected light. It was thus possible to examine roughly the contents of a piece of material without making any thin sections. In this way much time was saved, and suitable examples of stems, petioles, and roots detected at once.

As mentioned above, the Pettycur plants are usually preserved in calcareous material, and the thickenings on the cell walls are generally distinct. I have never, however, seen such perfect preservation as is exhibited in these silicified specimens. Locally in the blocks the petrifying substance had been replaced by iron pyrites, and the tissue could only be seen by reflected light, when it appeared like black tracery in the yellow matrix. On the whole the preservation is magnificent. As previously remarked, however, the whole matrix is very dark, and so the preparations require to be very thin before they become transparent. With care the sections can easily be reduced to about ·025 mm., the homogeneity of the material and its lack of cleavage rendering this easier than in the case where calcite is the petrifying medium. The test used to determine whether the sections were thin enough, was that employed in the preparation of rock sections, viz. silica (quartz) grey to clear between crossed nicols.

In a previous paper * it has been noted that the silica is present in two states, (*a*) chalcedony, and (*b*) quartz. The chalcedony appears to have been laid down first, and forms a layer round the wall of each element of the tissue. With this layer increasing in thickness the lumen is reduced in size. After the cell lumen is reduced to about one-quarter of its original size, the whole is filled in by crystalline quartz. All the silica, whether chalcedony or quartz, is almost perfectly transparent, and the strong contrast between the glassy interior of the cell and its dark walls has rendered the preparation of photo-micrographs much easier and more effective than in cases where calcite forms the matrix. In this latter case the cleavages sometimes interfere with the delicate cell structure, and so good photographs can hardly be obtained.

In May of last year a more systematic study of the specimens contained in the fragments of the large block was begun. Several additional examples of the stem were obtained, and their occurrence among so many petioles might have been cited as a proof that stems and petioles belonged to one and the same plant. Such evidence, however, is of very little value and cannot be relied upon. This is especially the case when other genera occur in the same block. As a general rule the Pettycur blocks contain a great number of different genera; indeed, practically the whole flora may be represented by

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* GORDON, *Trans. Geol. Soc. Edin.*, vol. ix., 1909.

the specimens in one block. In the siliceous masses, on the other hand, there are singularly few genera, and at first sight this lends weight to the evidence of association. There was, however, another member of the Zygopterideæ present—*Stauropteris burntislandica*, P. Bertrand,—and therefore the evidence of mere association must be discarded. The other genera present in the block were *Botryopteris antiqua*, Kidston; *Lepidophloios Scottii*, Gordon; *Lepidostrobus cylindricus*, Gordon in MS.; *Lepidocarpon Wildianum*, Scott; *Bensonites fusiformis*, R. Scott; and *Stigmaria ficoides*, Brongn.

In the meantime Miss BENSON, D.Sc., F.L.S., had discovered a similar stem, also associated with numerous petioles of *Metaclepsydropsis duplex*, in one of the calcareous blocks from Pettycur. In her subsequent investigation Miss BENSON obtained "a considerable amount of the stem (22 inches) without securing any well-preserved nodes."* A petiole-trace was closely associated with this stem towards one end, but, unfortunately, the stem emerged on the surface of the block just as the petiole-trace became fused with it. The specimen, which Miss BENSON very kindly placed at my disposal and which is a co-type with my own specimens, illustrates clearly the great length of the internodes in this species, and proves the distance between two nodes, in some cases, to be at least 22 inches.

Fragments of petioles of *Metaclepsydropsis duplex* were exceedingly numerous in the silicified blocks, but they were usually of no great length. Some were about 8 inches long, but many did not exceed 3 inches, while others were under 1 inch in length. Most of these petioles were crushed, but often there were short lengths which showed no crushing. There were so many specimens that, by choosing the uncrushed portions only, a complete picture of the anatomy of the genus could be obtained. One remarkable feature about the specimens is that very few would be classed as *normal* petioles of *M. duplex*, and yet they would never be referred to any other genus, as will be seen later.

By October 1910 sufficient positive evidence had been obtained to refer the stems found in the block to *M. duplex*. The more perfect specimens figured here were not discovered, however, until January 1911. Since then the early stages of petiolar development have been ascertained. The preparations examined number about 220. Most of these were prepared by myself, in order that nothing important might be lost during the process of preparation. As a rule the slides number 12 to 14 per inch of material, and they are generally in fairly long series. The series showing the branching of the stem and the departure of the petiole-trace was obtained from a piece of stem 3 inches long. From this piece 39 sections (including two longitudinal sections each ¼ inch long) were prepared; the sections were cut very close together, and run about 16 to the inch.

Apart from the silicified specimens, I have made several series of sections from calcified examples as they happened to illustrate points not shown in the case of the

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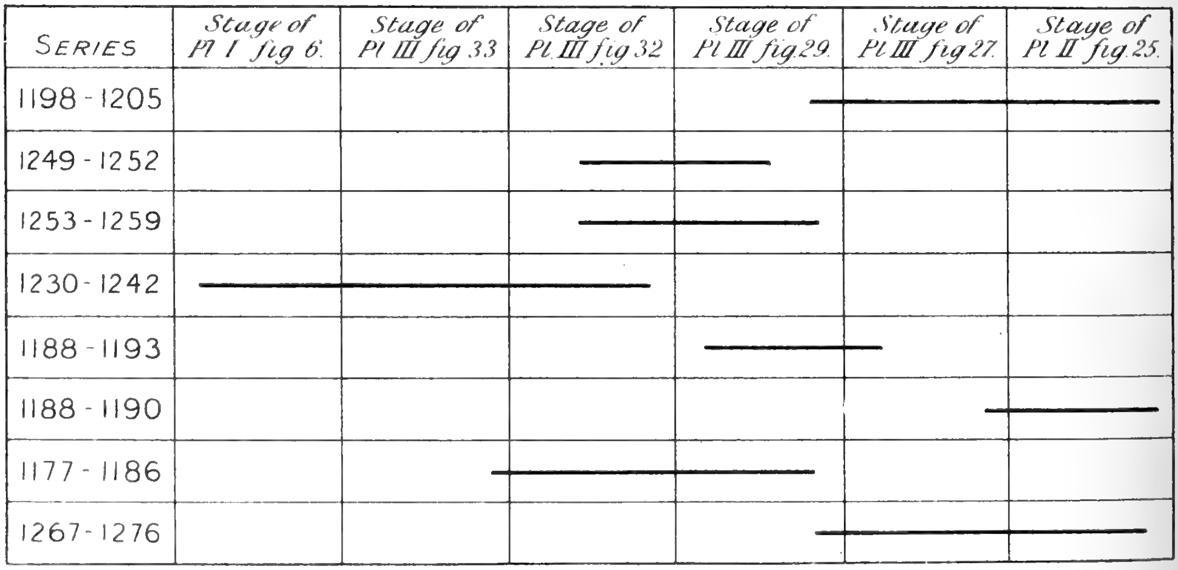
* Letter, 17th May 1911.

siliceous petrifactions. For the sake of completeness, also, it is proposed to redescribe the species, particularly as previous accounts have been based on a few isolated sections from several distinct individual specimens, and thus several points have not been recorded. All previous work on this genus has been based on petioles whose xylem strand had an hour-glass shape, but I hope to show that this trace has been developed from a simpler type.

Metaclepsydropsis duplex was first recorded by WILLIAMSON in 1874 under the name *Rachiopteris duplex.*[*] His specimens had the hourglass-shaped xylem strand so characteristic of the mature petiole. From 1874 until P. BERTRAND'S description in 1909 no further work was done on this genus, although it was constantly referred to. KIDSTON and GWYNNE-VAUGHAN, in Part IV. of their memoir on the fossil Osmundaceæ,[†] refer to *Metaclepsydropsis*, but have discussed its affinities rather than its anatomy. Apart from KIDSTON, no observer seems to have had more than a few isolated sections to deal with. Some years ago, however, Dr KIDSTON had a particularly fine series prepared, and these he has kindly placed at my disposal. In addition to showing the anatomy so far as it is known, they exhibit the remains of aphlebiæ and the passage of the aphlebia-traces out to these organs (text-fig. 2). The unique opportunity I have had of studying numerous petioles of all sizes has resulted in the elucidation of the petiolar development. The material on which I have been working is practically a felted mass of petrified stems, roots, petioles, pinnæ, and pinnules of the species. All of them are fragmentary, but, by cutting series of sections from various individuals, a more or less continuous chain of development has been established. The extent of the overlapping in these series is shown in the following table :—



TEXT-FIG. 1.—Diagram illustrating the extent to which the various series of sections overlap. These series consist of sections which only show early stages of the petiole-trace.

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[*] *Phil. Trans. Roy. Soc.*, vol. clxiv., 1874.

[†] *Trans. Roy. Soc. Edin.*, vol. xlvii., 1910.

General Structure.

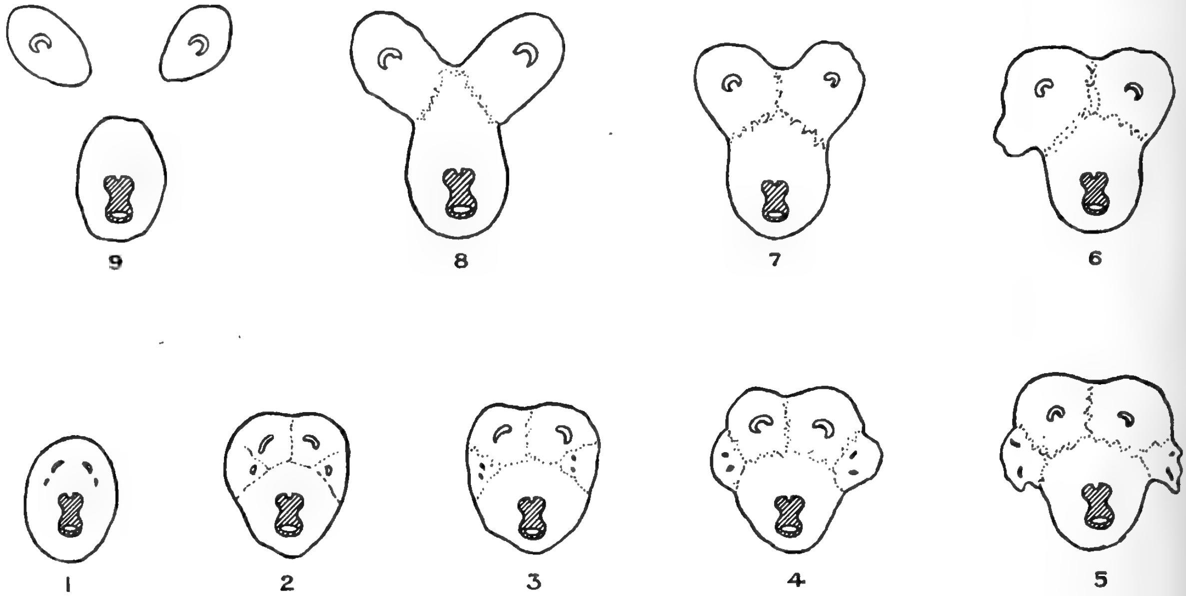
In order to obtain a general idea of the organisation of this fern—*Metaclepsydropsis duplex*—it will be most convenient to follow its tissues from above downwards. By proceeding in this way we shall find that we pass from what is already known to what is unknown. In the first place we shall concentrate our attention on the xylem tissue, partly because it is better preserved and more continuous than any other, but chiefly because it changes very considerably as we descend.

In the smallest divisions of the pinnæ with which we are acquainted—namely, tertiary pinnæ—the trace is curved in form, with tapering, incurved ends. In the sinus, formed between the hooked ends and the body of the trace, the protoxylem elements may be found. These bundles then are C-shaped or horseshoe-shaped, and they are emitted, alternately on each side, from the ends of a similarly shaped secondary pinna-trace. At the point of emission of the tertiary pinna-trace the combined trace of tertiary and secondary pinna has four protoxylem groups. Lower down the two inner groups die out, and the resulting trace is again C-shaped, with hooked ends, and two protoxylem groups in the sinuses formed by these hooks.

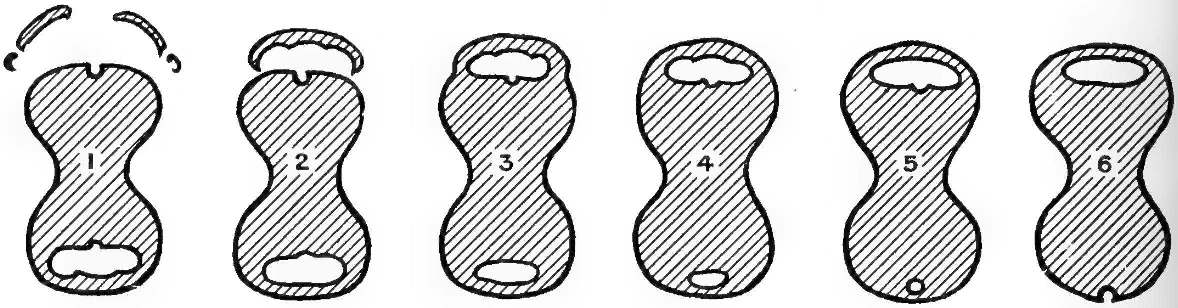
The smallest traces known are distinctly curved, and have parenchyma in the concavities. In one or two examples, however, the secondary pinna-trace is not open, although it gives off open tertiary traces. In this case the emission of the small strand strongly resembles the departure of the secondary pinna-trace from the primary one in the genus *Clepsydropsis*. Pl. IV. fig. 42 is a good example of this emission.

The occurrence of a similar "closed" bundle has also been noted in several primary pinnæ (Pl. IV. fig. 43). This probably only takes place some way along the pinna, because, as such primary pinnæ are followed downwards into the petiole, each pinna-trace becomes like a much flattened C with hooked ends. No primary pinna-trace has been observed which was "closed" while still passing through the cortex of the petiole. Apart from these few exceptional examples, the pinna-traces of one order join those of a lower order alternately on opposite sides as described above.

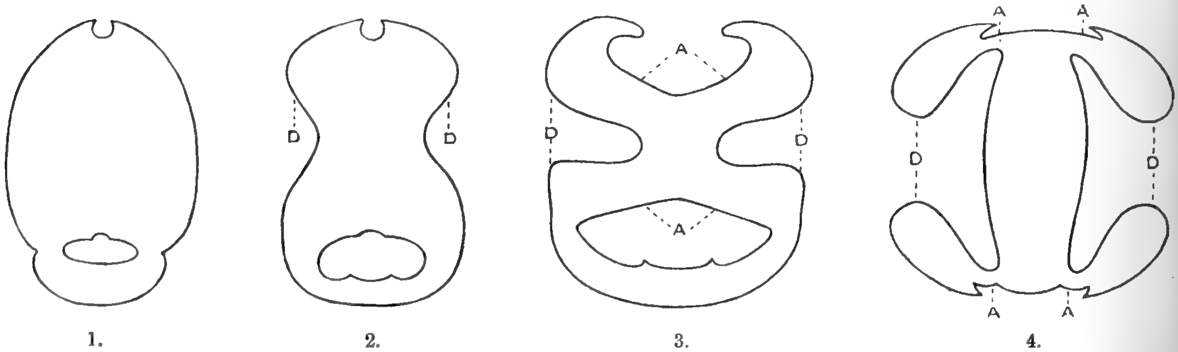
When we come to the primary pinnæ, however, a change takes place. They do not enter the petiole separately but in pairs (Pl. IV. fig. 40, *pin. tr.*), and these pinna-pairs enter alternately on each side of the petiole. Two primary pinna-traces, then, enter the cortex of the petiole at the same level and pass downwards to join the petiole trace. (Before joining the petiole-trace, however, each pair of pinna-traces unite to form one xylem arc, as will be explained later (Pl. II. fig. 19, *b*).) They are placed symmetrically one on each side of the principal plane of the petiole, and are thus "mirror images" in this plane of symmetry. A short distance below the point where the two primary pinna-traces enter the cortex of the petiole, two pairs of very small traces may be seen to pass into the petiole. These are the aphlebia-traces. These also are "mirror images" of one another in the principal plane of the petiole. They are situated outside the pinna-traces. A transverse section through a petiole at this level shows seven



TEXT-FIG. 2.—*Metaclepsydropsis duplex.* Series of transverse sections of petiole showing pinna departure and position of aphlebiæ. Natural size. After sections 1310–1318, Kidston Collection.



TEXT-FIG. 3.—Formation and gradual reduction of islands of parenchyma in the petiole-trace. The series illustrates: (*a*) the formation of the island on the upper ends of the trace, and (*b*) the formation of the groove on the lower ends. The groove is seen dying out on the inner side of the island at the top of the traces. Complete series shown by figures in following order: 1, 2, 3, 4, 5, 6 (upper ends), 3, 4, 5, 6 (lower ends), 1, 2, 3, 4, 5, 6 (upper ends, inner side of island).



TEXT-FIG. 4.—Diagram to illustrate distinction between "arms" and mere dilatations of the arms or of the ends of the trace. (1) *Dineuron ellipticum*, × 45. (2) *Metaclepsydropsis duplex*, × 12. (3) *Diplolabis römeri*, × 7. (4) *Etapteris Scotti*, × 14. A = arm; D = dilatation. Slightly diagrammatic drawings from actual specimens. Magnification indicated after name.

traces—the petiole-trace, two primary pinna-traces, and two pairs of aphlebia-traces (text-fig. 2, No. 3, 4, and 5, and Pl. IV. fig. 40).

Lower down in the petiole the four aphlebia-traces unite to form two, or, if we momentarily change our point of view and follow the aphlebia-traces upwards, the single strands each bifurcate (Pl. IV. fig. 40, *aph. tr.*). In Pl. IV. fig. 39 a section at a still lower level is shown. The aphlebia-traces have almost joined on to the outer ends of the pinna-traces. In Pl. III. fig. 38 the junction is complete, but the four protoxylem groups on each combined-trace indicate that there has been a fusion of two distinct strands. The two inner protoxylem groups die out downwards, and at the level of Pl. III. fig. 37 each combined-trace has two protoxylem groups, one at each end.

Proceeding still lower, the two combined-traces unite to form the pinna-trace-bar, on which there are four protoxylem groups. A short distance below this the bar joins on to the hourglass-shaped xylem of the petiole. In Pl. II. figs. 19 and 18 the bar (*b*) is shown immediately before and immediately after its union with the petiole strand. (These figures are not, however, from the same specimen.) An island of parenchyma thus appears at the end of the petiole-trace (Pl. II. fig. 18, *is*), and round the periphery of the island there are six protoxylem groups (Pl. II. fig. 21). Four of these belong to the pinna-trace-bar and two to the petiole-trace. These latter lie on the sides of a small bay situated at the end of the hourglass-shaped petiole strand (Pl. II. fig. 21, prx^c_1, prx^c_2). Still continuing downwards, the island gradually becomes smaller and the protoxylem groups of the pinna-trace-bar unite in pairs to form two groups (Pl. II. fig. 20, prx_1, prx_2). The small bay with its two protoxylem groups also gradually disappears, and the island assumes an elliptical form with a protoxylem group at each apex (Pl. II. fig. 21, prx^b_1, prx^b_2).

As we descend still further, the island becomes circular; then it opens to the exterior again, and an open bay with two protoxylem groups results (Pl. II. figs. 17, 18, 19, 22, 23, and 24, *g*). This bay is vertically below the one which was mentioned above, and so the mistake has arisen that there was a permanent groove running down the petiole-trace on each side. As has been shown above, the groove ultimately dies out and is re-formed lower down; indeed, it is the last vestige of the wedge of parenchymatous tissue shut in between the entering pinna-trace-bar and the petiole-trace. The disappearance of the groove and a diagrammatic representation of the reduction of the island are represented in text-fig. 3.

So far we have seen that two primary pinna-traces and their "spreads"* of pinnæ of a higher order have joined the petiole-trace and gradually disappeared into it. A similar sequence is shown at the opposite end of the petiole-trace, but the two ends are never in the same phase of pinna-trace emission. Thus four orthostichies of pinna "spreads" are borne by each petiole. Up to this point every stage has been ascertained by reference to numerous series.

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* A pinna spread is the whole assemblage of secondary pinnæ borne by a primary pinna and spread out into one plane.

In following out the changes in the petiole-trace much greater difficulty has been met with, and the stages figured are not from long series. This was due to the fact that the material consisted of short lengths of petioles, no specimen exceeding 6 inches. In that distance the changes were very slight, so that long—very long—series would probably be necessary to show the gradual change from one of the stages figured, to the next. In spite of this discontinuity, the position I take up will be readily accepted, for there is sufficient evidence to prove the general problem, namely, that there is a gradual disappearance of the "waist"* or constriction in the middle of the hourglass-shaped petiole-trace, and that this reduction takes place as we descend in the petiole. The last part of the problem is much more difficult to prove than the first, but, concurrently with the disappearance of the "waist" of the petiole-trace, there is a marked reduction in the size of the whole trace and in the pinna-traces which join it. We know that the petiole-trace in other ferns gradually becomes smaller as we descend towards the stem, and that there are reduced pinna-traces towards the base of the petiole. This is what one would naturally expect. It is not surprising, therefore, to find a similar condition in *Metaclepsydropsis.* But apart from the xylem tissue, we find that the outer cortex loses its sclerotic outer layer as we follow this series. Now, from a study of the stem cortex, which has no sclerotic elements, we should naturally expect that the free petiole near its base would have no sclerenchyma in the outer cortex. From this evidence also we must conclude that the series, as figured, shows the various stages in a descending order. In other words, the proof of the problem lies in the following observations:—The size and shape of the petiole-trace, the development of the pinna-trace-bar and pinna-traces, and the sclerotic outer cortex are all gradually reduced as we proceed through the figures shown from Pl. II. fig. 17 to Pl. III. fig. 34.

It might be said that this was not conclusive, since all the figures do not represent different levels in one and the same specimen, and that there are perhaps several different species mixed up in the series. Such an objection can easily be met, for each stage figured is intermediate between its two neighbouring figures; there is no sudden jump at any point from one type of trace to a totally different one. In fact, there is a continuous variation in one direction, and this is the only variation that is shown by the specimens.

Pl. II. fig. 17 represents a petiole-trace perfectly typical of the species *Metaclepsydropsis duplex*; the waist is very pronounced, and the pinna-trace-bar is also well marked. The specimen shown in fig. 18 is also perfectly typical though rather smaller, but, apart from a few details in the phase of the pinna-trace departure, the two figures represent specimens which are specifically identical. In fig. 19, however, the waist is much less marked than in figs. 17 and 18, while fig. 20 exhibits a trace with hardly any constriction in the middle. There is still a slightly sinuous appearance in fig. 21, but in figs. 22 and 23 this has entirely disappeared. Indeed, had the petiole whose trace is shown in the last-mentioned figure been discovered separately, there is no doubt

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* The word "waist" is used here as it gives the idea of a constriction in the middle of the trace.

that it would have been referred to another genus, namely, *Dineuron.* Fig. 24 represents another example where the trace is even more like *Dineuron* than that of fig. 23.

The next two figures (25 and 26) are cut rather obliquely, and the traces are perhaps not really quite so long as they appear, but the angle of section is very near 90°, so that any reduction in their size on account of the obliquity of section must be very slight. They are from different specimens, but represent stages which are practically identical and show the departure of a much reduced pinna-trace-bar (*b*). Fig. 26 is probably further up the petiole than fig. 25, and the bar (*b*) shows clearly that it will divide into two portions. A somewhat similar example, cut from the same specimen as fig. 26, is shown in Pl. III. fig. 27, though here the trace is rendered shorter than it really should be by a slight crushing. In Pl. III. fig. 28 the trace is still further reduced, but it is clearly identical with that of fig. 27, while that shown in fig. 29 is also similar.

Pl. III. figs. 30 and 31 represent examples quite comparable with that shown in fig. 29.

The next three figures represent sections taken from the same specimen, and the petiole joins the stem two sections below that shown in fig. 34. Fig. 32 is similar to fig. 31, except that both ends of the trace are closed instead of only one end, as in the former figure in which the left-hand end exhibits an island of parenchyma in the xylem, while the right hand end has a bay. Fig. 33 shows clearly the two almost circular islands, one at each end of the trace, and also the stem (*st*) which the petiole joins at a lower level. Near the junction with the stem the islands disappear and only the small protoxylem elements remain. These protoxylem groups occur in pairs at each end in fig. 33, but in fig. 34, where unfortunately the lower part of the trace is crushed, there only appears to be one group. Two sections lower down in this series the petiole-trace joined the stem (figs. 33 and 34, *st*). The petiole-trace of *M. duplex* has thus been followed through all its stages into a stem which, while presenting certain peculiarities, is very simple in structure.

A typical transverse section of this stem is shown in Pl. I. fig. 1 or Pl. IV. fig. 45. Two regions may at once be distinguished, an outer of large tracheides which are seen to be reticulately thickened, when viewed in longitudinal section, and a central zone composed of a mixture of tracheides and parenchyma. The inner tracheides are long, pointed elements and have reticulate or scalariform thickenings on their walls, but they are smaller in diameter as a rule than those of the outer zone. The stem was long and dichotomously branched.

On the whole it had the appearance of a rhizome, and evidence in favour of this will be brought forward immediately.

Root-traces have been met with on one or two occasions, but only one example actually joined the stem xylem. One of these root-traces is shown in Pl. IV. fig. 44. It is large for a root-trace and is diarch.

So far merely the xylem tissue has been considered, but the cortex is also of some importance; for, while there is a sclerotic layer in the cortex of the mature petiole, there is none in that of the stem or of the lower parts of the petiole. The inner cortex has generally all decayed, but small patches sometimes appear in the islands formed between the pinna-trace-bar and the petiole-trace. It has always the appearance of a delicate parenchyma.

Numerous groups of sporangia, probably synangia, occur scattered through the blocks containing the petioles and stems of *M. duplex.* There are generally four sporangia in each group, but there is no evidence that these were borne by the pinnules of this plant

HISTOLOGY OF THE STEM.

The stem which has just been referred to *M. duplex* is of peculiar interest both on account of its simple structure and because it is of considerable phylogenetic importance. In transverse section it is circular in outline (Pl. I. fig. 1, and Pl. IV. fig. 45), and about 1·8 mm. in diameter. Two zones may easily be distinguished, the inner consisting of a mixture of parenchyma and tracheidal tissue, and the outer being made up entirely of tracheides. Pl. IV. fig. 45 probably gives the best idea of the distribution of the tracheides and parenchyma in transverse section. (Although a petiole-trace connected to the stem has been cut away at the bottom of the figure, it has not disturbed the more central tissues.) In other examples the tracheides are almost absent, and in Pl. IV. fig. 47 such a specimen is figured; only one tracheide (*t*) is present, and it is immersed in the centre of a thin-walled parenchyma (*p*). The general circular shape of the stem is distorted in this specimen, and a petiole-trace is shown connected with the stem. This trace apparently belonged to a petiole which had been torn away, leaving a ragged stump still connected to the stem, and the tissues of the trace are so crushed that one of the protoxylem groups is unrecognisable, and the whole trace very irregular in outline.

In most specimens, however, the parenchyma has been ruptured and only fragments of the delicate cell-walls remain. As a result the tissue is seen better in transverse than in longitudinal section. In one example (Pl. IV. fig. 46) a peculiar condition was discovered. There is no parenchyma present in the stem, and there is a distinct radial arrangement of the tracheides at *a*. This stem is very much smaller than any of the others, and I have only seen it in one preparation.

I am inclined to think that it is an unequal dichotomy of the stem, and it will be referred to later. In the meantime the absence of conjunctive parenchyma is worthy of notice.

The tracheides of this inner zone are generally small in diameter and vary considerably. The largest are only between 45μ and 50μ, while the small ones are 30μ and under. Those nearest the periphery are generally the largest, and they abut on the inner tracheides of the outer xylem zone, which are not much larger than the outer tracheides of the mixed pith. The thickenings on the walls of the inner elements are scalariform in the smallest but reticulate in the largest. In the same tracheide the transition between scalariform and reticulate thickening is often clearly seen (Pl. I. fig. 2). The largest of these elements have rarely more than three rows of pores on each wall.

The outer zone of the stem xylem is four to five cells deep and constitutes a ring of solid wood round the inner zone. The elements of this ring are much larger than those of the inner wood, but the tracheides towards the inner margin of the ring are smaller than the others as a rule. The average size is from 100μ to 130μ, but near the bifurcation, to be noted shortly, some of the elements are as much as 250μ in diameter. Some of these large tracheides may be seen in Pl. I. figs. 4, 5, and 6. At the departure of a petiole-trace larger elements also occur (Pl. I. fig. 8). Like those of the inner zone, the outer tracheides are long, pointed, and their walls reticulately thickened, but there are six to nine rows of pores on the walls. The pores on the walls of the elements of both zones are about the same size. Groups of small tracheides may occasionally be seen in the outer xylem zone, but these are the decurrent protoxylem elements of a petiole-trace and do not belong to the stem itself.

Outside the xylem there is generally a dark layer which in very thin section is seen to consist of cellular tissue. This tissue no doubt represents inner cortex and phloem, but it seems to have been composed of very delicate elements, which are too much crushed to warrant more than a passing notice. The outer cortex, on the other hand, is generally well preserved. It consists of a thick-walled parenchyma, but there are no sclerotic layers present. This outer cortex is sometimes produced into ragged protuberances.

To the stem xylem, petiole- and root-traces are attached, but they only occur at considerable distances from each other. In the material examined only three or four of such emissions have been noted, and in but one case was a root-trace found joining the stem. In the case of each of these appendages, however, there is sufficient evidence to show that the departure is protostelic, *i.e.* the outer xylem ring is never broken, thus exposing the inner zone on the surface of the cylinder.

Branching of the Stem.

In several of the stems examined it was possible to cut long series of sections, but the changes were very slight, except in the neighbourhood of the emission of a petiole- or root-trace. In one specimen, however, just above the point of departure of a petiole-trace, I was fortunate enough to discover both a root-trace emission and a bifurcation of the stem, within a length of 1½ inches. In another case, just above a petiole-trace departure the very small solid stele of Pl. IV. fig. 46 was discovered, and this is possibly an unequal dichotomy of the stem.

Pl. I. fig. 3 represents the first stage of such a bifurcation (the small trace *rt. tr.* represents a root-trace which arches over at this point, and the top of the arch is here shown), and the inner zone of mixed pith is distinctly elongated, as is the whole stem xylem. Roughly speaking, the stem xylem is an ellipse. Higher up the stem the mixed pith divides into two large masses connected by a thin neck, or, in other words, becomes figure-of-eight-shaped, the outer xylem still remaining elliptical. As a result of this, the large elements previously noted are found towards the outside of the narrow neck connecting the two masses of the mixed pith (Pl. I. figs. 4 and 5). The pith then divides into two separate masses and the outer xylem becomes figure-of-eight-shaped, with large xylem elements in the constriction of the eight (Pl. I. fig. 6); and finally the two parts separate. The division is into two equal parts, *i.e.* it is an equal dichotomy. During the division there is no appearance of a branch gap, *i.e.* the departure of the branch is protostelic. Thus all emissions from the stem, whether of petiole, root, or branch-trace, have proved to be protostelic. The small solid branch—if it be a branch—is of interest because it is quite similar to a case noted in *Diplolabis römeri* (Solms), where the inner wood almost entirely disappeared at a bifurcation of the stem.* Such a reduced branch also might be expected to show primitive characteristics and to give some indication of the race from which the plant had sprung. The evidence from this specimen points to an ancestor with a solid stele, and this is in harmony with the evidence from a study of the petiole.

Histology of the Petiole.

It is generally admitted that, at the junction of the petiole with the stem, ancestral characters may be expected, so it is very important that the changes in the petiole-trace near the base should be carefully noted. In making a minute examination of the xylem tissue in this region, it will be found more convenient to work up the petiole, and not down as in the general description.

The first figure to be noted is Pl. II. fig. 16, which represents a transverse section of the stem in a rather flattened condition. At *a* a short arm of parenchymatous tissue may be seen stretching from the central mixed pith into the outer xylem. Near the end of this radial arm are some rather small elements which constitute one of the protoxylem groups of a petiole-trace. The other protoxylem group is not differentiated until later, so that, at this early stage, the difference in phase of the two ends of the petiole-trace is quite marked. In the next section of the series (Pl. II. fig. 15) the arm *a* is much longer, and the protoxylem group (prx^1) is at the end of the arm furthest from the inner zone of mixed tracheides and parenchyma. There is still no sign of the second protoxylem group. Fig. 14, which follows, shows one group of protoxylem elements isolated in the outer xylem zone, the arm of parenchyma and its accompanying small tracheides having disappeared. On the inner margin of the outer wood, a short distance round from where the first medullary arm appeared, a second small sinus containing protoxylem may be seen at *a′*. The next section, represented by fig. 13, shows the first protoxylem group (prx^1) well out in the outer zone and the second group (prx^2) quite distinct.

In Pl. I. fig. 12 both groups are clearly seen, and in the next two sections (figs. 11

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* Gordon, "On *Diplolabis römeri* (Solms)," *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 720, 1911.

and 10) little change can be noticed. One group has come to lie close to the margin of the stem xylem, while the other is at the outer extremity of the arm of parenchyma and small tracheides. When the level of fig. 9 is reached, however, the second arm has disappeared, and at that end of the stem xylem there are two sunk protoxylem groups. At the same time the whole end of the stem has a distinct bulge on it. One section higher up (fig. 8) the bulge on the stem is still more pronounced; indeed, the petiole-trace has now become a distinct body connected to the stem at J by a number of very large tracheides. The protoxylem groups are placed at opposite foci of the elliptical trace.

In the section above that shown in fig. 8 the trace has separated from the stem as an elliptical mass (fig. 7). This trace was followed outwards for three sections, but no change was noted, and above that level it had disappeared. The subsequent changes in the petiole-trace will be followed in another series which starts with a much-crushed section just about the level shown in Pl. I. fig. 8. Below this level both stem and petiole have rotted away. The first section of this new series which is figured, is shown in Pl. III. fig. 34. Here the much-distorted petiole-trace is closely adpressed to the stem xylem, and only one protoxylem group can be seen. This group is quite similar in position and shape to either of those in Pl. I. fig. 7. A few sections higher up, however, each protoxylem group has divided into two (Pl. III. fig. 33, *prx*), and an island of parenchyma is developed at each end, separating the two parts into which each protoxylem group has divided (fig. 33, *is*). Fig. 32 represents the highest section in this same series, and at the top of the trace there is a mere filament of xylem tissue on the outer margin of the island of parenchyma. A closely similar specimen is represented by Pl. III. fig. 31, where one end of the trace is open while the filament is just leaving the other end. There has been some slight lateral crushing in this specimen, as is indicated by the flattened cortex, but it has not affected the trace very much.

In Pl. III. fig. 29, however, a similar trace is shown, but in this case there appears to have been no distortion. The left-hand end of the trace is open, and shows the bay *g* with the protoxylem elements at each side. The other end is closed and, there also, the two groups of protoxylem are clearly seen. So far no distinct pinna-trace-bar has been detached from the petiole-trace; though the filaments no doubt represent very reduced examples of such departures. The trace shown in Pl. III. fig. 28, while practically identical in form with that of fig. 29, is slightly larger, and on the left-hand end the filament of xylem of fig. 29 is represented by a stouter bar. Unfortunately these petioles were only short fragments, generally less than half an inch long, so that the pinna-trace-bars could not be followed very far. In one example, however, from which about twenty sections were prepared, two of these bars were followed a short distance, but they never, as far as could be seen, passed out into distinct pinnæ. Though these figures are taken from different specimens, it will be noticed that as the trace increases in size the pinna-trace-bar becomes more and more robust.

Pl. III. fig. 27 represents a cross-section of another of these petiole fragments which is exactly similar to that of fig. 28. The one end is open and the other closed by a pinna-trace-bar in exactly the same condition as in the latter figure. At a higher level in the specimen the pinna-trace-bar became detached from the petiole-trace and showed some signs of dividing into two (Pl. II. fig. 26, *b*). A twisting of the whole petiole-trace at this level gives a much longer appearance than is shown in Pl. III. fig. 27. In the next figure (fig. 25) an exactly similar section is represented. The plane of section in this case is horizontal, except at the left-hand side. In this specimen there is also a reduced pinna-trace-bar given off from the petiole-trace, and, as in the case of fig. 26, the bar shows signs of dividing in the middle to form two traces.

Passing to the trace represented in Pl. II. fig. 24, the first thing to be noticed is that it has suffered no distortion and that it is essentially similar to that of fig. 25. In general form it greatly resembles Pl. III. fig. 29, but it is larger and the pinna-trace-bar *b* at the top of the figure is much better developed than in the former specimen. The petiole from which the section was prepared is about 6 inches long, and a little above the level of this section two pinna-traces were noted. They were fairly well developed, but did not penetrate the cortex to enter into distinct pinnæ. The outer cortex (*o.c.*) in the figure is also worthy of notice, since it contains no sclerotic layer.

A very similar example is shown in Pl. II. fig. 23. The trace is not quite so long as the last, but it is much stouter, and the bar *b* is rather better developed. Yet this bar also never gives rise to traces which enter into distinct pinnæ. In fig. 23 it is practically divided into two, but both parts die out higher up. The outer cortex in this specimen had a distinct sclerotic band towards the periphery. Up to this point all the traces examined would have been referred to *Dineuron* had they occurred separately, and indeed would still be referred to that genus unless the next three stages had been discovered. The first of these transition forms is shown in Pl. II. fig. 22. It is essentially like that of fig. 23, but a flattening is making its appearance in both sides and the pinna-trace-bar is rather well developed. A similar flattening may be noted in Pl. II. fig. 26, but this is largely due to the obliquity of the plane of section, which causes an apparent elongation of the trace. Pl. II. fig. 21 exhibits another of these transition stages. Here the trace gives some indication of a waist. The pinna-trace-bar, also, is much more robust than in the last figure. This trace is exactly intermediate, both in size and shape, between the *Dineuron*-like example of fig. 24 and the normal *Metaclepsydropsis* trace of figs. 17 and 18.

In the specimen shown in fig. 20 we have the last of the transition types. A distinct waist is shown in this example, and therefore the trace, in transverse section, has the appearance of an hour-glass. An early stage of pinna-trace departure is also demonstrated by the specimen, and the bar is quite robust and well developed. Probably even this specimen would only be referred to *Metaclepsydropsis duplex* with some misgivings. Fig. 19, however, supplies the last link in the chain, and, while the trace shown in it would at once be accepted as typical of *Metaclepsydropsis duplex*, there is one peculiarity, the broad waist, which links up the trace of fig. 20 with those of figs. 17 and 18.

While it would be absolutely impossible to pass from the trace of Pl. II. fig. 17 to that of Pl. I. fig. 7, or even that of Pl. II. fig. 24, yet when all the intermediate stages are shown it becomes not only possible but quite simple. The whole development may be summed up thus:—The demands made on the xylem of the petiole by more and more robust pinna-traces have caused the petiole-trace (1) to become larger, and (2) to increase the size of the ends so as to accommodate the much stouter pinna-trace-bar. A closely similar conclusion was arrived at in the case of the petiole-trace in *Diplolabis römeri*, but instead of the ends of the trace becoming inflated they were drawn out into two long arms at each end.

In Pl. III. fig. 36 an interesting example is shown. The specimen was very short, but it happened to include the portion of the petiole to which the primary pinnæ are attached. These pinnæ were seen to be quite normal though small. This has led me to believe that the specimen must have been a portion near the top of a petiole. In that region we would naturally expect the trace to be smaller, and, if the hypothesis be correct that the hour-glass shape was impressed on the petiole-trace in order that it might accommodate more robust pinnæ, we would also expect that the petiole-trace near the apex would revert to its elliptical form, since the pinnæ diminish in size near the top of the frond. The trace in this example is exactly similar to that in Pl. II. fig. 21, except that it is smaller, and the latter figure represents a section well down towards the base of the petiole.

Turning now to examine the primary pinna-trace, we find that one of the earliest obvious stages in its development on the petiole-trace is seen in Pl. IV. fig 39, where, at *g*, a round island of parenchyma is seen. At each side of this island there are groups of small elements—the protoxylem. Such a stage, however, is not the earliest that may be seen, for the protoxylem groups may be observed before the island is formed, *i.e.* when there is a *groove* at the end of the petiole-trace and not an island (Pl. II. figs. 17, 18, 19, 22, 23, 24, prx^{a}_{1}, prx^{a}_{2}). (The island has, of course, been formed by the production of xylem elements at the horn-like extremities of the sides of the groove. When the xylem outgrowths from the two sides meet in the centre the groove becomes an island of parenchyma.) The protoxylem groups may be distinguished at a still lower level, where the groove has become very shallow; indeed, the groove is a mere depression between the two protoxylems (Pl. II. fig. 21, prx^{c}_{1}, prx^{c}_{2}, and fig. 17, prx^{b}_{1}, prx^{b}_{2}). Pl. II. fig. 18 is probably just below the level at which the last vestiges of these protoxylem groups are visible, although the bay or groove which results from the island opening to the outside is still seen to persist at C.

A stage beyond that of fig. 39 is shown in Pl. II. fig. 21, at the lower end of the trace. The island of parenchyma which was circular in the former figure is elliptical in the latter, and has still two protoxylem groups, one at each end of the major axis of the ellipse. At a still higher level (Pl. IV. fig. 39, *lower end of trace*) the island is much larger, and the protoxylem groups of the pinna-traces, vertically above the pair represented by the pinna-trace-bar we are considering, are quite distinct on the inner margin of the island. A somewhat similar example may be seen at the top of the trace in Pl. II. fig. 20. There are at this stage four protoxylem groups arranged round the island. The groups at the ends of the island then spread out on the outer margin and afterwards divide into two. The stage just before the division is shown in the last-mentioned figure.

Passing to the top of the trace in Pl. II. fig. 22, it will be noticed that the pinna-trace-bar has four protoxylem groups peculiar to itself. These have been derived as indicated above from the two original groups. There are thus six groups round the island, which has now attained a larger size. Two closely similar examples are figured in Pl. II. fig. 21 and fig. 18, at the top of the trace in each case. In figs. 17 and 19 the bar has become detached from the petiole-trace and gives some indication that it will divide into two equal parts. Pl. III. fig. 37 represents a still later stage where the division is complete and two curved xylem strands are produced. In the next section, other protoxylem groups make their appearance on the inside of each of the curved xylem strands, but they are near the lower ends of these strands and not in the centre. Two sections above this last one these extra protoxylems are distinct, and the arc of xylem is converted into a double arc (Pl. III. fig. 38, *pin. tr.*, *aph. tr.*). In Pl. IV. fig. 39—about three sections above fig. 38—the small traces are cut off from the larger median bundles. The small bundles pass out to supply aphlebiæ, and during their passage outwards they each bifurcate. The two branches of each bifurcation pass out at the same level (Pl. IV. fig. 40, *aph.* $tr._a^1$, *aph.* $tr._a^2$), and not, as in *Diplolabis römeri*, at different levels.

The larger median bundles—destined to supply pinnæ—become more curved (Pl. IV. fig. 41), and finally pass out at the same level into the pinnæ, of which there are two for each pinna-trace-bar. In some cases, however, the incurved ends unite, and the arc then becomes a closed ring of xylem (Pl. IV. fig. 43). Such a closed trace is very interesting and probably indicates an ancestral character. Very few of such annular traces have been discovered, and unfortunately they could not be followed far enough to see if they ultimately resumed the open form, though they probably do resume the horseshoe shape higher up. In one secondary pinna-trace a similar character was noted, and here the emission of the tertiary pinna-trace is exactly comparable with the emission of the secondary pinna-trace from the primary in *Clepsydropsis antiqua*, as shown by Dr P. Bertrand.*

Apart from these abnormal cases the pinna-trace is open and consists of reticulately thickened tracheides with scalariform protoxylem elements in the sinuses formed by the incurved ends. The pinnæ of one order are cut off from the ends of the trace of lower order, and pass out alternately at each side.

The foliage and fructifications of this species are quite unknown, though several

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* P. Bertrand, *Études sur la fronde des Zygoptéridées*, 1909.

groups of sporangia occur in the same sections as contain the petioles and pinnæ of the plant. In the absence of evidence of continuity, however, it would not be safe to connect the two.

Histology of the Root.

The root-trace is very similar to that of *Diplolabis römeri* (Solms); it is barrel-shaped and consists of reticulately thickened tracheides. There are two protoxylem groups of scalariform elements situated one at each end of the barrel-shaped trace. In one specimen a rootlet seems to be given off from the main trace, but it is very much crushed, and one cannot determine whether the smaller rootlets were similar to the large ones. Another specimen curved upwards at first, but ultimately turned and grew in the opposite direction to that in which a petiole-trace was emitted. Very few root-traces were discovered, and of these only the xylem was preserved.

Comparison with other Species.

In their memoir on the fossil Osmundaceæ, Kidston and Gwynne-Vaughan have divided the Zygopterideæ into three great groups, and, although few stems belonging to this family are known, at least one of the recorded specimens belongs to each group. *Ankyropteris corrugata* (Williamson), *A. Brongniarti* (Renault), and probably *A. scandens* (Stenzel) belong to the first group; *Diplolabis römeri* (Solms) and *Metaclepsydropsis duplex* (Williamson) to the second; and *Etapteris di-upsilon* (*Zygopteris Grayi*) (Williamson) to the third. The stele of the stem in all of these species is either circular or roughly stellate in transverse section. When examined in detail, however, there are considerable differences between them.

In comparing the newly discovered stem of *Metaclepsydropsis duplex* with the others, we shall begin with the *simplest* known type (it is also the *oldest* known type), *Diplolabis römeri*. This latter species has been recorded from the same locality as *M. duplex*, viz. Pettycur, as well as from other localities in France and Germany where *M. duplex* does not occur. In it the stem xylem is circular in transverse section and consists of two kinds of tracheides, both of which have reticulate thickenings on their walls. The xylem elements are arranged in two zones, the inner of which contains only short, square-ended tracheides, while the elements of the outer zone are long and pointed. The inner tracheides are smaller in diameter than those of the outer zone, and they are arranged in vertical series as though they had been derived by the septation of long elements. There is no conjunctive parenchyma present in the stele. The stem branched dichotomously, and was probably a rhizome.

The departure of the petiole-trace from the stele is protostelic, and the trace is at first elliptical, with sunk protoxylem groups, one near each focus of the ellipse. In the subsequent development of the petiole-trace long arms are gradually produced, and the trace then becomes **H**- or **X**-shaped. Primary pinnæ depart from the petiole in pairs, one pair alternately on each side, so that four rows of primary pinnæ are produced on the one petiole. The root-traces also leave the stem xylem in a protostelic manner; they are diarch and barrel-shaped.

As we have seen, the stele of *M. duplex* is also circular in outline, and the xylem consists of two kinds of tracheide. Both kinds are long, pointed, and reticulately thickened, except the smallest in the inner zone, which have scalariform thickenings on their walls. There is conjunctive parenchyma present, however. The stem branched dichotomously and was a rhizome, as in the last-mentioned species.

The petiole-trace leaves the stem-stele in a protostelic manner as an elliptical mass with two sunk protoxylem groups, but its subsequent development is quite different from that of *Diplolabis römeri*. No arms are produced, but both ends of the trace become dilated. In *D. römeri* the island of parenchyma enclosed by the entering pinna-trace-bar is constant in size, whereas that in *M. duplex* gradually diminishes until it is exceedingly small, when it opens to the exterior, and a small groove is left in the petiole-trace instead of the wide **V**-shaped groove between the arms in *D. römeri.*

The primary pinnæ are borne in four orthostichies just as in *Diplolabis,* but occasionally the trace becomes closed as in *Clepsydropsis.* The roots of *M. duplex* are also quite similar to those of *D. römeri.* I have gone into considerable detail in this comparison, as these two species have many points of similarity and form two important links in a possible chain of evolution among the Zygopterideæ.

In comparing *M. duplex* with *Ankyropteris corrugata*, a great similarity in the shape of the stele must be noted. Both have two zones of tracheides, and there is conjunctive parenchyma in the inner zone in each. But while only a few of the elements in the inner zone in *M. duplex* are scalariform tracheides, all the elements in both zones of *A. corrugata* have that type of thickening. It has also been shown that the arms of parenchyma and tracheidal tissue which radiate out from the inner zone of the stem-stele do not persist for any great vertical distance in *M. duplex.* In the case of *A. corrugata,* on the other hand, these arms seem to persist for a greater vertical distance—so much so, that the outer zone of the stele-xylem appears to consist of five groups of tracheides alternating with five parenchymatous arms which project from the inner zone. The largest tracheides in *A. corrugata* appear in the centre of each group, and in *M. duplex* the largest are in the central portion of the outer xylem; but if the radiating arms broke up the outer ring as in *A. corrugata* the smaller tracheides would be situated along the sides of the arms, and then the large tracheides would occupy a central position in the resulting groups of the outer xylem zone. In both species these radiating arms of parenchyma and tracheides are intimately connected with the petiole-trace departure, and this emission is more distinctly protostelic in character in *M. duplex* than in *A. corrugata.* In the type of branching shown by both species there is a striking similarity; it is a dichotomy in each case, and in neither case has any "axillary" branching been recorded. It is also worthy of notice that the *Botrychioxylon*-like specimen shown in Pl. IV. fig. 46 is paralleled in one of Williamson's figures of *A. corrugata.**

The petiolar development, however, is entirely different in the two species, *A. corrugata* having only two rows of primary pinnæ, and these, as KIDSTON and GWYNNE-VAUGHAN point out,† being little more than scale leaves.

The French Permian species *A. Brongniarti* is also very similar to *M. duplex* as far as its stem-stele is concerned. In size they are almost identical, but in *A. Brongniarti* the radiating arms are exceedingly well developed and the tracheides have all scalariform thickenings on their walls. Very little is known about this species, particularly about the petiole-trace, but the petiole referred by RENAULT to the species is distinctly of the *Ankyropteris* type. The branching of the stem is of the "axillary" type now shown to be of the nature of an unequal dichotomy.

Compared with *Etapteris di-upsilon* (*Zygopteris Grayi*), the stem of *M. duplex* is very distinct. The stellate structure of the stem xylem in the former species is the result of the rapid emission of petiole-traces, and, when one has departed, the outline becomes rounded and not stellate at that part of the stem. The arms of parenchyma and tracheides radiating from the central zone of the stem xylem are much more prominent here than in *A. corrugata* or *A. Brongniarti*; and the type of branching is an unequal dichotomy. The petiole-trace which is emitted from the stem belongs to the third group, as defined by KIDSTON and GWYNNE-VAUGHAN. This correlation of the petiole known as *Etapteris di-upsilon* (Williamson) with *Zygopteris Grayi* has only recently been published by Dr KIDSTON.‡ The species is therefore distinct from *M. duplex* in all its salient features.

Ankyropteris (*Zygopteris scandens*) (Stenzel) is another Zygopterid fern with a stellate stem-stele. It was in this species that the presence of the "axillary" branch was first demonstrated, and in some respects it is closely similar to *Etapteris di-upsilon.* The petiole-trace, however, is of the *Ankyropteris* type. It is thus quite distinct from *M. duplex.*

Quite apart, then, from the appearance of the petiole-trace, *M. duplex* may be distinguished from all other species of the Zygopterideæ by the structure of the stem. As regards the petiole-trace itself, there is no species so far described with which it is likely to be confounded in its mature stages; but, as has already been shown, the early stages of the petiole might quite well be confused with *Dineuron.* It is true that no specimen of *Dineuron* has been discovered which has as large a stele as *M. duplex*, but it is conceivable that some species of *Dineuron* may be discovered with a petiole-trace as large as that of the early stages in the trace of *M. duplex.* None of the early stages of petiolar development in the latter species is comparable with *Clepsydropsis.* In

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* WILLIAMSON, *Phil. Trans. Roy. Soc.*, vol. clxvii., 1876, pl. v. fig. 19.

† KIDSTON and GWYNNE-VAUGHAN, *Trans. Roy. Soc. Edin.*, vol. xlvii., 1910.

‡ *Ann. Bot.*, vol. xxiv., April 1910.

Diplolabis, on the other hand, there was a distinct resemblance to that species (*Clepsydropsis*) in the early form of the petiole-trace.

SUMMARY.

In this paper a fern stem is described, and the evidence for referring it to *Metaclepsydropsis duplex* (Williamson) is cited. The stem is shown to be a long, dichotomously branched rhizome, from which petioles and roots are only emitted at considerable intervals; indeed, although several inches of one stem were cut into transverse sections, only one petiole departure was observed, and Miss BENSON followed another stem for nearly 2 feet without discovering any such emission. Several pieces of the stem were discovered. Branching of the stem is shown to be of the nature of a dichotomy.

The petiole-trace is followed from the earliest stages of its differentiation from the stem until it departs as a separate trace. From that level it is followed through several series until the normal form of the *M. duplex* petiole-trace is attained. The *Dineuron*-like type of the early petiole-trace is recorded.

The pinna-trace departure is next studied, and the changes noted from the time the pinna-trace-bar leaves the petiole-trace until the tertiary pinnæ are reached. Several cases of abnormal traces are noted in which the xylem forms a closed ring. The resemblance which such an abnormal type has to what is the normal form in *Clepsydropsis* is commented on.

Root-traces are also observed, and they are diarch, with a barrel-shaped xylem mass.

The cortex is dealt with in general terms, as there is nothing of special note in its organisation. In the cortex of the stem and early stages of the petiole, however, there is no sclerenchyma present.

One specimen of the stem is recorded which shows secondary thickening, but it is probably abnormal. It appears similar to *Botrychioxylon*.

The species is then compared with the members of the Zygopterideæ which resemble it.

Metaclepsydropsis duplex (Williamson).

1874. *Rachiopteris duplex*, Williamson, *Phil. Trans. Roy. Soc.*, vol. clxiv.
1889. *Asterochlœna* (*Clepsydropsis*) *duplex*, Stenzel, *Die Gattung Tubicaulis.*
1896. *Clepsydropsis* sp., Renault, *Bass. houill. et perm. d'Autun et d'Épinac.*
1909. *Metaclepsydropsis duplex*, P. Bertrand, *Études sur la fronde des Zygoptéridées.*
1910. „ „ Seward, *Fossil Plants*, vol. ii.

DIAGNOSIS.

Stem long, dichotomously branched; xylem of stem circular in transverse section; 2 mm. in diameter; elements in two zones. Inner zone of long, narrow, reticulately or scalariformly thickened tracheides, together with some conjunctive parenchyma.

Arms of inner zone radiate into outer zone in certain places. Outer xylem of long, broad, reticulate tracheides. Protoxylem groups, of scalariform elements, not cauline but decurrent from the petiole into the stem, disappear at outer margin of inner xylem zone. Cortex without sclerenchyma.

Petiole-trace at first elliptical in transverse section, with a sunk protoxylem group near each end. Ends ultimately enlarged and trace becomes hourglass-shaped, with sinus (groove) at the middle of each end. Protoxylem groups, two at each end, situated on sides of sinus. Tracheides with reticulate thickenings, except protoxylem elements, which are scalariform. Primary pinnæ in *four* orthostichies; inserted on petiole in pairs. Tertiary pinna-traces join secondary pinna-traces in *two* orthostichies. Insertion of secondary pinnæ on primary similar to tertiary on secondary. Trace of primary pinna sometimes closed, but open lower down. Last traces to join primary pinna-traces are from aphlebiæ. Aphlebia-traces bifurcate during passage through petiole-cortex, and both branches pass out at the same level.

Pinna- and aphlebia-traces unite to form pinna-trace-bar, which joins petiole-trace.

Root-traces large, barrel-shaped, diarch.

Foliage and sporangia unknown.

Localities.—Calciferous Sandstone Series (= Culm), Pettycur, Fife; Culm of Régny.*

CONCLUSIONS AND GENERAL CONSIDERATIONS.

The discovery of stems of Zygopterid and Osmundaceous affinity has recently thrown considerable light on the stelar evolution in both these families. As a result of research along this line, the occurrence of a comparatively simple stem-stele in *M. duplex* does not come as a surprise. In only one case has a simpler stele been recorded, viz. in *Diplolabis römeri*. The elements of the stem xylem in *M. duplex* also show an archaic type of thickening on their walls—a reticulate type—and in this they are similar to the tracheides in the stem of *Diplolabis römeri*, while quite distinct from the xylem elements in the xylem of other Zygopterid stems. In the inner zone of the xylem, however, some of the elements have scalariform thickenings, but this will be considered later.

The mixed pith in this species does not play so conspicuous a part as in *Ankyropteris corrugata* and the other known Zygopterid stems. The radiating arms of parenchyma and tracheides so prominent in *A. corrugata* are certainly present in *M. duplex*, but they are not very well marked. In all cases they are closely connected with the emission of the petiole-trace, as, for example, the radial arm figured in Pl. II. fig. 15, *a*, which is shown to be intimately related to one of the protoxylem groups of the trace of Pl. I. fig. 7. Indeed, the insertion of the petiole-trace into the stem has probably been the cause of the stellate appearance of the latter in *Etapteris di-upsilon* (*Zygo-*

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* P. BERTRAND, *Études sur la fronde des Zygoptéridées*, p. 206, Lille, 1909.

pteris Grayi); and a similar cause may be assigned to the apparent grouping of the xylem into certain areas in *A. corrugata* and *A. Brongniarti.* In other words, the departure of the petiole-trace is beginning to have a greater effect on the stem xylem in *M. duplex* than it had in *Diplolabis*, and the series from *Diplolabis* to *Etapteris* (*Zygopteris Grayi*), through *Metaclepsydropsis duplex* and *Ankyropteris corrugata* and *Brongniarti*, foreshadows a type of petiole-trace departure which will no longer be protostelic, but cause a gap in the outer xylem ring. In the Zygopterideæ the departure seems to have been protostelic in all cases, but the Osmundaceæ show the change from the one type to the other. *M. duplex* is thus, as far as the axis is concerned, distinctly intermediate between the *Diplolabis* type and that of *Ankyropteris corrugata*; indeed, it holds the same position among the Zygopterideæ with four rows of primary pinnæ, that *Ankyropteris corrugata* does among those with two orthostichies of such appendages.

Dividing up the Zygopterideæ according to this criterion, as Kidston and Gwynne-Vaughan have done, we establish the two stem series: (1) *Diplolabis römeri—Metaclepsydropsis duplex—Etapteris di-upsilon* (*Zygopteris Grayi*), and (2) *Ankyropteris corrugata—Ankyropteris scandens.* To make the intermediate position of *M. duplex* in the first series quite clear, the following table has been inserted:—

		Diplolabis.	*Metaclepsydropsis.*	*Etapteris.*
Shape of stem xylem in transverse section		Circular, with inner and outer zones.	Circular, with inner and outer zones.	Pentagonal, with inner and outer zones.
Type of stele		Solid.	With conjunctive parenchyma in central zone.	With conjunctive parenchyma in central zone.
Type of tracheide	Outer zone . .	Long, pointed, reticulate.	Long, pointed, reticulate.	Long, pointed, scalariform.
	Inner ,, . .	Short, square-ended, reticulate.	Long, pointed, reticulate or scalariform.	Long, pointed, scalariform.
Arms radiating from inner zone . .		Absent.	Slightly developed.	Strongly developed.
Type of branching		Equal dichotomy.	Equal dichotomy.	Unequal dichotomy, so-called "axillary" branch.

It has been shown that the reticulate type of thickening on the walls of tracheides is more primitive than the scalariform type, so that as far as we can judge *M. duplex* occupies a position above *Diplolabis* in the Zygopterid series; and the other criteria at our disposal all point to the same conclusion.

Before passing to a discussion of the systematic position of the petiole, I wish to enumerate the reasons for believing that the stem was a rhizome :—(1) The xylem of the stem is small compared with that of the petiole; (2) the internodes (if we may call the distance between two petioles by this name) are long; (3) what evidence there is regarding the distribution of adventitious roots seems to indicate that they are irregular in their occurrence; (4) the petiole-trace is at first small and then grows larger, as though it were supported in the lower portion either by overlying vegetable matter or soil, and did not attain its maximum development until it got above the substratum; (5) there is no sclerenchyma in the cortex of the stem or of the lowest part of the petiole; (6) the pinnæ are in four orthostichies on the petiole, and the latter must therefore have been held erect.

The study of the petiolar development has demonstrated certain points of interest. The term "arm" has sometimes been used to characterise the portion of the petiole-trace between the protoxylem groups and the "horizontal bar," and while such arms do exist in *Diplolabis* and most other Zygopterid petioles, they do not occur in *Metaclepsydropsis duplex*. The increasing size of the island of parenchyma at the emergence of a pinna-trace-bar from the petiole no doubt gives the petiole-trace at certain levels the appearance of having such arms (Pl. II. fig. 18), but this stage is not constant. As has been already pointed out, the ends of the trace in *M. duplex* have become dilated instead of being produced into arms. This has permitted the insertion on the petiole of more robust pinnæ. In *Dineuron* we find a petiole-trace quite similar to that of the early stages in *M. duplex*, but in no case have petioles of the former genus been discovered which had dilated ends.

Etapteris, on the other hand, appears to be a case where the dilatations have increased to such an extent that they have become quite arm-like. These arm-like processes are quite different from the arms in *Diplolabis*; they are mere swellings similar to the dilatations on the outer ends of the arms in *Diplolabis* and on the ends of the trace in *M. duplex*. Dr P. BERTRAND has pointed this out in his memoir on the Zygopterid petiole-trace, and has also demonstrated the manner in which the pinna-traces depart from the petiole-trace. As Dr BERTRAND has further pointed out, there is some slight trace of arms in *Etapteris* comparable with those in *Diplolabis*. This will be made clear by a glance at text-fig. 4.

In order to decide whether arms are present on the petiole-trace or not, it is necessary to examine a section immediately above the level of a pinna-trace-bar departure. In the case of *Diplolabis* very distinct arms may be seen, with protoxylem groups at the ends, and the same applies to *Etapteris*; but *Metaclepsydropsis* and *Dineuron* do not exhibit such arms, the ends of the trace have grooves in them, and in these grooves lie the protoxylem elements. The grooves of *Metaclepsydropsis* and *Dineuron* are therefore equivalent to the wide bay in *Diplolabis*, *Zygopteris*, and *Etapteris*. In all cases except *Etapteris* the development of new pinna-traces is essentially similar; small tongues of xylem elements are developed round each protoxylem group, and these grow towards one another until they meet and form a xylem bar across the end of the trace. The bay or the groove now becomes an island of parenchyma.

In *Diplolabis* the xylem bar is well developed and the size of the island is constant, as is also the case in *Zygopteris.* In *Etapteris* the tongues of xylem do not meet, but break away and unite after becoming detached; this is rather a specialised type of pinna-trace departure. *Dineuron* and *Metaclepsydropsis,* however, exhibit quite a different type. The small groove is bridged across much more quickly than in *Diplolabis* and *Zygopteris,* but subsequent growth causes the island to become larger and larger until it reaches a maximum at the level of the departure of the pinna-trace-bar. In *Dineuron,* it is true, the island does not reach the proportionate dimensions that it does in *Metaclepsydropsis,* but the increase is distinct, and I believe that these two genera must be grouped together.

Such a grouping would necessitate the division into two groups of the first subdivision of the Zygopterideæ with quadriseriate pinnæ, as given by KIDSTON and GWYNNE-VAUGHAN. In the first group would be included all forms with well-marked arms and the bay between them always constant in size :—

Diplolabis römeri (Solms).
Zygopteris primaria (Cotta).

The second group would include forms where distinct arms are not developed, and where consequently the bay is reduced to a mere groove. The island of parenchyma formed by the bridging of this groove becomes gradually larger until a maximum is reached just before the departure of the pinna-trace-bar :—

Dineuron ellipticum, Kidston, and *D. pteroides,* Renault.
Metaclepsydropsis duplex (Williamson).

This subdivision, however, is based entirely on the mature form of the petiole-trace. In certain members of each division (*Diplolabis* and *M. duplex*) it has been shown that in early stages of petiolar development the traces are distinctly similar in appearance to that of *Dineuron.*

In a recent paper on *Diplolabis römeri* * I drew attention to an hypothetical type of petiole-trace (*Protoclepsydropsis*) from which some other Zygopterid traces might be derived, and, in a tabular form, indicated what I believed to be the relationship of these Zygopterid petioles to one another. The table is inserted below (text-fig. 5), and in it *M. duplex* has been placed in close relation to *Dineuron*; in fact, it has been considered one of the forms directly derived from a *Dineuron* ancestry. *Zygopteris* and *Diplolabis* have been grouped together as the second derived form, and *Etapteris* as the third. It is exceedingly interesting to find that the discovery of the stem and early stages of the petiole-trace of *M. duplex* has entirely confirmed the view set forth in that table.

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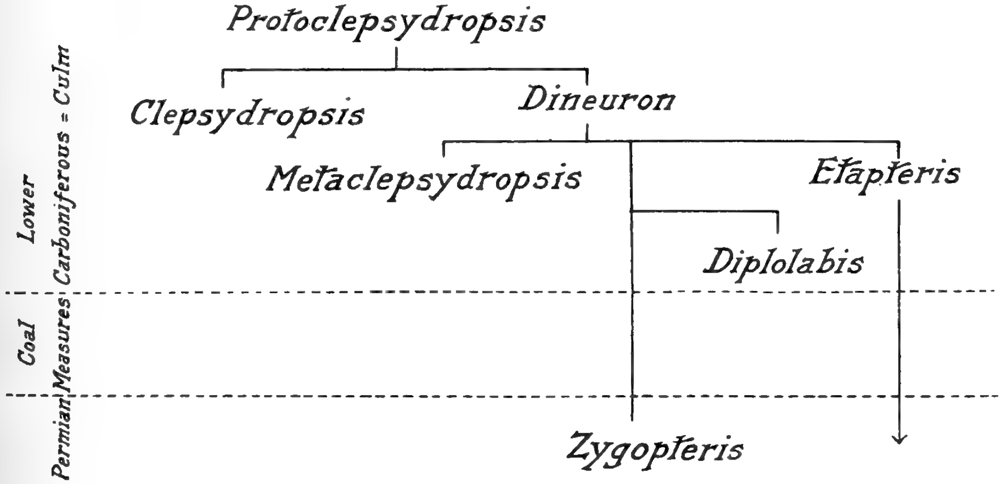
* GORDON, "On the Structure and Affinities of *Diplolabis römeri* (Solms)," *Trans. Roy. Soc. Edin.*, vol. xlvii. pt. iv.

Of course all this grouping has been based on the hypothesis that the forms of the trace at low levels in the petiole (*i.e.* at early stages of development) are comparable with ancestral forms. This is also the basis of the work of KIDSTON and GWYNNE-VAUGHAN on the fossil Osmundaceæ, and of SINNOTT's studies on recent ferns. The hypothesis seems reasonable, and when applied to *Diplolabis* and *Metaclepsydropsis* (two forms closely allied on other grounds) the results lead to the same conclusion, and show that evolution was parallel in these two genera.

As far as the relationships between the Osmundaceæ and Zygopterideæ are concerned, the stem of *M. duplex* occupies an important position. In the medullation of the Zygopterid stele the series taken was *Diplolabis*, *Ankyropteris corrugata*, *Etapteris di-upsilon* (*Z. Grayi*). Now this is open to criticism, for the first and last named have quadriseriate primary pinnæ and petiole-traces with two planes of symmetry, while the central type has biseriate primary pinnæ and one plane of symmetry in the petiole-trace. If we substitute *M. duplex* for *Ankyropteris* we strengthen the position from two points of view, for (1) we get a series of forms which are similar in all respects, and (2) we may construct a parallel series in the Zygopterideæ with biseriate primary pinnæ and one plane of symmetry, thus :—*Ankyropteris corrugata*—*A. scandens*. To complete the series in this second main division of the Zygopterideæ we only want a form with a solid stem stele similar to *Diplolabis*. *Clepsydropsis* may supply this form, for the stems referred to that genus by Dr PAUL BERTRAND* are not above suspicion. Typical *Clepsydropsis* petioles have *not* been traced into these stems, and until this is done the Cladoxylons cannot be accepted as the stems of *Clepsydropsis*.



TEXT-FIG. 5.—Table to show the relation of *Metaclepsydropsis* to the other Zygopterideæ which have quadriseriate pinnæ.

Meanwhile the general trend of evolution as shown in the Zygopterideæ is parallel to that demonstrated by KIDSTON and GWYNNE-VAUGHAN in the Osmundaceæ, namely, from a simple to a more complex type, *i.e.* both groups show an ascending series as we pass upwards in the geological succession.

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* *Comptes Rendus des Séances de l'Académie des Sciences, Paris*, 16th November 1908.

In concluding this paper I desire to express my thanks to Dr Kidston, Dr Scott, and Miss Benson, with whom I have been in constant communication during my work on the genus described here. I have also benefited greatly by a study of Dr Paul Bertrand's memoir on the Zygopteridean frond, and, although I cannot agree with all his conclusions, this work has been of great service to me.

I have also to express my thanks to the Executive Committee of the Carnegie Trust for defraying the expenses of illustrating this paper.

EXPLANATION OF PLATES.

(*Photographs from untouched negatives.*)

Unless otherwise stated, the sections figured are in the author's collection.

Plate I.

Metaclepsydropsis duplex.

Fig. 1. Transverse section of stem. x^1 = outer xylem; x^2 = pith with tracheides; p = parenchyma. Slide 1129. × 28.

Fig. 2. Longitudinal section of stem. x^1 = outer xylem; x^2 = inner xylem. Slide 1128. × 28.

Fig. 3. Dichotomy of the stem, stage 1. x^1 = outer xylem; x^2 = inner xylem; *rt. tr* = root trace. Slide 1120. × 18.

Fig. 4. Dichotomy of stem, stage 2. Lettering as in last figure. Slide 1121. × 18.

Fig. 5. Dichotomy of stem, section above fig. 4. x^1 = outer xylem; x^2, x^2 = inner xylem. Slide 1122. × 18.

Fig. 6. Dichotomy of stem just before the branches separate. Lettering as before. Slide 1123. × 18.

Fig. 7. Insertion of petiole-trace in stem. Petiole-trace detached. prx^1, prx^2 = protoxylem groups; x^1 and x^2 as before. Slide 1110. × 18.

Fig. 8. Insertion of petiole-trace in stem. Petiole-trace attached. x^1 = outer zone of xylem; x^2 = inner zone; prx^1, prx^2 = protoxylem; J = large xylem elements. Slide 1109. × 18.

Fig. 9. Stage below that of fig. 8. prx^1, prx^2 = protoxylem groups. Slide 1108. × 18.

Fig. 10. Section further in than fig. 9. prx^1, prx^2 = protoxylem groups as before. Slide 1107. × 18.

Fig. 11. Below fig. 10. a^1 = radial arm from inner xylem zone; prx^1, prx^2 = protoxylem groups. Slide 1106. × 18.

Fig. 12. Stage preceding that of fig. 11. Lettering as before. Slide 1105. × 18.

Plate II.

Metaclepsydropsis duplex.

Fig. 13. Insertion of petiole-trace in stem. Stage below Pl. I. fig. 12. prx^1, prx^2 = protoxylem groups; a^1 = arm of parenchyma and tracheides radiating from inner xylem zone. Slide 1104. × 18.

Fig. 14. Section following that of fig. 13. prx^1 = first protoxylem group. a^1 = sinus which is really the beginning of another radial arm similar to that of fig. 16. Slide 1103. × 18.

Fig. 15. Section below that shown in fig. 14. prx^1 = first protoxylem group of petiole-trace; a = radial arm of parenchyma and tracheides. Slide 1102. × 18.

Fig. 16. Section below that shown in fig. 15. prx^1 = protoxylem group; a = arm of tracheides and parenchyma radiating from inner zone of stem axis. Slide 1101. × 18.

Fig. 17. Transverse section of mature petiole-trace showing hour-glass shape. w = waist; b = pinna-trace-bar; g = groove; prx = protoxylem groups; *end* = endodermis. Slide 1146. × 17.

Fig. 18. Transverse section of mature petiole-trace showing a large island (*is*) of parenchyma at one end and an open groove at the other. *w* = waist; *b* = pinna-trace-bar; *g* = groove; *prx* = protoxylem group; *is* = island of parenchyma; *c* = shallow depression—the last vestige of the groove. Slide 1155. × 17.

Fig. 19. Section similar to fig. 18. Pinna-trace-bar just detached from petiole-trace. Waist not so well marked as in last two figures. Lettering as before. Slide 1151. × 17.

Fig. 20. Example of a petiole-trace with waist still less marked than in fig. 19. At the top an early stage in the development of the pinna-trace-bar is shown. Lettering as before. Slide 1167 × 17.

Fig. 21. Transverse section of petiole-trace in which the waist is scarcely developed at all. A pinna-trace-bar is shown attached to the petiole-trace at the top of the figure. Prx^b_1, prx^b_2, prx^c_1, prx^c_2 = protoxylem groups on petiole-trace; prx_1, prx_2, prx_3, prx_4 = protoxylem groups on pinna-trace-bar; *is* = island of parenchyma; *b* = pinna-trace-bar. Slide 1171. × 17.

Fig. 22. Section of a petiole-trace from which all indication of a waist has vanished. Lettering as in other figures. Slide 1152. × 17.

Fig. 23. In the petiole-trace of this figure a further reduction to an elliptical trace is clearly seen. The pinna-trace-bar (*b*) is a much reduced one, and the pinna-traces do not pass beyond the cortex of the petiole, *i.e.* they are reduced. Slide 1264. × 16·5.

Fig. 24. Transverse section of petiole-trace showing distinct elliptical form. Pinna-traces in this case also are reduced. The outer cortex (*o.c*) has no sclerotic layer. Slide 1194. × 18.

Fig. 25. Rather oblique transverse section of a reduced petiole-trace. Pinna-trace-bar (*b*) does not divide into two pinna-traces. Slide 1189. × 15.

Fig. 26. Another oblique transverse section of petiole-trace. Pinna-trace-bar shows a double curve, but it does not divide into two to supply two pinnæ. Slide 1204. × 15.

Plate III.

Metaclepsydropsis duplex.

Fig. 27. Transverse section of petiole-trace. Fig. 26 shows this same trace at a higher level. Slide 1199. × 15.

Fig. 28. Transverse section of petiole-trace similar to that of fig. 27. Slide 1184. × 15.

Fig. 29. Transverse section of another closely similar petiole-trace. *prx* = protoxylem groups; *g* = groove. Slide 1189. × 17.

Fig. 30. Transverse section of petiole-trace similar to that of fig. 29. It is inserted to show resemblance at this level of the traces of *Metaclepsydropsis* and *Dineuron*. Slide 1180. × 16·5.

Fig. 31. Transverse section of petiole with trace slightly flattened. The outer cortex contains very little sclerenchyma, if any. Slide 1252. × 16·5.

Fig. 32. Furthest-out section of a series showing the connection between petiole-trace and stem xylem. Slide 1242. × 15·5.

Fig. 33. Section below that shown in fig. 30. The interval between is about $\frac{1}{4}$ inch. *prx*, *prx* = protoxylem groups; *is* = island of parenchyma; *st* = xylem of stem. Slide 1240. × 15·5.

Fig. 34. Section some distance below that of fig. 31. Petiole-trace crushed against stem. Two sections below this the two unite, but are very much crushed at that level. Slide 1233. × 15·5.

Fig. 35. Transverse section of petiole to show the arrangement of the tissues. The sclerotic outer zone of the cortex is very distinct. The petiole-trace is shown more highly magnified in Pl. II. fig. 21. *pet. tr* = petiole-trace; is^1, is^2 = islands of parenchyma; *sc.o.c* = sclerotic outer cortex; *o.c* = parenchymatous outer cortex. Slide 1171. × 8·3.

Fig. 36. Transverse section of petiole-trace at a high level in the petiole. Slide 1140. × 17.

Fig. 37. Transverse section of petiole-trace and combined pinna- and aphlebia-traces. *is* = island of parenchyma; a^1, a^1 = combined pinna- and aphlebia-traces; *prx* = protoxylem groups. Slide 1248. × 19.

Fig. 38. Transverse section above that of fig. 37. The combined traces show signs of a division into two; the larger (upper) trace is the pinna-trace; *pin. tr* = pinna-trace; *aph. tr* = aphlebia-trace; *prx* = protoxylems. Slide 1244. × 19.

Plate IV.

Metaclepsydropsis duplex.

Fig. 39. Transverse section of petiole-trace above level of Pl. III. fig. 38. g = groove ; *pin. tr* = pinna-trace ; *aph. tr* = aphlebia-trace. Slide 1243. × 19.

Fig. 40. Transverse section petiole to show the various traces departing from it. *pet. tr* = petiole-trace ; *pin. tr* = pinna-traces ; *aph. tr* = aphlebia-traces. Kidston Collection, 1314. × 3·2.

Fig. 41. Transverse section of *normal* primary pinna-trace. The shape is like a horse-shoe with ends incurved. Slide 1261. × 40.

Fig. 42. Transverse section of an *abnormal* secondary pinna-trace with tertiary pinna-trace departing from it. Both traces are closed rings. Slide 1258. × 40.

Fig. 43. Transverse section of *abnormal* primary pinna-trace. The trace is a closed ring of xylem. Slide 1168. × 40.

Fig. 44. Transverse section of root-trace showing that it is diarch. *prx* = protoxylem group. Slide 1101. × 18.

Fig. 45. Transverse section of stem to show inner tracheides and parenchyma. x^1 = outer xylem ; x^2 = inner zone ; p = conjunctive parenchyma. Slide 1109. × 36.

Fig. 46. Transverse section of branch resembling *Botrychioxylon.* In places the xylem shows a perfect radial arrangement. Slide 1233. × 18.

Fig. 47. Transverse section of stem with petiole-trace attached. The stem has a central zone almost entirely composed of parenchyma ; only one tracheide can be seen. The petiole-trace is much distorted. p = parenchyma in the stem ; t = tracheide. Slide 1207. × 15.

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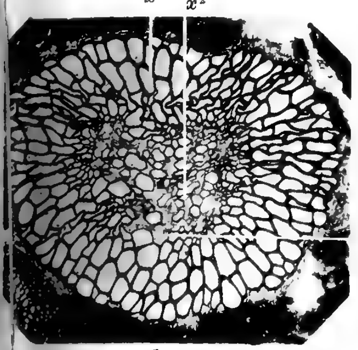
W. T. GORDON: ON THE STRUCTURE AND AFFINITIES OF METACLEPSYDROPSIS DUPLEX.—PLATE I.



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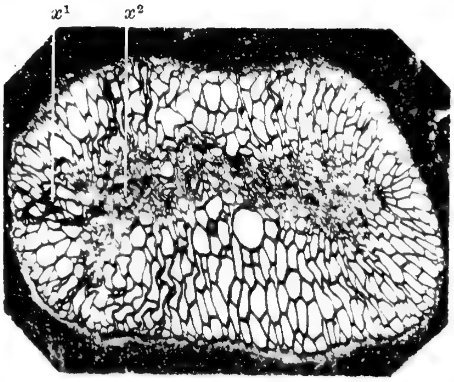

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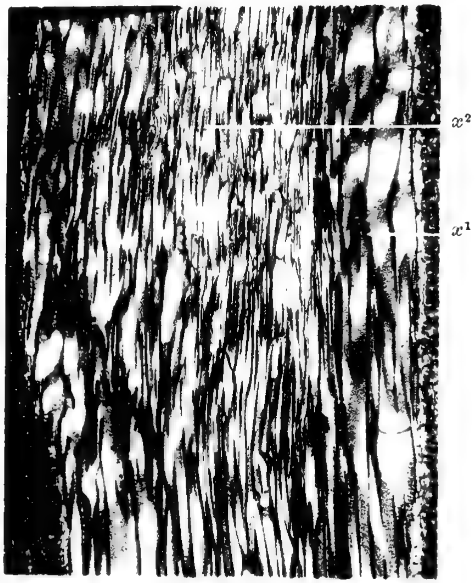

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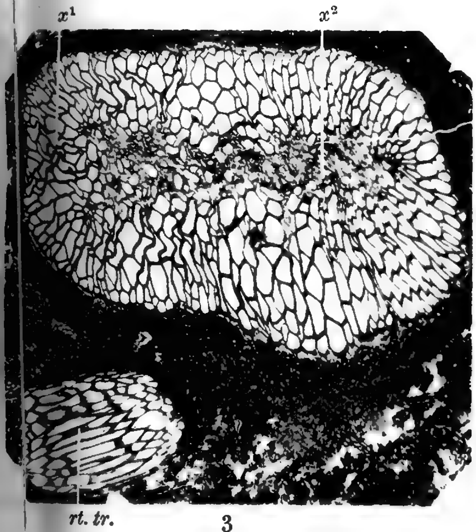

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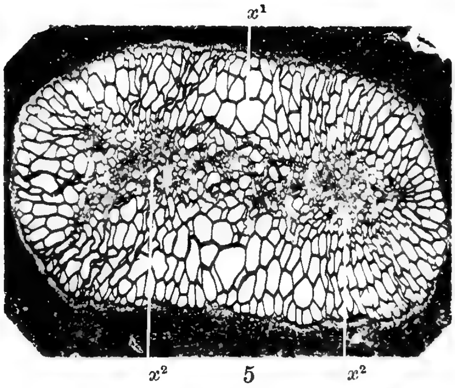

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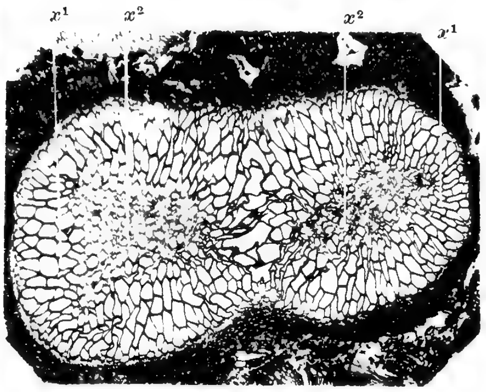

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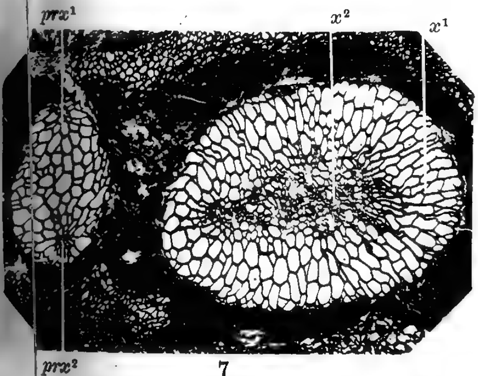

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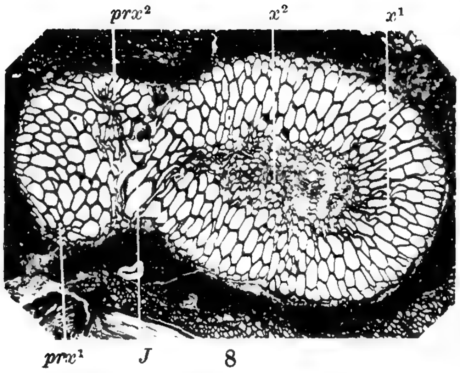

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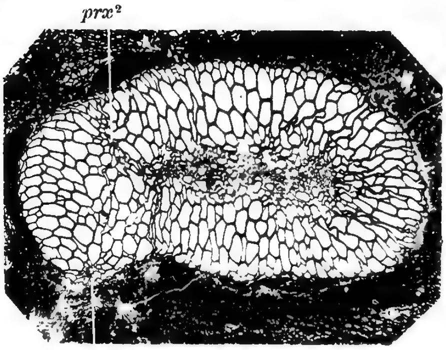

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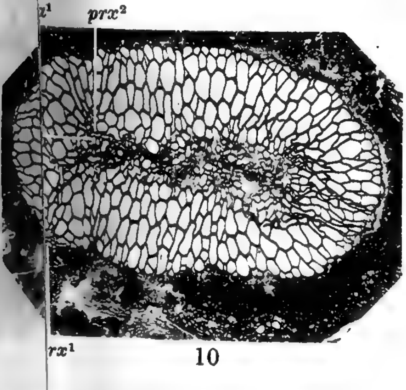

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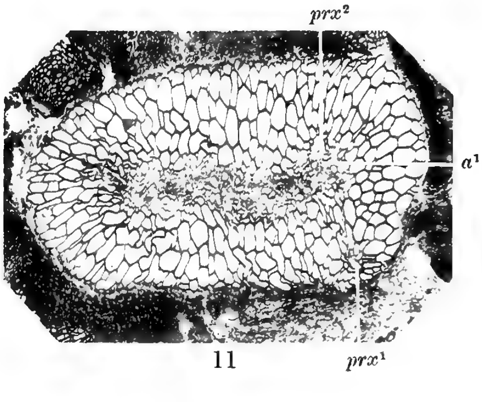

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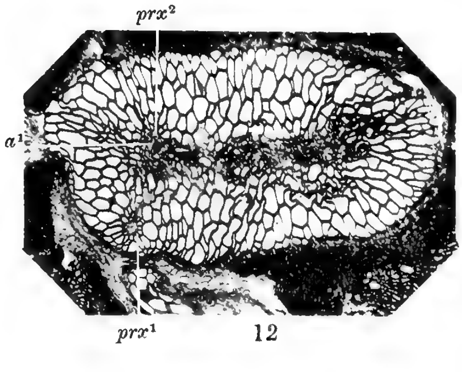

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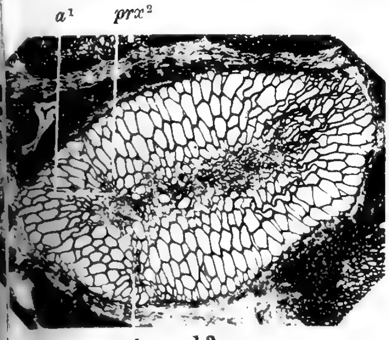
W. T. GORDON: ON THE STRUCTURE AND AFFINITIES OF METACLEPSYDROPSIS DUPLEX.—PLATE II.



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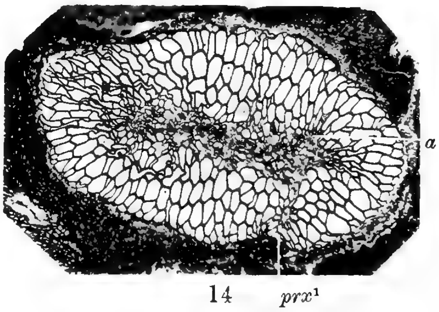

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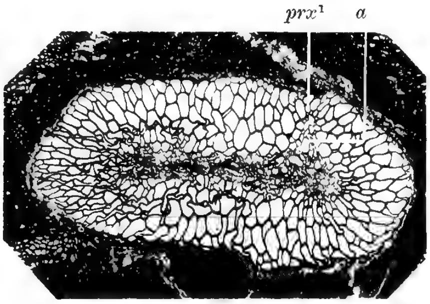

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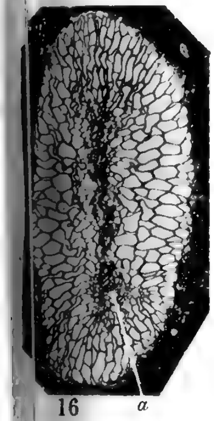

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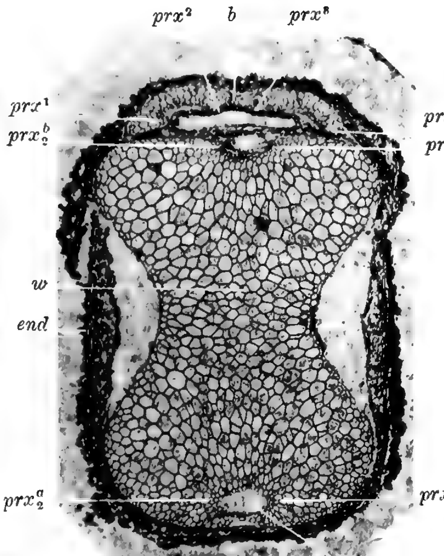

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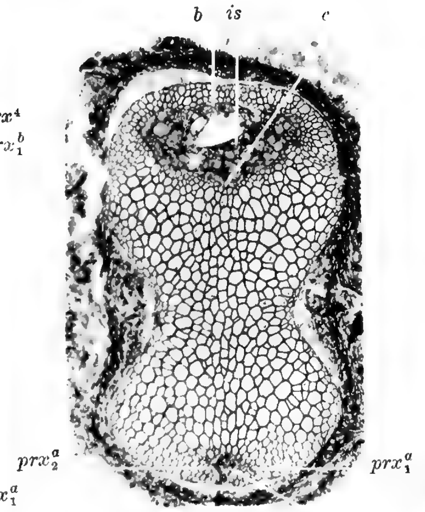

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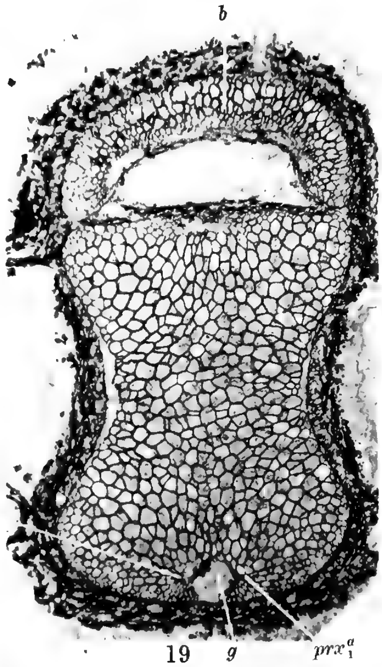

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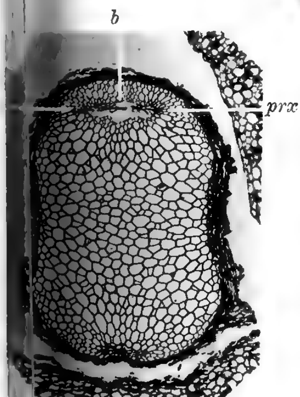

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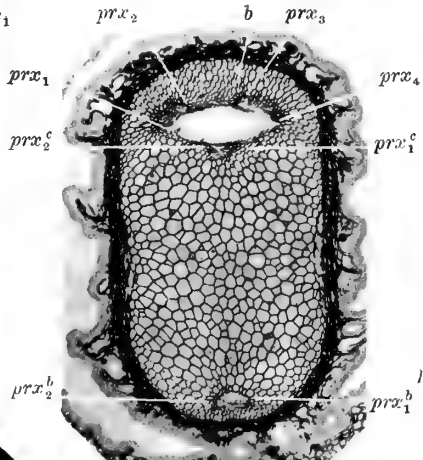

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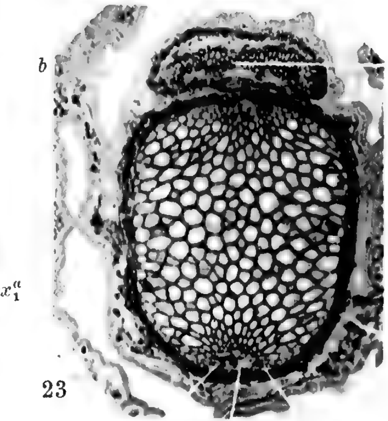

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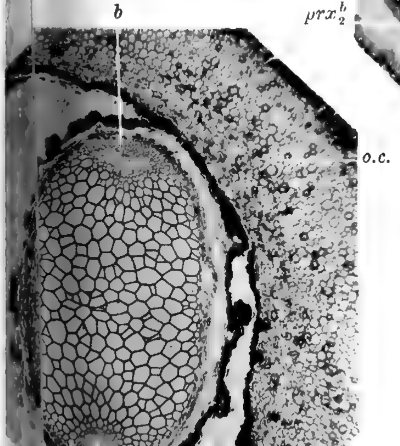

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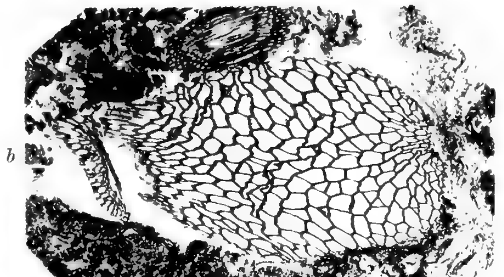

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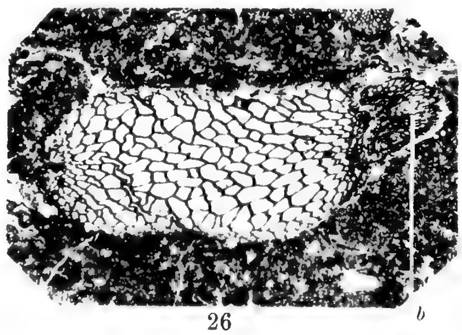

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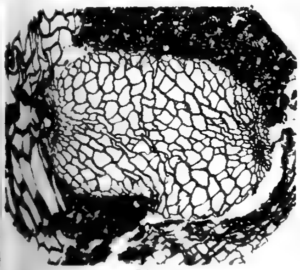
W. T. GORDON: ON THE STRUCTURE AND AFFINITIES OF METACLEPSYDROPSIS DUPLEX.—PLATE III.



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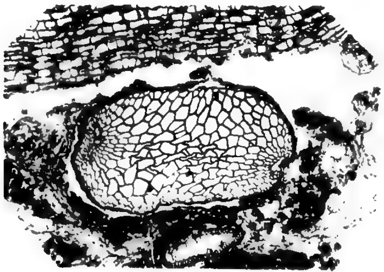

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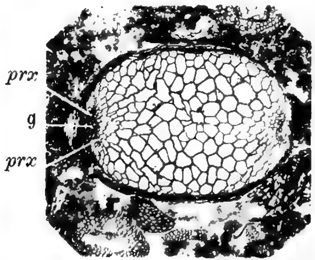

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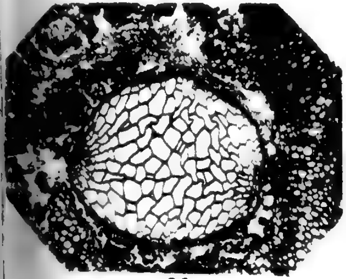

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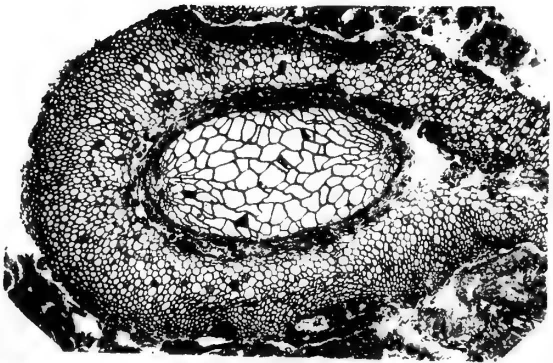

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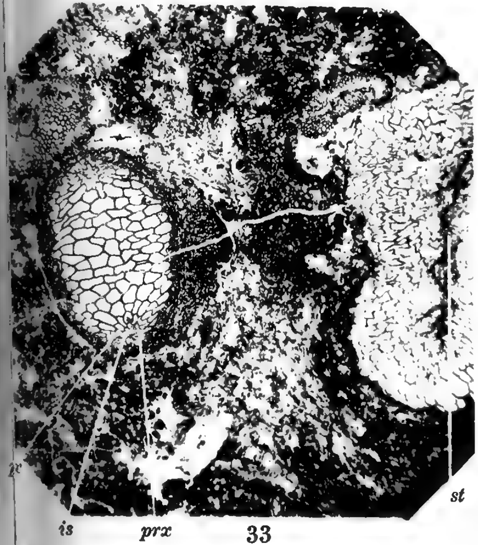

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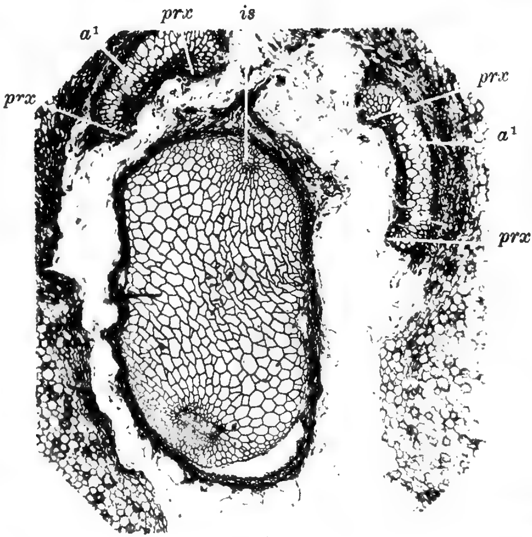

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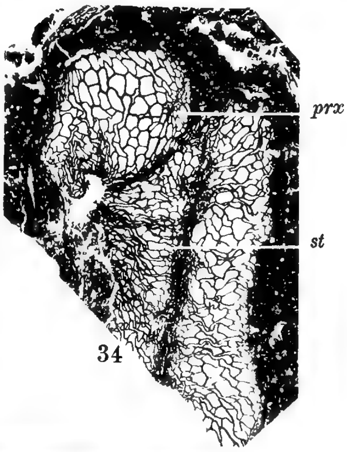

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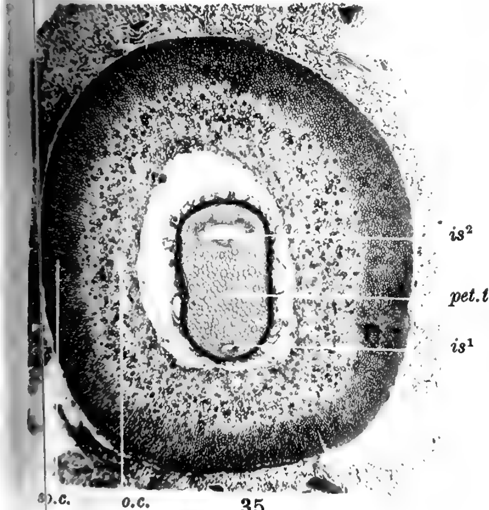

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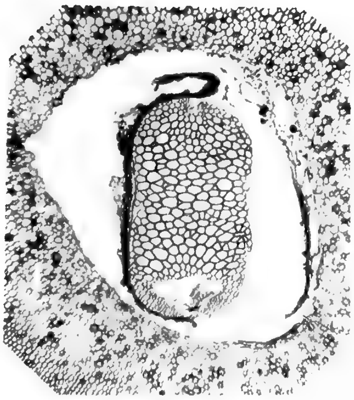

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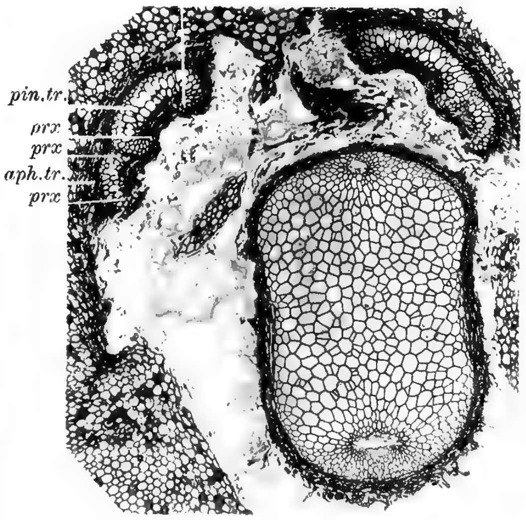

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W. T. GORDON: ON THE STRUCTURE AND AFFINITIES OF METACLEPSYDROPSIS DUPLEX.—PLATE IV

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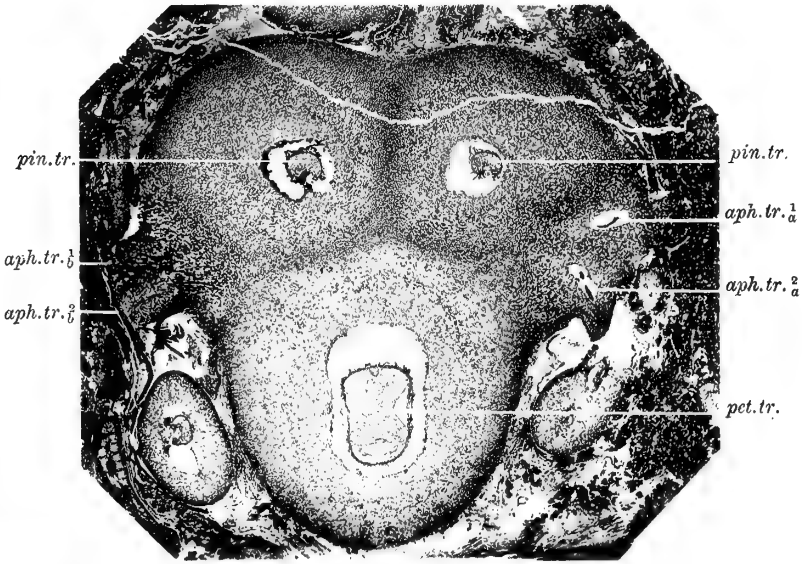

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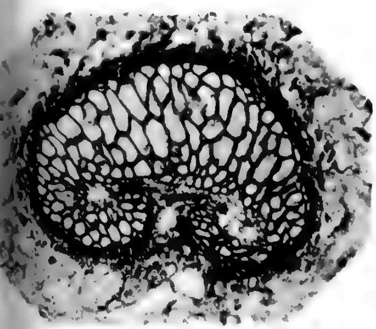

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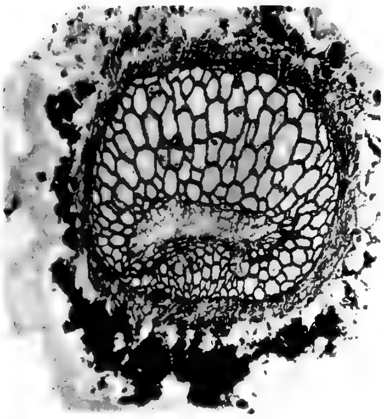

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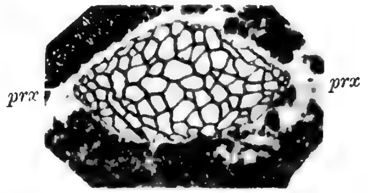

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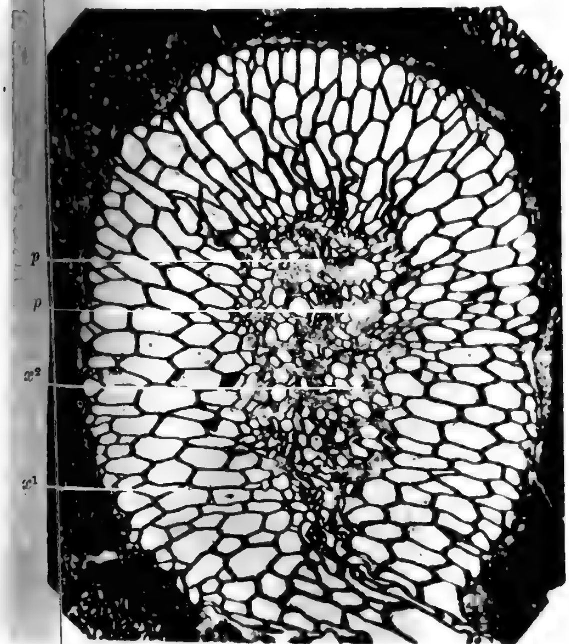

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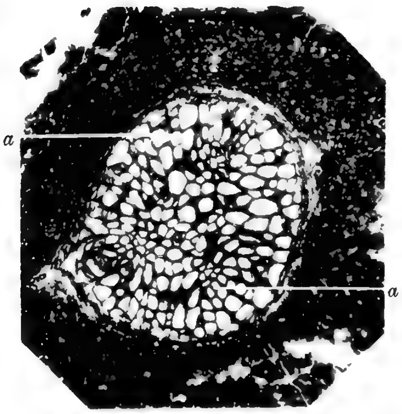

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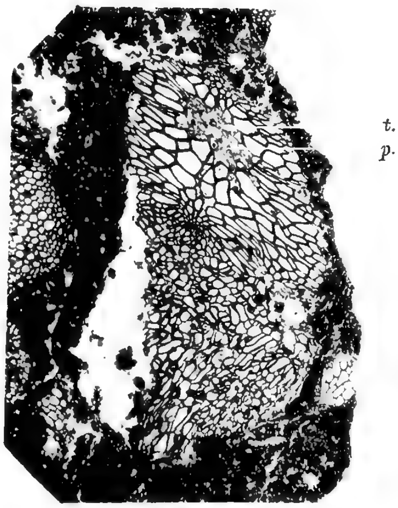

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IX.—Scottish National Antarctic Expedition: Observations on the Anatomy of the Weddell Seal (Leptonychotes Weddelli). By David Hepburn, M.D., C.M., Professor of Anatomy, University College, Cardiff (University of Wales). Part II.*

(MS. received December 4, 1911. Read January 8, 1912. Issued separately January 19, 1912.)

Genito-urinary Organs.

In my former contribution I gave a general summary of the animal under consideration, and discussed in detail the peritoneal arrangements of its abdominal cavity and the naked-eye anatomy of its alimentary organs. In the present paper I shall give an account of the genito-urinary system.

The kidneys were situated on each side of the dorsal mesial mesentery. Each was covered on its ventral aspect by the peritoneum forming the dorsal wall of the greater peritoneal sac. The right kidney was quite free from contact with the liver and the duodenum, while the left kidney was equally free from contact with the spleen. Both kidneys were therefore situated well back towards the pelvic end of the abdominal cavity. Each kidney measured 5 inches in the longitudinal diameter and 2 inches in the transverse diameter. The hinder or caudal end of each reached a point two inches from the pelvic inlet, which, as formerly described, was narrow and well defined by the course of the hypogastric (umbilical) arteries.

The surface of the kidney indicated lobulation, but the lobules were not separated from each other. The hilum was placed ventro-mesially, and at its point of emergence from the surface of the kidney the ureter was nearer to the caudal than to the cephalic end of the organ. On opening up the hilum, the ureter was seen to result from the union of two main tributaries, each of which, in its turn, was formed by the junction of several smaller rootlets, which corresponded more or less closely in number to the number of the kidney lobules. There was no distinct pelvis to the ureter, which was gradually formed by the junction of smaller ducts in the manner indicated. Nevertheless, the widest point of the ureter was found at the junction of its two main tributaries. The ureter and its chief tributaries lay on the ventral (anterior) aspect of the renal vessels, and not on their dorsal (posterior) aspect, as is the case in man.

The size of the ureter suggested a vessel about half the diameter of an average human radial artery. The ureter followed a course along the dorsal wall of the abdomen towards the pelvic inlet; and half an inch beyond the termination of the abdominal aorta, or, in other words, at the point where the common iliac artery divided into its external and internal branches, the ureter crossed to the mesial side of the internal iliac and hypogastric arteries, and continued its course along the margin of the pelvic inlet. In this position the ureter and the hypogastric artery were both in their turn crossed

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* Part I. was published in the *Trans. Roy. Soc. Edin.*, vol. xlvii., pt. i. (No. 3), 1909.

by the vas deferens, which now assumed the mesial position to both of the others. Up to this point the ureter had not entered the pelvic cavity, and about three-quarters of an inch onwards, that is, in the direction of the tail, the ureter, still lying close to the pelvic brim, entered the lateral aspect of the urinary bladder, travelling between the folds of a lateral vesical mesentery or peritoneal ligament. Thus, as a consequence of the great obliquity of the pelvic inlet, the ureter was able to reach the bladder by skirting the pelvic brim, and at no point did it require to enter or sink into the interior of the pelvis.

The urinary bladder was placed mesially, and was attached to the ventral wall of the abdomen by a ventral mesial mesentery composed of peritoneum, which, as formerly described, closely invested the bladder except on its pubic aspect. The apex of the bladder extended to the umbilicus, where it still presented an open lumen. There was no obliterated part or urachus, and throughout its entire length it presented a uniform calibre, suggestive of an empty portion of small intestine. Developmentally, it may be said to represent an enlarged and patent allantois; but as this animal was only two days old at the time of its death, probably a sufficient period had not elapsed for the closure of the umbilical end of the organ.

The hypogastric arteries were carried along each lateral aspect of the bladder, suspended in peritoneal folds half an inch in width, so that these arteries were not in contact with the wall of the bladder until they reached a point between 2 and 3 inches from the umbilicus, where the peritoneal folds disappeared, and the arteries closed in upon the sides of the bladder.

The length of the bladder from the umbilicus to the prostate gland was 10 inches. The prostate gland lay close to and on the abdominal side of the symphysis pubis.

The interior of the bladder was lined by a mucous membrane, presenting numerous rugosities, which to a large extent lay parallel to each other, and in the longitudinal axis of the bladder. Towards the outlet the mucous membrane became comparatively flat and smooth.

The orifices of the ureters were longitudinal oblique narrow slits 2 mm. in length and 5 mm. apart. The lateral margins of each of these openings were continued towards the outlet as slight ridges for a distance of 10 mm. These ridges met in the mesial plane, thus forming a mesial longitudinal ridge or uvula vesicæ. The actual trigonum vesicæ was therefore a triangular area 5 mm. wide at its base and 10 mm. long on each side.

The uvula vesicæ was continued into the urethra, and became continuous with the crista urethræ, which attained its greatest prominence 20 mm. from the apex of the trigonum vesicæ. The sinus pocularis was represented by a very small mesial aperture opening on the distal side of the summit of the crista urethræ.

The prostate gland did not attract attention, and at first sight one would have doubted its presence. Certainly in cutting into the urethra from its pubic aspect no variation in consistence was detected. Still, there was a definite thickening of the pubic wall of the urethra corresponding to the general position of the urethral crest. On the other hand, on the rectal or pelvic aspect of the urethra, and in relation to the urethral crest, there was a mesial longitudinal thickening of firm consistence, from 5–6 mm. in length. Into the hinder end of this denser part the vasa deferentia entered. The pelvic portion of the urethra was therefore not surrounded by visible prostatic tissue at its vesical end, and the prostatic tissue was not prolonged in relation to the urethra as far as the sub-pubic pelvic wall, because, whereas the prostate was only from 5–6 mm. in length, the pelvic urethra measured from 35–40 mm. long. No doubt the extreme youth of the animal accounts for the primitive condition of the prostate, but it is interesting to note that the part readily recognisable is the mesial longitudinal lobe. A portion of the prostatic part of the urethra, along with the surrounding tissue, was prepared for microscopic examination. Definite glandular prostatic tissue was revealed in relation to the pubic and lateral aspects of the urethra. On the rectal aspect of the urethra dense fibrous tissue was displayed. The two vasa deferentia were visible, each quite distinct from the other, so that their close proximity and apparent fusion previous to their entering the prostate on its rectal aspect was not a real fusion. The urethral crest presented the section faces of the bifurcated end of the uterus masculinus (Müllerian ducts).

Each testis was lodged in its own peritoneal pouch, which was situated to the outer side of the pubic body, in the depression between the *pubis and the head of the tibia.* These pouches were completely separated from each other by the keel-like projection of the pubic symphysis, and thus they did not form any object comparable to a scrotum. The testes had descended through the abdominal wall on the ventral aspect of Poupart's ligament, *i.e.* through the inguinal canal, and not through the crural canal, notwithstanding the novel position occupied by the testis in relation to the limb as a whole. The tunica vaginalis testis was in open communication with the sac or cavity of the abdominal peritoneum, and thus the whole condition might fairly be said to resemble two imperfectly descended testes, although in this case there was no scrotum into which they could have descended, nor was it possible for them to descend any farther. Each testis was considerably flattened, and measured 25 mm. long by 14 mm. wide.

No hydatids of Morgagni were visible. The epididymis presented a globus major and a globus minor. It did not lie close to the testis, but was supported by a mesentery, which at its deepest measured 10 mm. The vas deferens was similarly supported, and therefore it presented itself clear from the epididymis at the distal end of the testis, instead of lying close to it as far as the proximal end of the testis, as in man.

The vas entered the inguinal canal in the usual way and crossed the iliac fossa, running superficial to the external iliac vessels and the hypogastric artery. Thereafter it hooked round the hypogastric artery, and, passing to its mesial side, it proceeded backwards, *i.e.* tailwards, towards the base of the urinary bladder, taking its place to the mesial side of the ureter on its course. As the vas approached the proximal or pelvic end of the prostate gland it came into such close contact with its fellow of the opposite side that their adjacent walls became firmly blended together. This produced the appearance of an enlargement common to both of them, but there was no dilatation or ampulla on each one. There was no trace of seminal vesicles.

The penis was constructed on familiar lines. A strong, flexible cylindrical structure was present in the body of the penis extending 7 mm. from the base of the glans penis backwards. A portion of this structure was removed for microscopical examination. In transverse section it presented a circular outline, and was equally associated with the two corpora cavernosa penis. Its resistance to the knife suggested young bony tissue, and accordingly it was decalcified. Afterwards sections were cut out of paraffin, mounted, and stained in hæmatoxylin and eosin. Under the microscope it presented the distinctive characters of cancellated bone, being more spongy towards the centre of the section and denser towards the surface, where it was closely enveloped in a fibro-vascular sheet of membrane, comparable to periosteum. Numerous bone-cells were embedded in the developing processes of bone. No trace of hyaline cartilage could be detected. No doubt this short cylindrical piece of young bone is comparable to the much larger os penis of the walrus, as well as to the furrow-shaped and partly bilateral os penis of the fox and the dog. The bulb on each corpus cavernosum penis was situated in relation to the crus penis, and not on the penile portion of the organ. From the region between the bulb of the corpus spongiosum penis and the rectum, *i.e.* corresponding to the central point of the perineum, there were two parallel bands of tissue running forwards towards the distal end of the body of the penis. These were similar to muscular bands which I have elsewhere* described in connection with the penis of the porpoise. Probably these act as retractors of the penis. As in the case of the porpoise, a microscopic examination of sections cut longitudinally and stained after Van Giesen's method revealed unstriped muscular fibres, with fibrous tissue bundles. Since there is no scrotum in the porpoise, whose testes are situated intra-abdominal, and since in the seal under consideration each testis occupied a recess placed under the integumentary layers in relation to the inner side of the head of the tibia, it seems not unfair to consider these non-striped muscular bands as being homologous to the tunica dartos layer of an ordinary scrotum, more especially as the muscular fibres of the tunica dartos are of the unstriped or involuntary variety.

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* "The Anatomy of the Genito-urinary Apparatus of the adult male Porpoise," HEPBURN and WATERSTON, *Trans. Royal Physical Society, Edinburgh*, 1902.

X.—The Influence of the Ratio of Width to Thickness upon the Apparent Strength and Ductility of Flat Test-bars of Mild Steel. By W. Gordon, B.Sc., A.M.I.Mech.E., Lecturer in Mechanical Engineering in Leith Technical College, and G. H. Gulliver, B.Sc., A.M.I.Mech.E., Lecturer in Engineering in the University of Edinburgh.

(MS. received October 24, 1911. Read November 20, 1911. Issued separately February 28, 1912.)

1. INTRODUCTION.

In a large class of engineering structures it is essential that the materials employed should be both strong and ductile, so that not only shall the structure be able to resist heavy loads, but that if by any chance it is overloaded it shall not collapse suddenly. In order to ascertain whether a metal is suitable for a particular structure, its strength and ductility are determined experimentally. The test most commonly in use consists in applying a gradually increasing pull to a bar of the metal until fracture takes place. The maximum load supported per unit of the original cross-sectional area of the bar is called the tensile strength or *tenacity* of the metal, and the elongation of an initial measured length, expressed as a proportion of that length, is called the *extension*, and is used as an index of the ductility of the metal.

Experience shows that both strength and ductility, as measured in the tensile test, depend not only upon the properties of the metal, but also upon the shape of the test-bar. If there are abrupt variations in the cross-sectional dimensions, the apparent strength of the metal is greater, and the apparent ductility is less, than when these dimensions are constant or vary gradually. Again, the apparent ductility diminishes as the original length of the test-bar is made greater, on account of the well-known phenomenon of constriction; the bar suffers a considerable reduction of section in the region where fracture eventually takes place, and the extension in this part of the bar is correspondingly greater than elsewhere. It follows that the extensions of two bars of the same cross-sectional dimensions are not comparable unless the datum-lengths of the two bars are the same.

In measuring the extension of bars, similar in form but differing in dimensions, comparable results are obtained only by observing BARBA's principle of similitude, which may be stated thus: "Similar bodies of the same material remain similar when distorted by similar systems of applied loads." In other words, if the linear cross-sectional dimensions of one test-bar are double those of another, the datum-length of the former must be twice that of the latter. In practice, it is a great convenience to use test-bars of constant gauge-length, and this necessitates that the cross-sectional dimensions of all test-bars shall be the same also. This rule is observed generally in important work, but there are different standard gauge-lengths to suit different classes of material. The most common lengths in use in this country are 8 inches and 2 inches (1), corresponding closely with the Continental lengths of 200 millimetres and 50 millimetres.

There is one remaining difficulty, namely, that of securing comparable measurements with bars of different sectional form. The importance of this point is such that the proportions of the test-bar may make all the difference between an apparently satisfactory and an apparently unsatisfactory material. The great majority of bars submitted to the tensile test are either of circular or of rectangular section, and the difficulty consists in comparing among themselves the values obtained from rectangular bars having varying widths and thicknesses, and in turn comparing these with the values obtained from round bars. The object of the experiments to be described was to determine the variation of apparent strength and ductility caused by variation in the width of soft steel test-bars of constant thickness.

2. Earlier Investigations.

The earliest experiments which bear upon the point under discussion appear to be those of Barba (2). This investigator cut from a steel plate, 10 mm. (0·39 inch) thick, a number of test-bars with widths of 10 to 80 mm., and obtained the results set forth in Table I.

TABLE I.

Tensile Tests of Soft Steel Bars 10 mm. Thick (Barba).

Width. mm.	Ratio, $\frac{\text{width}}{\text{thickness}}$.	Yield-point.		Tenacity.		Extension per cent. on	
		Kg. per sq. mm.	Tons per sq. inch.	Kg. per sq. mm.	Tons per sq. inch.	50 mm.	100 mm.
10	1	24·8	15·8	38·4	24·4	37·6	31·0
20	2	24·6	15·6	40·1	25·5	45·0	34·0
30	3	25·4	16·1	39·4	25·0	48·0	35·0
40	4	25·0	15·9	39·8	25·3	52·0	37·0
50	5	24·6	15·6	38·1	24·2	56·0	39·0
60	6	24·9	15·8	37·7	23·9	61·0	40·8
70	7	24·8	15·8	37·8	24·0	57·0	38·5
80	8	23·5	14·9	38·4	24·4	52·0	34·5

The yield-point and the tenacity of the metal remain sensibly constant, but the extension, measured on two different gauge-lengths of 50 and 100 mm. respectively, shows considerable variation. In fig. 1 the extension is plotted against the ratio width/thickness, and both curves exhibit a well-marked maximum when the width is about six times the thickness.

Experiments by investigators subsequent to BARBA have thrown some doubt upon the existence of such a maximum. APPLEBY (3) found that the extension increased continuously up to the ratio width/thickness = 8, the highest ratio employed in his experiments, but he used a hard grade of Bessemer steel. The results obtained by UNWIN (4) with several different grades of mild steel and a constant gauge-length of 8 inches, show frequently a maximum value of the extension, but the ratio of width to thickness at which this maximum occurs is variable and often ill-defined. Moreover, in most of the series of test-bars the thickness was varied. This method has the disadvantage, from the present point of view, that it is difficult with a variable thickness of plate to maintain a sufficiently uniform quality of material.

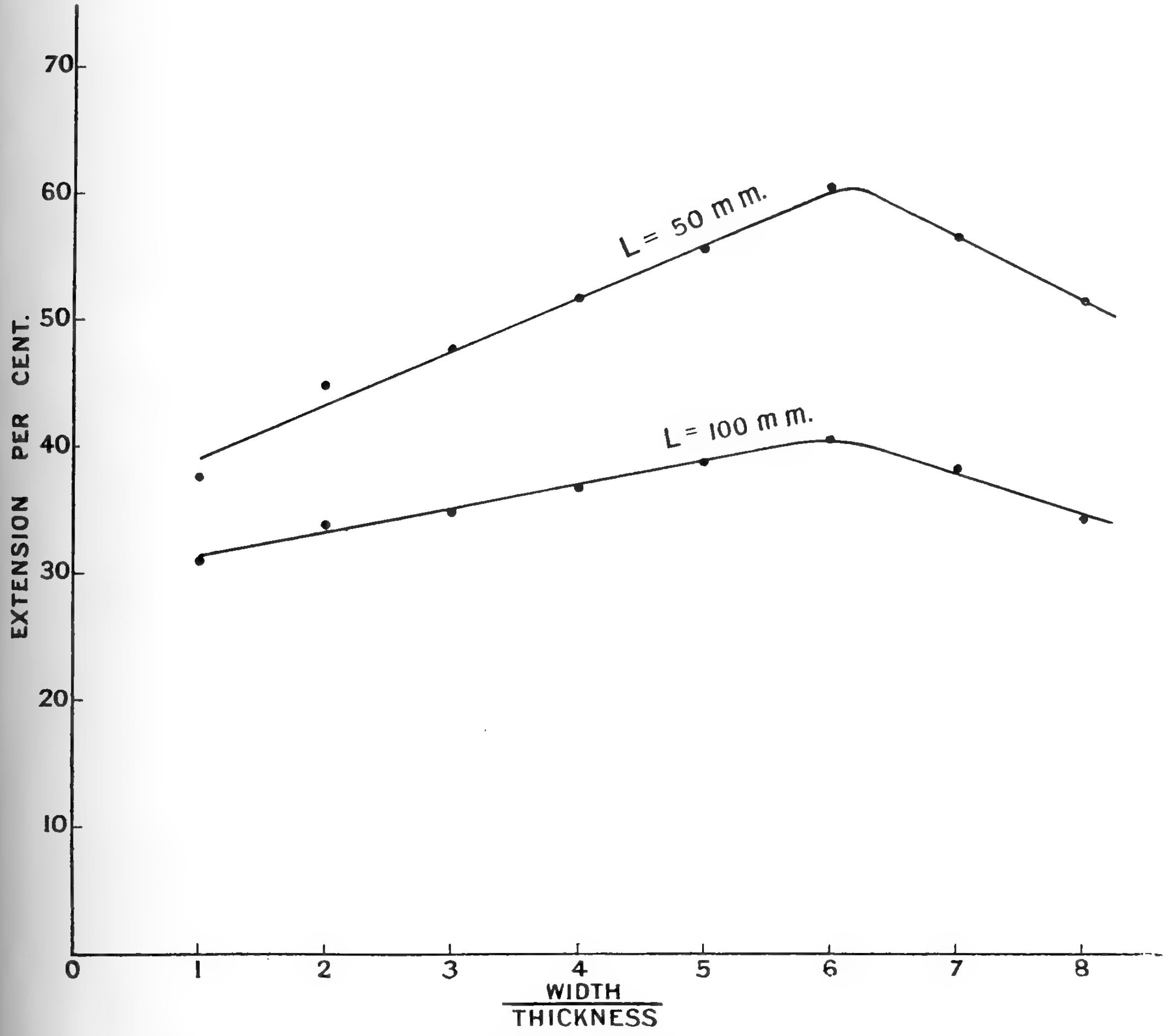

FIG. 1.—Variation of extension of flat test-pieces with change in the ratio of width to thickness; measurements obtained from bars of soft steel having widths from 10 to 80 mm., a constant thickness of 10 mm., and gauge-lengths of 50 and 100 mm. (BARBA).

Consideration of the principle of similitude suggests that the extensions of bars of dissimilar section would be more nearly constant if, instead of a fixed gauge-length, one proportional to the square root of the cross-sectional area were employed. By means of tests of round, square, flat, angle, and channel bars, BARBA has shown that this expectation is nearly fulfilled (2). The longer standard round test-bar in use on the Continent is 20 mm. diameter and 200 mm. long, the length being thus $11{\cdot}3\sqrt{\text{area}}$; bars of other shapes and sizes are therefore given a gauge-length of $11{\cdot}3\sqrt{\text{area}}$ when comparable measurements are required. The longer British standard round test-bar has a length eight times its diameter, equivalent to $9\sqrt{\text{area}}$; the shorter round standard has a length of $4\sqrt{\text{area}}$ (1), but for bars of rectangular section the length is fixed at 8 inches.

So long as the section is of compact form—that is, circular, square, or rectangular with a width not greater than about three thicknesses—the extension of any bar conforms closely with a simple linear equation due to UNWIN (4):—

$$e \text{ per cent.} = 100\left(a + b \cdot \frac{\sqrt{A}}{L}\right),$$

in which a and b are constants, A is the cross-sectional area, and L is the datum-length. In the case of rectangular bars having a breadth considerably exceeding the thickness, this simple equation is not fulfilled.

3. EXPERIMENTAL DETAILS.

The primary object of the present experiments is to investigate the variation in the extension of flat bars of mild steel of constant thickness as the width is gradually increased. The advantage of varying the width instead of the thickness of the test-bars is twofold:—

(1) The work of preparing the bars is less.
(2) The material is of more uniform quality.

The material employed was soft boiler plate, $\frac{1}{4}$ inch thick. No chemical analysis was made, but a section of the metal, magnified 100 diameters, is given in fig. 2. This shows the usual features of soft steel—the ground mass of ferrite or α-iron, the dark areas of pearlite or $Fe\text{-}Fe_3C$ eutectoid, and a few small slag inclusions of elongated form,—and it indicates the presence of 0·12 to 0·15 per cent. of carbon.

The plate was cut, in the direction of rolling, into strips, approximately $\frac{1}{2}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$, 3, $3\frac{1}{2}$, and 4 inches wide, and these were machined carefully on the edges, and lightly ground on the wide faces to remove the mill scale. There were three bars of each width, with the exception of those $3\frac{1}{2}$ inches wide, of which there were only two. Each bar had a total length of 18 inches, of which 3 inches at each end was held within the grips of the testing machine. A centre line was scribed on both wide faces of each bar; that on one face was divided carefully into inch lengths, and on the other a length equal to 11·3 times the square root of the area of the bar was set out and subdivided into a number of equal parts. On both faces the divisions were continued over the middle 12 inches of the length, in order that the extension might be computed in a satisfactory manner. The width and thickness of each bar were determined by a micrometer to ·001 inch; the maximum variation in dimensions did not exceed 0·5 per cent. In Table II. are given, averaged for each set of bars, the cross-sectional dimensions and area, the square root of the area, and the ratio of width to thickness.

FIG. 2.—Longitudinal section of soft steel plate containing 0·12 to 0·15 per cent. of carbon; etched with picric acid and sodium picrate; magnified 100 diameters.

TABLE II.

DIMENSIONS OF TEST-BARS.

Nominal Width. Inches.	Actual Width. Inches.	Thickness. Inch.	Area. Sq. inches.	$\sqrt{\text{Area}}$.	$\frac{\text{Width}}{\text{Thickness}}$.
$\frac{1}{2}$	0·450	0·255	0·115	0·339	1·76
1	0·967	0·254	0·245	0·495	3·81
$1\frac{1}{2}$	1·443	0·256	0·370	0·608	5·64
2	1·947	0·257	0·501	0·708	7·57
$2\frac{1}{2}$	2·478	0·259	0·642	0·801	9·57
3	2·897	0·260	0·752	0·867	11·14
$3\frac{1}{2}$	3·451	0·259	0·894	0·945	13·32
4	3·955	0·257	1·016	1·008	15·39

The bars from $\frac{1}{2}$ inch to 3 inches wide were tested in the Riehlé (gear-driven) machine, and those $3\frac{1}{2}$ and 4 inches wide in the Buckton (hydraulic) machine of the Engineering Department of the University of Edinburgh. When setting the bars in the testing machine, the centre line of one face was plumbed so that the load should be as nearly axial as possible. The wedge-grips of the Riehlé machine, in which most of the bars were tested, are made with slightly convex faces to assist in this respect. The rate of straining was kept constant throughout the tests at about 0·12 inch per minute, that is, 1 per cent. per minute on the 12-inch length between the grips.

The loads noted during the test were the yield load, at which permanent stretch becomes well marked, the maximum load carried, and the load sustained by the bar at the moment before rupture; the last is difficult to determine with great accuracy. After fracture the various dimensions of each bar were re-measured for comparison with the original dimensions. From these measurements the variations in mechanical properties, corresponding with change in the ratio of original width/original thickness of the bars, have been deduced. The more important quantities dealt with are:—

(1) The yield point, the tenacity, and the mean breaking stress.

(2) The extension on various constant gauge-lengths, on gauge-lengths proportional to the ratio width/thickness, and on gauge-lengths proportional to the square root of the cross-sectional area.

(3) The reduction of area at fracture.

4. Yield Point and Tenacity.

The *yield point* is the stress at which there is marked evidence of permanent distortion of the metal; it is found by dividing the yield load by the original area of cross-section of the bar. From the figures given in Table III. it is evident that the yield point is not affected sensibly by a change in the ratio width/thickness. The average yield point is at 18·14 tons per square inch.

TABLE III.

Variation of Yield Point, Tenacity, and Mean Breaking Stress, with the Ratio Width/Thickness.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$.	Yield Point. Tons per sq. inch.	Tenacity. Tons per sq. inch.	Mean Breaking Stress. Tons per sq. inch.
½	1·76	18·17	25·26	54·29
1	3·81	18·28	25·32	50·64
1½	5·64	18·29	25·45	48·77
2	7·57	18·10	25·45	46·00
2½	9·57	18·08	25·47	49·87
3	11·14	18·00	25·40	47·91
3½	13·32	18·05	25·66	50·03
4	15·39	18·16	25·87	50·75

The *tenacity* is the maximum load carried by the bar divided by the original cross-sectional area. This quantity also remains almost constant throughout the series of bars, though there is a slight tendency to rise as the width is increased; the figures are given in Table III. The average tenacity is 25·49 tons per square inch.

The tenacity, as defined above, though a useful quantity to the engineer, furnishes no information as to the maximum stress sustained by the metal. A near approximation to the actual maximum stress is obtained by dividing the actual load supported at the instant before fracture by the minimum cross-sectional area of the broken bar; it may be called the *mean breaking stress.* The actual load carried just before rupture is difficult to determine with accuracy on account of the localisation of the distortion and the relative rapidity with which the metal extends in this region, but much care was taken to secure correct results. In order to determine the minimum cross-sectional area of the broken bar the average thickness of the metal was obtained by a number of measurements at equidistant points along the fracture, and this was multiplied by the minimum width of the bar; the difficulties of measurement do not admit of extreme accuracy here. The values of the mean breaking stress are given in Table III., and are plotted in fig. 3; the amount of variation is not great, hardly more than may be due to uncertainties of measurement.

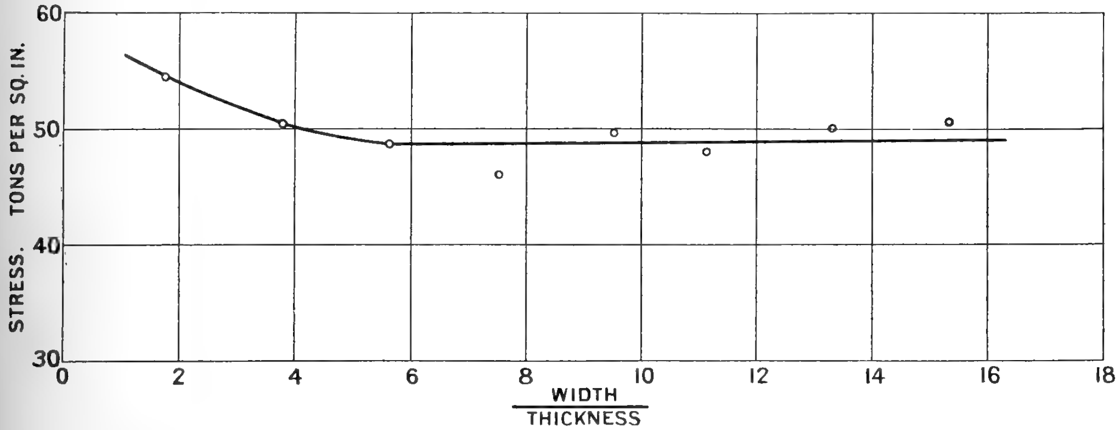

FIG. 3.—Variation of mean breaking stress of flat test-pieces with change in the ratio of width to thickness; measurements obtained from bars of soft steel having widths from ½ inch to 4 inches, and a constant thickness of ¼ inch.

5. EXTENSION.

The measurements of extension were taken chiefly from that side of each bar which was divided originally into inch lengths, and were always made symmetrically on each side of the inch within which fracture occurred. This procedure is necessary in order to nullify the variations due to the position of the fracture, and is employed in most important testing laboratories. The measurements were made along the longitudinal centre line of each bar, and the breadth of the gap left between the two broken surfaces was deducted from the total length. The gap is usually broadest at about the middle of the width of the bar, owing to the fact that fracture generally begins there, and that the neighbouring unbroken parts continue to stretch until they are sundered in turn. Fig. 4 is an outline of one of the bars after fracture; the thick irregular line shows the gap left when the two broken halves are pressed tightly together. The variation in the breadth of this gap with change in the size of test-bar can be obtained from Table V. and figs. 8 and 12.

In Table IV. are given the mean extensions of original lengths of 1, 3, 5, 7, 9, 11, 13, and 15 inches for each series of bars. The extension on a 1-inch length is the measured extension of the inch within which fracture took place; that on a 3-inch length is the extension of the fractured inch plus the extension of the inch on each side; the extension on a 5-inch length is the extension on the 3-inch length plus the extension of the next inch at each end, and so on. In the case where, owing to the fracture being nearer one end than the other, a datum inch is available only on one side of the previously measured length, twice the extension of this inch is added to the previous total. The extension in all cases is expressed as a percentage of the original gauge-length. The extension of the first inch is subject to error since the variation of position of the fracture within this length has been neglected; this error is more important in the wider bars. In the extension of longer lengths the error diminishes rapidly, and is negligible for greater lengths than 5 inches, even in the widest bars used; it is therefore of little consequence from the present standpoint. Another cause

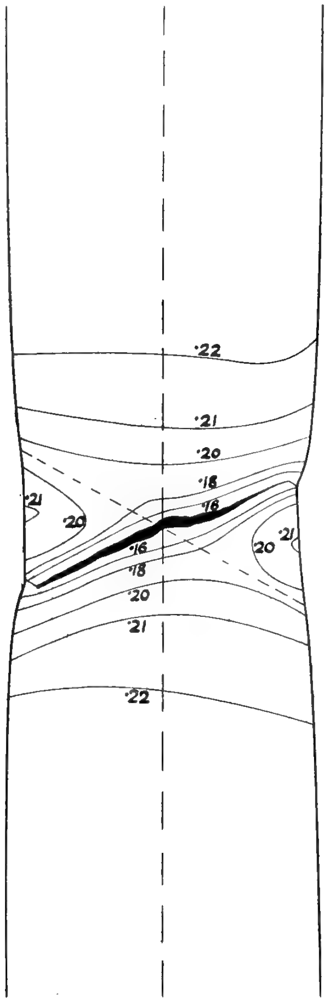

Fig. 4.—Outline of flat test-piece, originally 3½ inches wide and ¼ inch thick, showing the gap left between the fractured surfaces. The variation of thickness in the constricted region is indicated on the contour lines in hundredths of an inch.

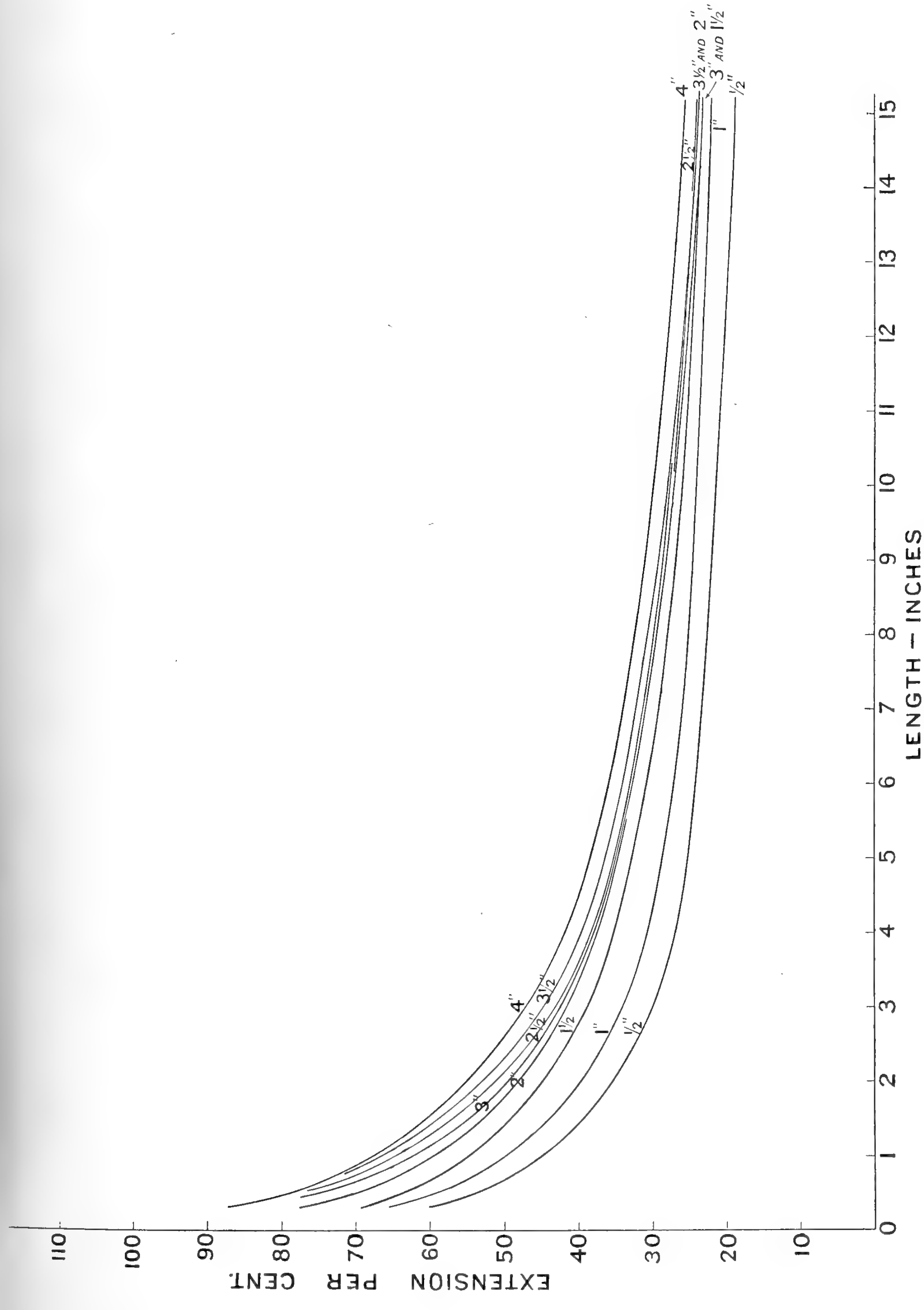

FIG. 5.—Variation of extension of flat test-pieces with change in length; measurements obtained from bars of soft steel having widths from ½ inch to 4 inches, a constant thickness of ¼ inch, and gauge-lengths from 1 inch to 15 inches.

TABLE IV.

Extension of Bars of Different Widths, Measured upon Various Fixed Lengths.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$	Extension per cent. on a Length of								
		0	1	3	5	7	9	11	13	15 Inches.
$\frac{1}{2}$	1·76	179	45·0	30·2	25·3	23·8	22·2	20·9	19·9	19·1
1	3·81	147	50·0	34·2	28·8	26·1	24·7	23·8	22·8	22·2
$1\frac{1}{2}$	5·64	128	55·0	38·9	33·0	29·4	27·1	25·5	24·3	23·3
2	7·57	122	59·7	41·7	34·7	31·0	28·2	26·5	25·2	24·0
$2\frac{1}{2}$	9·57	128	65·0	43·2	35·3	31·4	28·6	26·8	25·3	24·2
3	11·14	117	62·3	42·8	35·1	31·2	28·2	26·2	24·6	23·4
$3\frac{1}{2}$	13·32	127	67·0	44·8	36·5	32·4	29·3	27·0	25·3	24·0
4	15·39	121	68·0	47·3	38·6	34·4	31·2	29·1	27·1	25·7

of irregularity is the presence of one or more incipient constrictions along the length of a bar, other than that at which rupture has ultimately developed. Such a constriction gives rise to a local increase in the extension, and to a corresponding peak in the curve, but this is smoothed out by taking the average for each set of three bars. No allowance has been made for these small constrictions since they cannot be prevented in an ordinary test. The differences between the extensions of the bars in each set are due chiefly to these two causes.

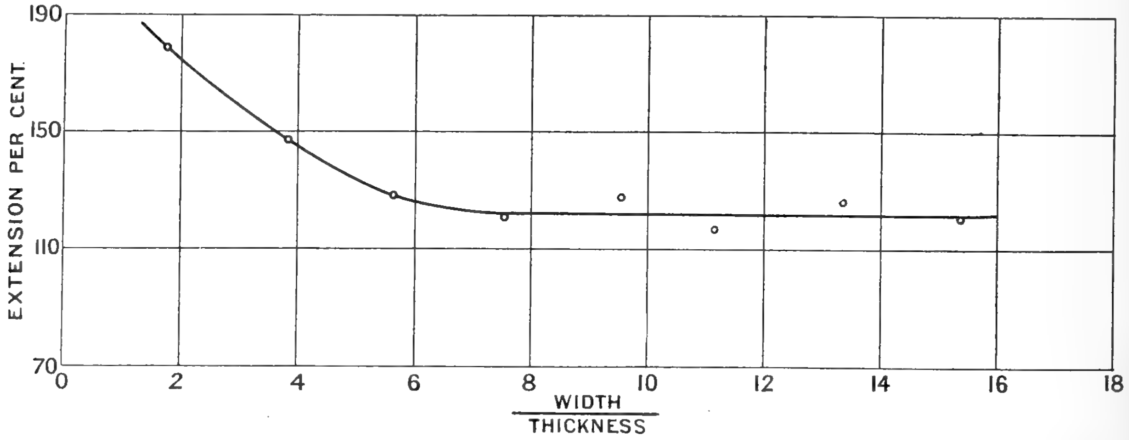

Fig. 6.—Variation of maximum extension at fracture of flat steel test-pieces with change in the ratio of width to thickness from 2 to 16, and a constant thickness of $\frac{1}{4}$ inch.

In fig. 5 are plotted the figures of Table IV. for each width of bar. The extension for all bars decreases at first very rapidly from the fracture, and then more slowly, tending towards a minimum which is probably about constant for all. Generally speaking, the curve of extension for one bar lies completely above that for another of less width, but this is reversed in the case of the $2\frac{1}{2}$- and 3-inch bars.

The extension at zero length, *i.e.* at the position of fracture, has been deduced from the area of the minimum cross-section. Let $\delta\lambda$ be the increase in length of an original length δl, through which the fracture passes. Let Ω be the original area of cross-section, and Ω' the final area of cross-section of the bar. Then, if the volume of the metal remains constant, a condition which is nearly fulfilled,—

$$\delta l \,.\, \Omega = (\delta l + \delta\lambda) \,.\, \Omega'$$

or the extension is,

$$\frac{\delta\lambda}{\delta l} = \frac{\Omega - \Omega'}{\Omega'}.$$

This gives approximately the maximum limiting extension. The mean values are given in Table VIII. and are plotted in fig. 6; there is a sharp drop at first, but for the bars wider than 1 inch the values are nearly constant.

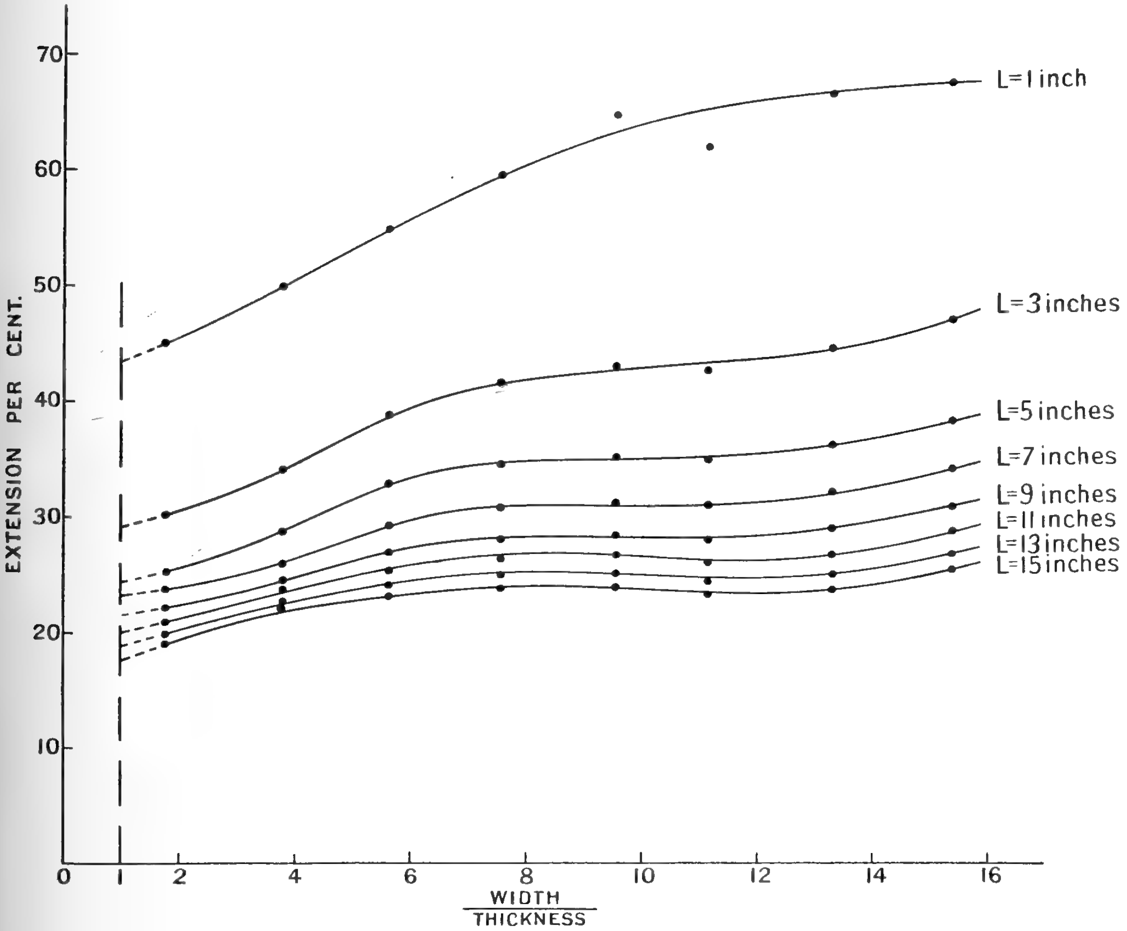

FIG. 7.—Variation of extension of flat steel test-pieces with change in the ratio of width to thickness from 2 to 16, a constant thickness of ½ inch, and gauge-lengths of 1 inch to 15 inches.

Fig. 7 shows the data of Table IV. plotted, not for each bar separately, but for each fixed length of bar, and it illustrates the manner in which the extension of a fixed length varies as the width of the bar is increased. The curves, excluding that for a 1-inch length, are all of the same type; the extension rises at first as the width of the bar is increased, then remains almost constant, and finally rises again at about the same rate as at first. In fig. 8 is drawn separately, with a more open vertical scale, the curve of extension for a length of 8 inches, the standard fixed length for flat test-pieces in this country. The vertical distance between the two curves of fig. 8 represents the breadth of the gap at fracture, expressed as a percentage of 8 inches. The numerical data are given in Table V.

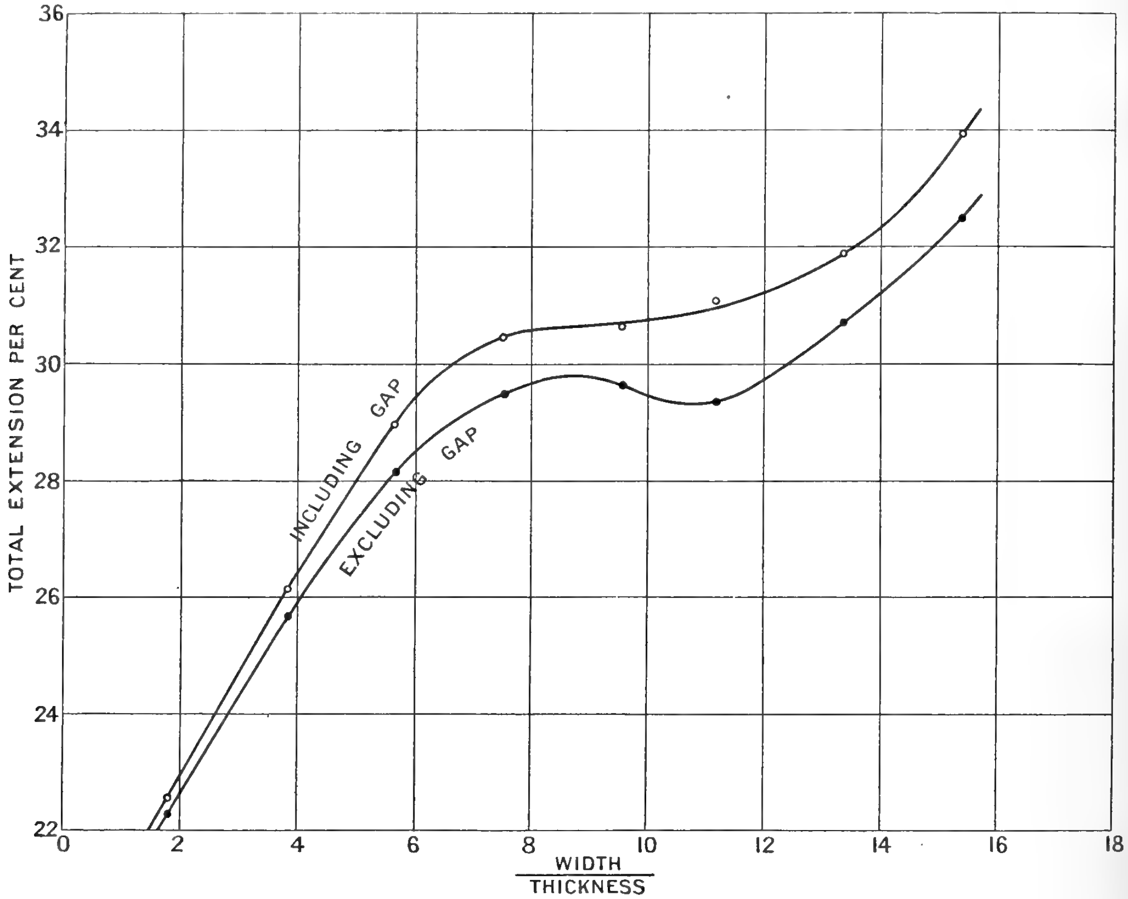

FIG. 8.—Similar to fig. 7, but with a gauge-length of 8 inches. The vertical distance between the two curves is the breadth of the gap at fracture, expressed as a percentage of 8 inches.

TABLE V.

EXTENSION OF BARS OF VARIOUS WIDTHS, MEASURED UPON LENGTHS OF 8 INCHES, AND 11·3 $\sqrt{\text{AREA}}$.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$.	Extension per cent.			
		Gauge-length = 8 Inches.		Gauge-length = 11·3 $\sqrt{\text{Area}}$.	
		Gap included.	Gap deducted.	Gap included.	Gap deducted.
½	1·76	22·58	22·29	28·18	27·57
1	3·81	26·15	25·69	28·79	28·13
1½	5·64	28·98	28·15	30·21	29·24
2	7·57	30·44	29·48	30·44	29·48
2½	9·57	30·61	29·61	29·39	28·51
3	11·14	31·10	29·35	28·75	27·32
3½	13·32	31·90	30·71	28·17	27·28
4	15·39	33·93	32·47	29·70	28·68

The form of the curves of extension given in figs. 7 and 8 differs from that obtained by Barba (fig. 1), in showing no well-marked maximum. If the process of deformation were the same in all the bars, so that the geometrical shape of the constricted region remained invariable, the extension of a fixed length would increase continuously with increase in the width of the bar. The fact that it does not indicates that the shape of the constricted region varies in such a way that there is less constriction, and therefore less corresponding extension, in a wide bar than in a narrow one. But, on the other hand, the extension of a fixed length of a wide bar is greater than that of a narrow bar because the length is relatively less. These two factors which influence the extension act therefore in opposite directions, and from the shape of the curves of figs. 7 and 8 it is evident that these factors approximately equalise each other over a certain range of the ratio width/thickness, namely from about 7 to 12.

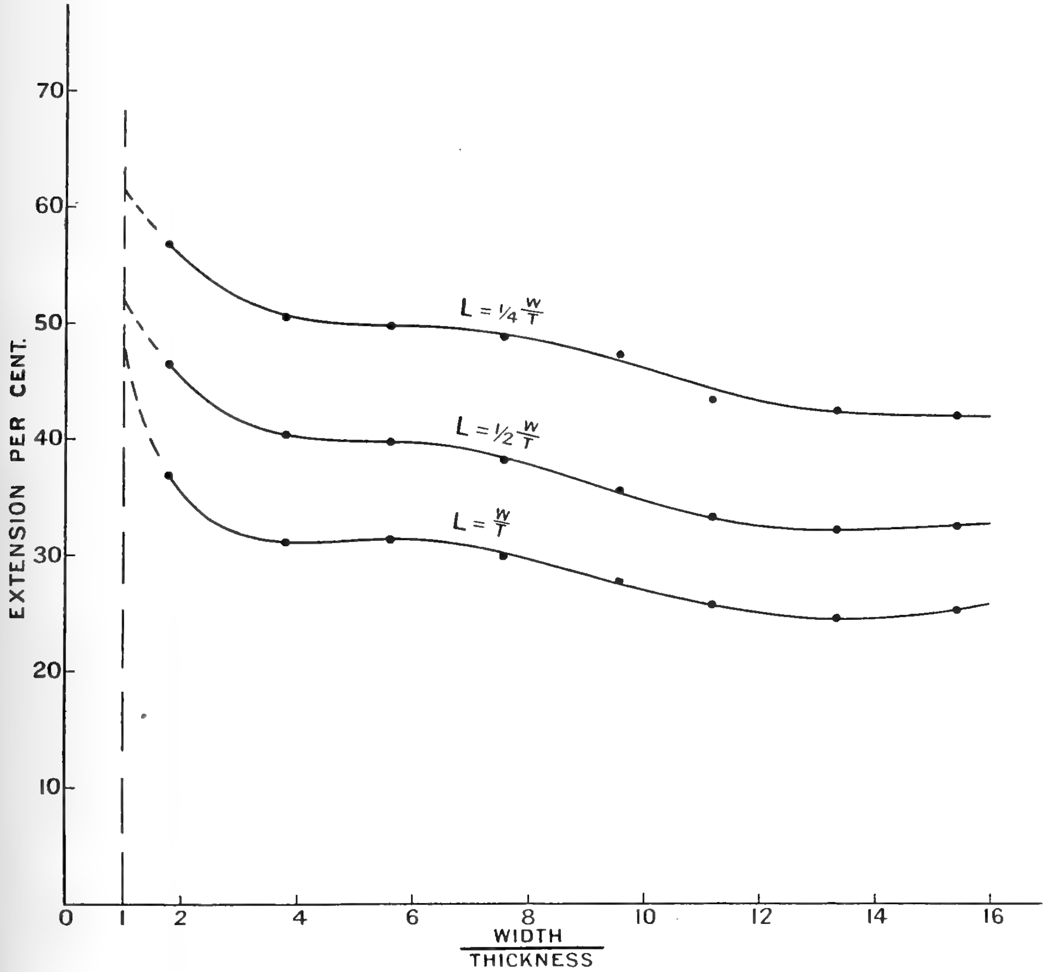

Fig. 9.—Variation of extension of flat steel test-pieces with change in the ratio of width to thickness from 2 to 16, a constant thickness of ½ inch, and gauge-lengths proportional to the ratio width/thickness expressed in inches.

That there is less constriction of the wider bars may be shown in two ways. In fig. 9 are plotted curves, from the values given in Table VI., showing the extension of lengths proportional to the widths of the bars; the extension diminishes generally as the width increases, though in a somewhat irregular manner. The more striking method is to compare the actual shapes of the fractured bars. This has been done in fig. 10, where the mean outlines of the bars originally about $\frac{1}{2}$, 1, 2, and 4 inches wide are drawn to the scale of their original dimensions, all reduced to the same size for convenience of comparison. It is evident that the proportional reduction in width is less the wider the bar, and that there is consequently less extension of the wider bars in the constricted region. The inset in fig. 10 shows in a similar manner the mean thickness of the same four sets of bars, as measured along the longitudinal centre line; the order of the curves is just the same as for the width. It is interesting to note that the final minimum thickness of all the bars measured at the broken surface is nearly constant. For the larger diagram the origin is at the centre of the gap, while for the

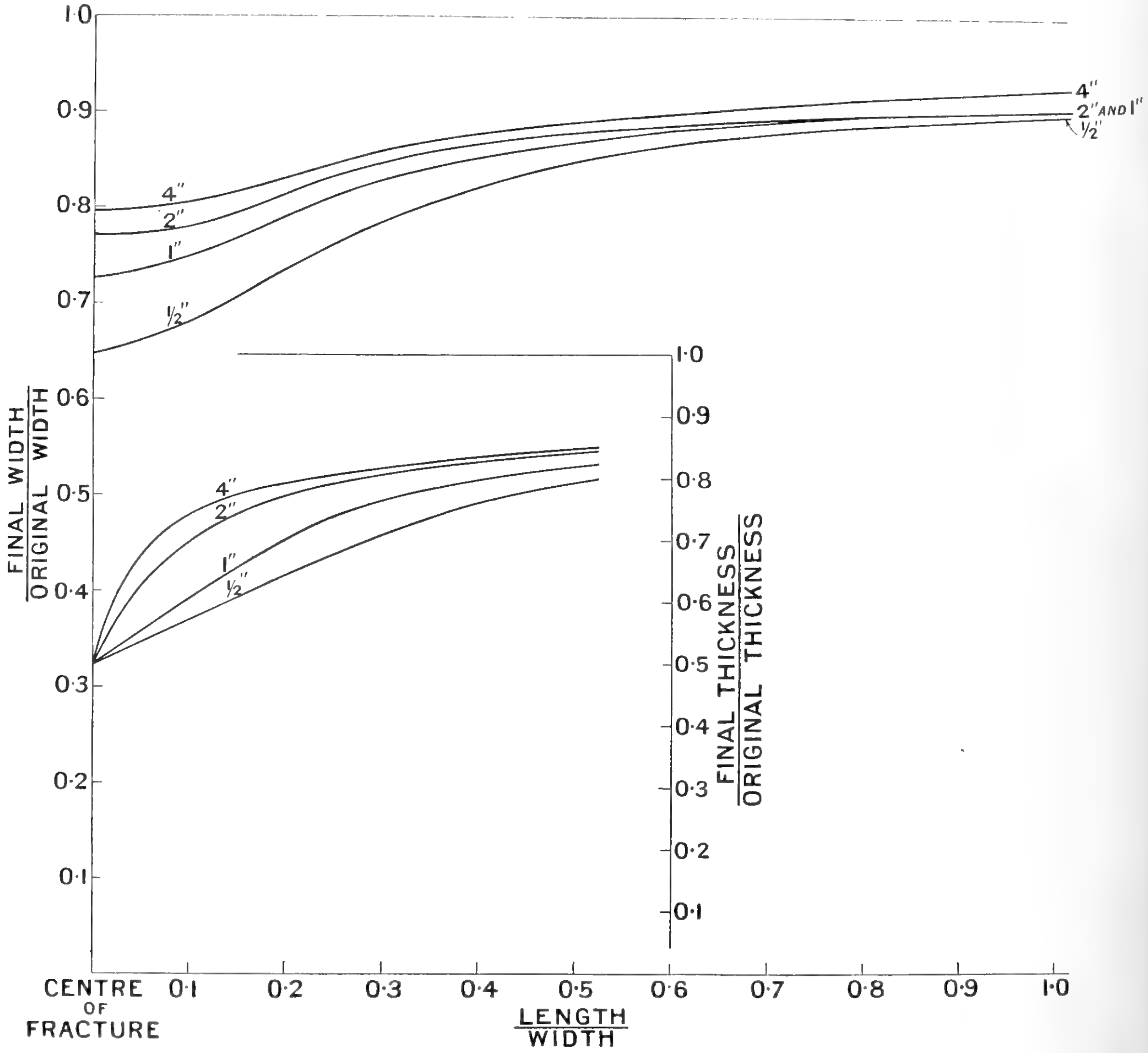

FIG. 10.—Mean profiles of width of flat steel test-pieces after fracture; measurements taken from bars having widths of $\frac{1}{2}$, 1, 2, and 4 inches, and a constant thickness of $\frac{1}{4}$ inch.
Inset.—Mean profiles of thickness of same bars, measured on longitudinal centre line.

inset the origin is shifted slightly so as to correspond with the edge of the broken surface. In both cases the cross dimensions have been set up from a straight base, so that the figures do not represent the true shape of the bars. The profiles of the 1½-, 2½-, 3-, and 3½-inch bars have been omitted for the sake of clearness.

TABLE VI.

Extension of Bars of Different Widths, Measured upon Lengths Proportional to the Ratio $\frac{\text{Width}}{\text{Thickness}}$.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$.	Extension per cent. on a Length equal to		
		$\frac{\text{Width}}{\text{Thickness}}$.	$\frac{1}{2}\cdot\frac{\text{Width}}{\text{Thickness}}$.	$\frac{1}{4}\cdot\frac{\text{Width}}{\text{Thickness}}$ inches.
½	1·76	37·0	46·5	56·8
1	3·81	31·3	40·5	50·6
1½	5·64	31·6	39·9	49·9
2	7·57	30·2	38·4	49·0
2½	9·57	28·1	35·8	47·5
3	11·14	26·1	33·6	43·7
3½	13·32	24·9	32·5	42·8
4	15·39	25·6	32·9	42·4

In fig. 4 the actual outline of one of the bars is shown, and the variations in thickness are indicated by the contour lines, drawn at intervals of ·02 inch (the contour for a thickness of 0·21 inch is given also). There are evidently two nearly straight depressions crossing the bar, and intersecting each other at about the middle of its width. This peculiar phenomenon, which is a characteristic of flat metal bars broken by tension, is known as the Contractile Cross; its essential features have been described elsewhere (5). Fracture takes place frequently, but not invariably, along one of the grooves; in the figure the line of fracture has followed one groove, and the bottom of the other groove is indicated by the oblique dotted line.

The extensions, as measured on various lengths proportional to the square root of the cross-sectional area of each bar, are given in Table VII., from which fig. 11 has been drawn. The extension is much more nearly constant than in the case of a fixed gauge-length, but there are still variations. The change in the form of the constricted region has here a greater effect than in the case of the fixed length; in other words, the factor which formerly was sufficient to neutralise the effect of relative decrease of length and to keep the extension nearly constant over a certain range, is now able to give rise to an actual depression in the value of the extension within that range. The curves of extension of fig. 11 are therefore of wave form, the extension at first increasing, then decreasing, and then increasing again as the ratio width/thickness is increased continuously. There is no great difference in the form of the curves for lengths between $2\sqrt{\text{area}}$ and $15\sqrt{\text{area}}$.

TABLE VII.

Extension of Bars of Different Widths, Measured upon Lengths Proportional to $\sqrt{\text{Area}}$.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$	Extension per cent. on a Length equal to				
		$\sqrt{\text{Area}}$.	$2\sqrt{\text{Area}}$.	$5\sqrt{\text{Area}}$.	$10\sqrt{\text{Area}}$.	$15\sqrt{\text{Area}}$.
½	1·76	59·0	50·0	37·7	28·7	25·3
1	3·81	59·2	50·0	36·6	28·8	25·7
1½	5·64	61·6	52·2	38·7	30·7	26·8
2	7·57	65·0	53·8	39·3	30·8	26·8
2½	9·57	68·8	55·7	38·4	29·8	26·0
3	11·14	64·7	52·2	36·8	28·6	24·6
3½	13·32	67·8	54·0	37·2	28·6	24·3
4	15·39	67·6	55·0	38·4	29·8	25·6

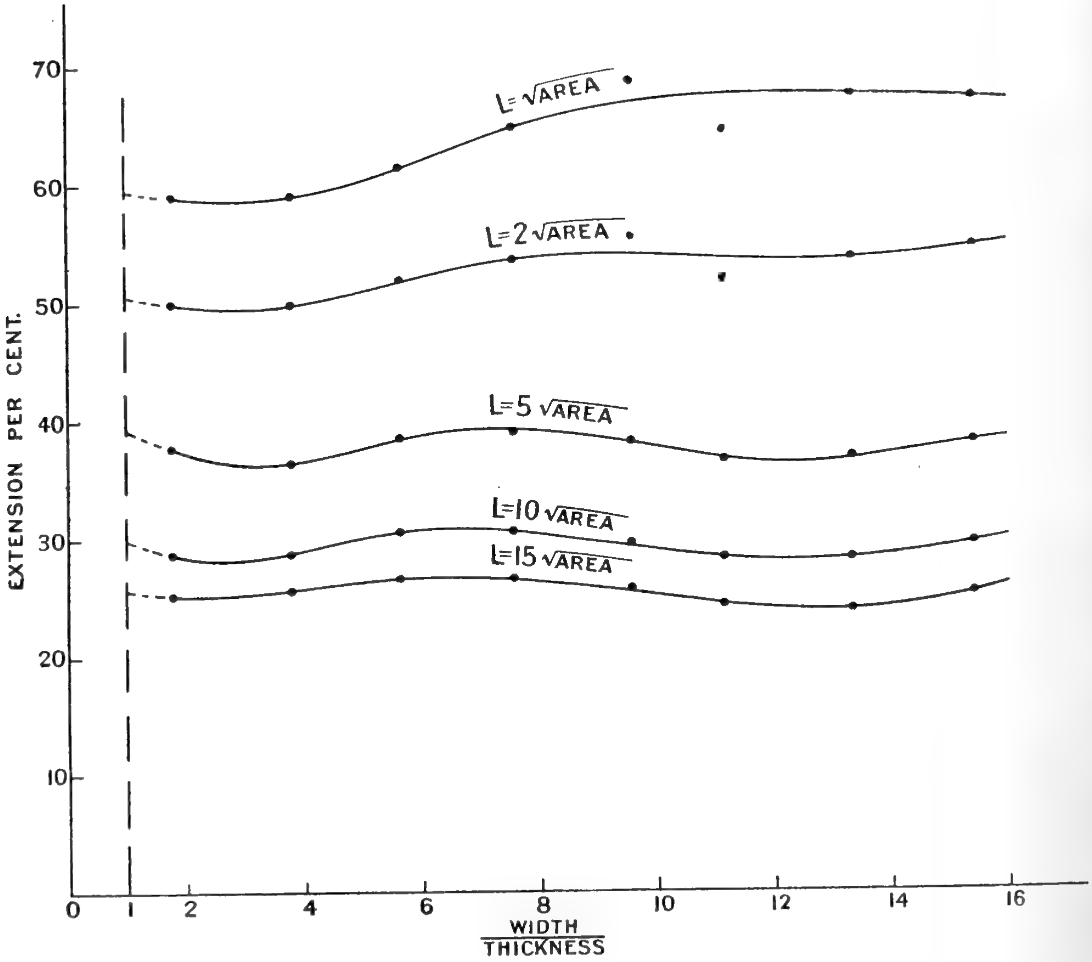

Fig. 11.—Variation of extension of flat steel test-pieces with change in the ratio of width to thickness from 2 to 16, a constant thickness of ¼ inch, and gauge-lengths of $\sqrt{\text{area}}$ to $15\sqrt{\text{area}}$.

In fig. 12 the curve of extension for a length equal to $11{\cdot}3\sqrt{\text{area}}$, the Continental standard variable length, is plotted separately with a more open vertical scale; it has much the same characteristics as those of fig. 11. Notice may be taken of the fact that the breadth of the gap varies almost directly as $\sqrt{\text{area}}$, the two curves of fig. 12 being nearly parallel. The data for fig. 12 are given in Table V.

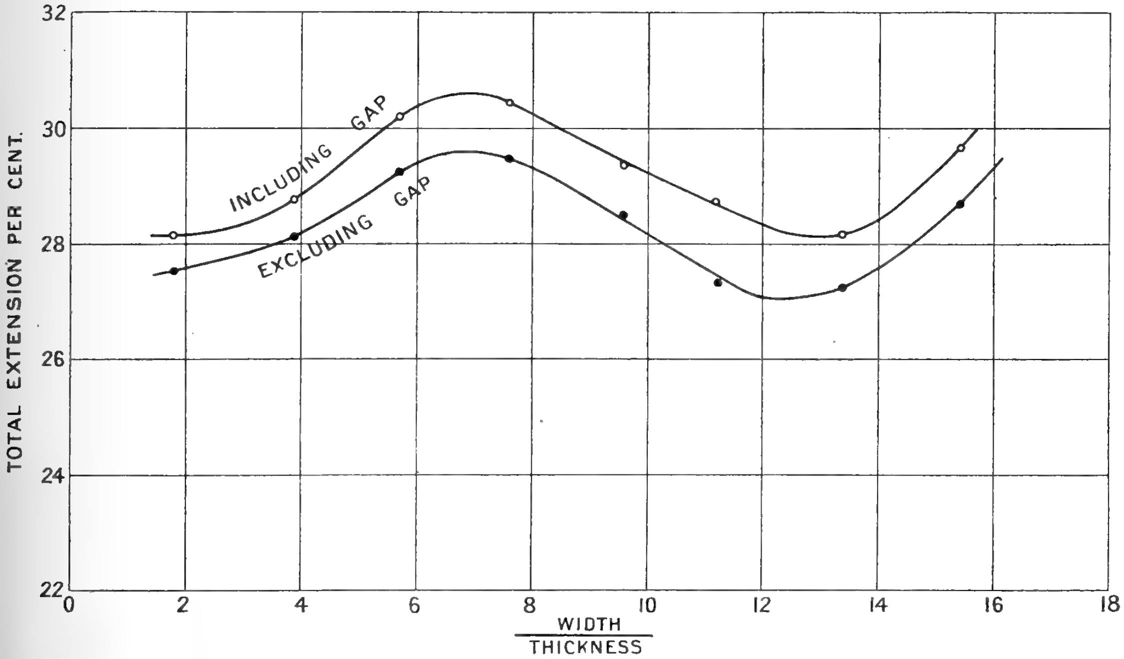

FIG. 12.—Similar to fig. 11, but with a gauge-length of $11{\cdot}3\sqrt{\text{area}}$. The vertical distance between the two curves is the breadth of the gap at fracture, expressed as a percentage of $11{\cdot}3\sqrt{\text{area}}$.

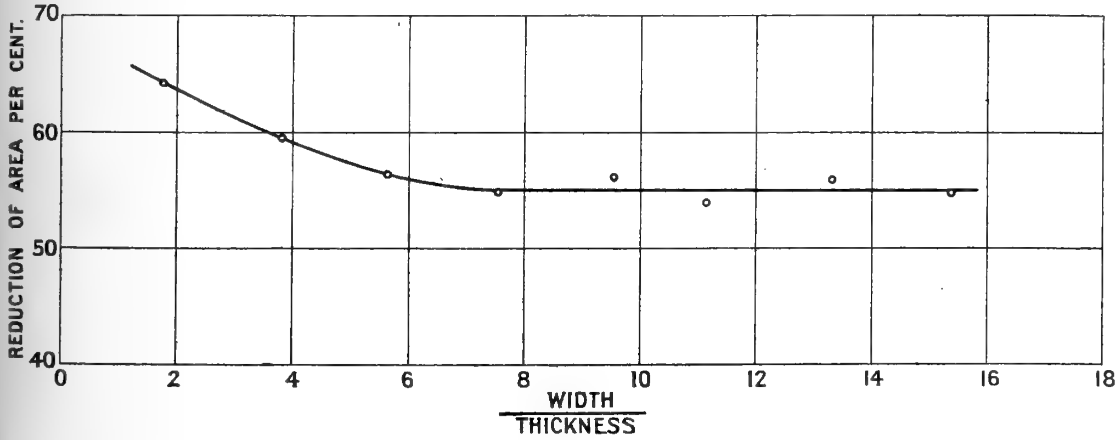

FIG. 13.—Variation in reduction of area of flat steel test-pieces, with change in the ratio of width to thickness from 2 to 16, and a constant thickness of $\frac{1}{2}$ inch.

6. REDUCTION OF AREA.

The *reduction of area* is the difference between the original cross-sectional area of the bar and the minimum area measured after fracture, expressed as a fraction of the original area; that is, the reduction of area is $\Sigma = \frac{\Omega - \Omega'}{\Omega}$, where Ω and Ω'

represent the original and the final area, respectively. The values of this quantity are given in Table VIII., and a curve showing its variation with the ratio width/thickness is drawn in fig. 13. The curve is of the same form as that of fig. 6, the curve of maximum extension at fracture, the two quantities being related thus:—

$$\text{Maximum extension, } \frac{\delta\lambda}{\delta l} = \frac{\Sigma}{1-\Sigma}.$$

TABLE VIII.

Reduction of Area, and Maximum Extension at Fracture.

Nominal Width. Inches.	$\frac{\text{Width}}{\text{Thickness}}$.	Reduction of Area. Per cent.	Maximum Extension at Fracture. Per cent.
$\frac{1}{2}$	1·76	64·1	178·7
1	3·81	59·5	147·8
$1\frac{1}{2}$	5·64	56·2	127·9
2	7·57	54·9	121·5
$2\frac{1}{2}$	9·57	56·2	128·8
3	11·14	54·0	117·1
$3\frac{1}{2}$	13·32	56·0	127·3
4	15·39	54·7	120·8

The method of determining the final area has been described already, and the difficulty of securing accuracy has been mentioned. In the neighbourhood of fracture the section of a bar initially rectangular is not a rectangle, but has curved sides, the curvature being less pronounced the wider the bar. Moreover, the ratio of width/thickness does not remain constant but increases during extension; in other words, the metal is reduced relatively more in thickness than in width, a result quite to be expected. Similarly the width is reduced less in the wide than in the narrow bars, even when compared with the diminished thickness. The values of the final ratio of width to thickness are given

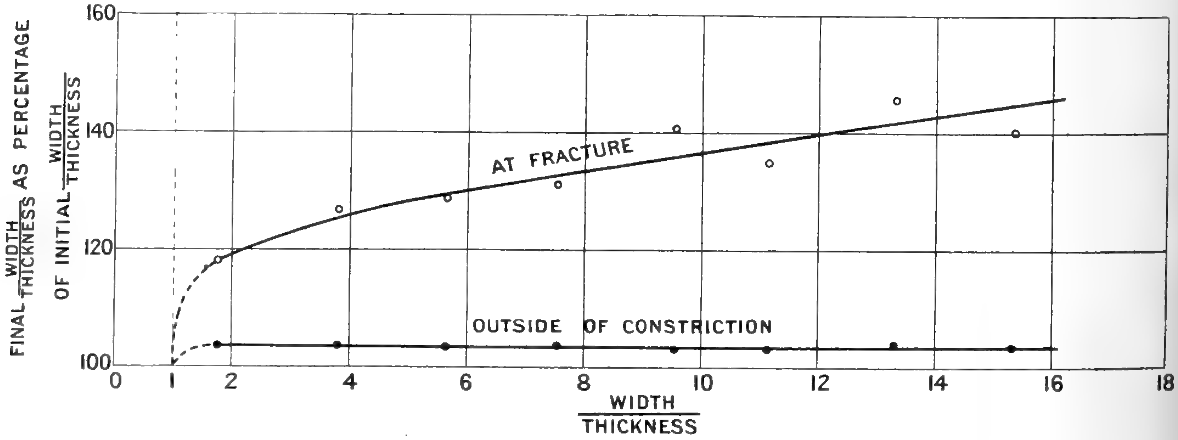

Fig. 14.—Change in the ratio of width to thickness of flat steel test-pieces after fracture. The upper curve shows the increase in the ratio at the fracture itself, and the lower one the increase in the sensibly parallel portion of the bar.

in Table IX., both at the fracture and at a point originally distant therefrom a length equal to the width of the bar. From fig. 14, in which these values are plotted, it is seen that the change in the ratio increases fairly continuously with the ratio itself as regards the measurements at fracture, while in the sensibly straight portion of the bar the increase of the ratio is almost constant at about 3½ per cent.

TABLE IX.

Initial and Final Ratios of Width to Thickness.

Nominal Width. Inches.	Width/Thickness.			Final ratio / Initial ratio. Per cent.	
	Initial.	Final.			
		At Fracture.	Outside of Constriction.	At Fracture.	Outside of Constriction.
½	1·76	2·07	1·82	117·6	103·4
1	3·81	4·85	3·95	127·3	103·7
1½	5·64	7·30	5·85	129·4	103·7
2	7·57	9·91	7·86	130·9	103·8
2½	9·57	13·53	9·88	141·4	103·2
3	11·14	15·01	11·50	134·8	103·2
3½	13·32	19·50	13·85	146·4	104·0
4	15·39	21·60	15·92	140·4	103·4

Summary.

In a series of flat test-bars of mild steel, of constant thickness and variable width, the effect of the ratio of width to thickness upon the apparent strength and ductility of the metal has been determined.

(1) The strength, both elastic and ultimate, is sensibly unaffected.

(2) The extension, measured on a fixed gauge-length of 8 inches, increases as the ratio width/thickness is increased from 2 to 7, remains sensibly constant from 7 to 12, and rises again as the ratio passes from 12 to 16. The extreme difference of extension is 10 per cent. on 8 inches, that is, nearly one-half of the extension of the narrowest bar.

The extension on other fixed gauge-lengths varies in a manner closely similar to the above.

(3) The extension, measured on a variable gauge-length equal to some definite proportion of the ratio width/thickness expressed in inches, decreases somewhat irregularly as the ratio itself increases.

(4) The extension, measured on a variable gauge-length equal to 11·3 $\sqrt{\text{area}}$, increases as the ratio width/thickness is increased from 2 to about 7, then decreases from 7 to about 12, and then increases as the ratio passes from 12 to 16. The extreme

difference of extension is only 2 per cent. on the gauge-length, that is, about one-fourteenth of the extension of the narrowest bar.

The extension on other variable gauge-lengths proportional to $\sqrt{\text{area}}$ changes in a somewhat similar manner.

(5) The reduction of area decreases as the ratio width/thickness is increased from 2 to 6, and then remains sensibly constant.

(6) The thickness of a flat bar is reduced relatively more than the width, and the width of a narrow bar is reduced relatively more than that of a wide one.

(7) The critical ratios of width to thickness are not strongly marked, and probably vary with the absolute thickness of the bar, and with the quality of the metal.

In conclusion, the thanks of the authors are due to Prof. Hudson Beare for the facilities accorded, and for the interest which he has shown in the work.

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XI.—A Monograph on the general Morphology of the Myxinoid Fishes, based on a study of Myxine. Part IV.—On some Peculiarities of the Afferent and Efferent Branchial Arteries of Myxine.

By F. J. Cole, D.Sc. Oxon., Professor of Zoology, University College, Reading. *Communicated by* Dr R. H. Traquair, F.R.S. (With One Plate.)

(MS. received November 21, 1911. Read January 8, 1912. Issued separately April 1, 1912.)

The first three parts of this work, on the skeleton and muscles, were published in the *Transactions* of the Society in 1905, 1907, and 1909.

In 1905[*] I briefly drew attention to the existence of vascular papillæ on the afferent branchial arteries of *Myxine*, which had up to that time escaped notice, and which I then described in the following words: "In addition to the definite blood-vessels, *Myxine* possesses a system of large lacunar spaces, such as the extensive subdermal cavity, the spongy tissue of the head, the peribranchial sinuses, etc., which have been generally regarded as belonging to the lymphatic system. I have, however, long been convinced that these spaces were in communication with the blood vascular stream. Jackson, in his work on the vascular system of *Bdellostoma*, mentions the passage of injection mass from the vessels into the lymphatics, but believes the connection between the two to have been an artificial one, since he does not find red blood corpuscles in the lymphatics in fresh and uninjected material. If this is true, then *Myxine* is greatly different, as blood is invariably to be found in the lymphatics in living material. Ewart, in his paper on the vascular peribranchial spaces in the Lamprey, correctly appreciates the situation, and explains the general appearance of blood in these spaces by connections between them and the internal jugular vein found by him.

"I shall enter fully into the morphology of these spaces in my fourth part on the vascular system of *Myxine*. In the meantime I may mention that I have discovered projecting from the posterior surface of each afferent branchial artery, at the place where this artery enters the gill sac, one or more papillæ, and I have found these in every specimen which has been dissected for them. On cutting serial sections of several of these papillæ it is seen that the base of each is widely excavated, and is, in fact, an evaginated portion of the cavity of the artery, whilst from this excavation there passes to open on to the exterior one or more fine channels lined by epithelium. The calibre of these channels is usually only slightly in excess of the *width* of an average red blood corpuscle. The presence of these channels at once explains the appearance of blood in the peribranchial sinuses in the normal living fish, and it seems certain that there must be other connections between the blood-vessels and the so-called lymphatic spaces in other parts of the body."

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[*] *Anat. Anz.*, Bd. xxvii. pp. 325–6.

Since writing the above I have examined the curious structures in question much more closely by means of serial sections, injections of various fluids and masses, and by whole preparations, and I am now able to add considerably to the description just quoted.

1. Methods.

It will readily be admitted that if the vascular papillæ are in open communication with the surrounding spaces, so that blood may pass from the arteries into the lymph sinuses or pleural sacs by which the gills are enclosed, we have to do with a fact so unexpected that nothing short of complete demonstration will ensure its acceptance.

Assuming such a connection to exist, it may seem at first sight a simple matter to establish it. It is, however, by no means easy to do so; and I had continuously investigated these structures for some time, and had actually written withdrawing my preliminary statement, when some final injections settled the matter in favour of its accuracy. Such a contradictory result is partly accounted for by the fact that whilst in some papillæ there is an undoubted communication between the artery and the sinus, in others, and perhaps the majority, the communication has been closed, and the papillæ are vestigial structures.

My preliminary statement was based on the study of serial sections; and if in some of those sections (*e.g.* figs. 2–5) the existence of the communication seems beyond question, it is so easy to misinterpret the sections that such evidence in itself cannot be held to be convincing.

Injections of preserved material are useful, but not decisive. I have tried a large number of such injections with all the ordinary injection fluids and masses, and have never once found the medium to pass right through the gills into the efferent arteries. Hence negative results obtained by this method prove nothing either way. An injection, to be completely successful, must be carried out on an animal as soon as possible after it has been removed from the sea, and immediately after death, with the heart still beating. One can, in fact, almost deduce the time the animal has been dead by the speed with which it may be injected. A syringe injection may be so rapid that some of my first attempts, put on one side as failures owing to apparent leaking, were afterwards found to be injected throughout the whole body, and the leakage due to the injection mass, having returned to the heart, escaping through the cut auricle.

Myxine are not only difficult to kill—like so many marine animals in captivity they will neither live nor die—but their reflexes remain functional for a long time. This spoils many an injection. After trying a number of methods, I find the best is to snip off the tail immediately behind the cloaca, and to immerse the animal in warm sea-water. The latter to a certain extent acts as an anæsthetic, whilst the main blood-vessels are drained, and the tail can be ligatured as soon as the injection mass begins to escape.

Gelatine masses are unsatisfactory for two reasons: (1) they must be thrown in hot, and the passage of a hot mass through the vessels of a cold-blooded animal affects the elasticity of their walls so as to almost vitiate the result where very fine channels are concerned; (2) subsequent treatment is difficult. The mass expands and contracts according to the amount of water present. It contracts considerably on dehydration, and expands again if the sections are stretched on water on the slide. Preparations are completely ruined as regards the finer details if they are placed after injection in formalin or weak alcohol, owing to the excess of water producing expansion of the gelatine and consequent rupture of the tissues. Further, gelatine becomes brittle and difficult to handle in paraffin.

Syringes must be avoided. It is difficult to regulate the pressure, and still more difficult to inject with the minimum pressure required. Syringe injections generally "blow off" the tops of the papillæ, and what appears to be a demonstration of the communication is only an illustration of the crudeness of the method.

What I regard as a convincing proof of a connection between the artery and the surrounding sinus *via* the papillæ may be readily obtained in the following way. The injection fluid is a simple solution of Prussian blue in distilled water. This is placed in a glass vessel which is raised about five feet above the laboratory bench, and an india-rubber tube leads from it to the bench, and has at its end a glass cannula drawn out to a capillary tube. The flexible tubing is closed by a screw clamp placed just above the cannula. The base of the latter may be passed through a cork, so that when it is in position in the vessel from which the injection is to be made, the whole can be held and kept steady by the clamp of a retort stand, leaving both hands of the observer free. Immediately the animal is motionless it is strapped down under sea-water, and the ventricle and ventral aorta are exposed. The free extremity of the ventricle is snipped off, and the cannula pushed into the root of the aorta and a ligature applied. The afferent branchial arteries may now be carefully exposed under a Braus-Druner dissecting microscope by removing the external walls of the pleural sacs, and the whole of the subsequent operations kept under continuous microscopic observation, since all that is needed to start the injection is to slightly turn the screw of the clamp. The speed of the injection is thus under complete control, but to demonstrate the openings of the papillæ without rupture, as the latter are clearly the weakest points of the arteries, the injection fluid should be allowed to pass very slowly into the ventral aorta. Watching the papillæ under the microscope, and in the living animal they are more or less transparent, the injection is seen to pass immediately into the large cavity at the base of the papillæ (figs. 2, 3, 5). Then fine blue threads spring out, connecting this cavity with the apex of the papilla. There is a slight pause, and finally delicate spirts of blue are discharged from the papilla into the cavity of the surrounding sinus. It seems, therefore, that when the pressure in the artery is low, there will be no discharge of blood into the sinus, but that when the pressure rises beyond a certain limit, blood is transferred from the cavity of the artery to that of the peri-branchial lymph sinus or pleural sac.

The use of an injection medium which is a cold *solution*, ensures an easy passage into the finest vessels, and as it is readily precipitated by the addition of alcohol—in fact it may be watched precipitating as it travels through the vessels,—serial sections can be cut of the tissues; and as far as the *finer* vessels are concerned, this injection is as satisfactory as any. An additional advantage is that it exercises no staining effect on the tissues, nor is it itself stained by histological dyes. The walls of the vessels can therefore be stained red, and preparations obtained which are both clear and convincing. The only objection to its use—and it is unfortunately a serious one—is its tendency to precipitate during the operation by combining with the organic fluids with which it is brought into contact, and therefore to block in the smaller vessels. This may be avoided by thoroughly washing out the vessels before throwing in the blue—an important precaution, since the precipitate is of a clinging, flocculent, obstructive nature. I find it convenient to use a cannula with a double lead. Two different fluids can then be employed successively without unshipping the cannula.

2. General Anatomy of the Parts.

The ventral or cardiac aorta of *Myxine* (fig. 1, *c. ao.*) courses directly forward from the ventricle of the heart (*vent.*), giving off on each side as it goes along the afferent branchial arteries (*af. br.*). The walls of the latter have capillaries, and are in fact richly vascular. Each afferent vessel passes straight up to its gill, and enters it below and slightly behind the exit of the efferent gill duct.

Examination of a large number of specimens reveals peculiarities in the first and last afferent branchial arteries * which are of very common, even if not of universal, occurrence. The former, on its way up to the gill, gives off a very short *anterior* twig (fig. 1, *), which varies somewhat in its structure, but is always blind and connected with the neighbouring tissues by one or more fine but strong threads. We know from Stockard's work that a hyomandibular and two post-hyomandibular clefts develop and then degenerate between the mouth and the first functional gill of *Bdellostoma*, and it is therefore possible that this twig may represent the vestiges of the arterial supply of these structures. An additional reason for this view is found in the variations of the twig itself. Sometimes there is more than one arising from the arterial trunk, and when that occurs they soon meet and fuse. Or the twig may give off some branches large enough to be easily recognisable. Or, most important of all, it may terminate in a capillary network or *rete mirable*, which thus represents all that is left of the gill. This network, when present, is situated in a pear-shaped expansion at the extremity of the twig, and the network itself is easily demonstrable by injection. I have never found any traces of an opening to this twig, and we note that it is situated further down on the arch than the vascular papillæ. I therefore consider it to represent a different type of structure, although it may not be homologous in all specimens.

J. Müller, who noticed this structure both in *Bdellostoma* and *Myxine*,† finds in the Cape *Bdellostoma* a connection between it and the carotid system by means of a

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* The most anterior or first gill is supplied by the first afferent branchial artery, and so on.

† *Abh. Ak. Berlin*, Jahr 1839, p. 191.

very fine imperforate thread. At its afferent and efferent extremities this connection is wider, hollow, and contains blood derived from the corresponding arteries. He therefore regards it, and quite justifiably, as a ductus Botalli or vestigial aortic arch, corresponding to the one immediately in front of the existing first. In spite of numerous and most careful dissections of *Myxine*, I have not found any traces of this connection; nor does JACKSON find it in *Bdellostoma dombeyi*. He says:* "The last [= my first] afferent branchial artery of each side gives off a small branch a short distance from the gill. This branch possesses a lumen only at its origin, if at all. It soon becomes reduced to a slender string of connective tissue which becomes lost in the connective tissue around the 'club muscle.' Attached to this string is a small spheroidal body, apparently made up of fibrous and fatty tissue." "In addition to the observation of MÜLLER, I have added that a spheroidal or flattened mass of connective tissue is found attached to the 'ductus' a short distance from its origin. This body is larger and more saccular in appearance in *Bdellostoma forsteri*, and evidently may be interpreted as the rudiment of the *gill pouch* corresponding to the obliterated branchial artery." The discovery of the *rete mirable* in *Myxine* naturally supports JACKSON's suggestion, as I have above indicated.

The peculiar feature associated with the last afferent branchial artery occurs generally on the left side rather than on the right. The artery usually divides sooner, and forms two large vessels, the posterior of which gives off a branch which passes backwards and upwards, it may be for quite an appreciable distance; but sooner or later it loses its lumen, becomes thread-like, and finally disappears altogether. Connected with it, as a rule, are several vascular papillæ (*cp.* fig. 1, †). The significance of this structure becomes obvious when we investigate the variations in the gills. Of the eight cases I have carefully examined, six consisted of an extra gill on the left side only, and the remaining two of an extra gill on both sides. Also, in five out of these eight cases the extra gill was supplied by a branch from the last afferent branchial. Again, in another case, with the normal number of gills, there were only five afferent branchial arteries, the sixth gill being supplied by a branch from the last of these. I think, therefore, that the blind twig from the last afferent branchial artery is associated with the former existence of a seventh pair of gills.

The structures which I have called vascular papillæ were first described in my preliminary paper. They are found both on the afferent and efferent branchial system (fig. 1), but are larger and more conspicuous on the former. They vary somewhat considerably both in number and structure, but I have never found them absent on a single occasion, although a very large number of individuals have been examined. The reason why they have hitherto been overlooked on the afferent vessels (which are more usually dissected) is due, doubtless, to their position. As a rule, they are situated high up on the artery, near the point where it disappears into the gill, and are therefore tucked away under the efferent gill duct (*e. g. d.*); but they do on occasion occur lower down,

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* *Univ. Cincinnati Bull.*, No. 5, 1901, pp. 21, 37.

as shown in the second afferent branchial of fig. 1. Generally, also, they are found on the posterior surface of the artery, and are hence directed backwards. Their structure, which will be described in detail later, varies from a simple papillæ with an unbranched cavity to an elaborate digitiform structure with a complex cavity.

The efferent branchial arteries of *Myxine* (fig. 1, *ef. br.*) differ from the afferents in so far as there are two of them to each gill. In *Bdellostoma dombeyi* there is only one to each gill pouch, but there are two in *B. forsteri.* In *Myxine* each afferent gill duct (*a. g. d.*) has an artery immediately in front of and behind it (*ef. br.*). All the efferent arteries open into a commissural vessel known as the common carotid (*c. car.*), which is attached to the side of the œsophagus (*oes.*), in front, passing straight forwards to the head, whilst behind, it rises to open into the systemic aorta (*s. ao.*) just posterior to the sixth gill. The systemic aorta is prolonged forwards in the median line over the gut as the anterior systemic aorta (*a. s. ao.*).

The common carotid and anterior systemic aorta are connected up by three anastomoses, and although I have found this number to be very constant, the same three are not always present. For example, in fig. 1 the anastomoses are connected with afferent gill ducts three, four, and five, but they may be associated with four, five, and six. It seems, on the whole, probable that each anastomosis is formed either by the fusion of a pair of efferent arteries, or represents the dorsal extension of one.

It is hardly likely that the common carotid has any existence *per se*, but stands for merely a series of longitudinal anastomoses. This is borne out by the state of affairs both in *Myxine* and *Bdellostoma.* In the former the common carotid usually narrows down behind the fourth afferent gill duct (*cp.* fig. 1), and between the fifth and sixth gills it may become so fine a thread as to be almost imperforate. In such a case the last two transverse anastomoses are clearly the direct continuations of efferent branchial arteries, and the posterior section of the carotid which rises to fuse with the aorta is obviously the continuation of the last efferent branchial.

There are no vascular papillæ on any part of the dorsal aorta, either in the branchial region or anteriorly to it. Dorsally the papillæ are confined to the common carotids (fig. 1), but are by no means restricted to the branchial region. The common carotid between the first gill and the division far forwards into external and internal carotids, always bears a number of the papillæ. They are, however, largely confined to the posterior four-fifths of this anterior section of the carotid, as the following count, from behind forwards, exemplifies: 8, 11, 7, 4, 2. The pre-branchial papillæ are simpler in structure than those occurring in the immediate neighbourhood of the gills, and if they open externally at all, it must be very rarely.

It now becomes necessary to describe the spaces into which blood is discharged by the afferent and efferent branchial arteries through the agency of the vascular papillæ. In front of the branchial region, *i.e.* in the region of the club muscle, there is a large dorso-ventrally flattened lymph sac between the notochord and the œsophagus, but which extends some distance laterally on each side of the gut. The anterior median aorta and the paired common carotids lie morphologically outside the roof and floor of this sinus respectively. Below the gut is another large sinus of similar form, which covers practically the dorsal surface of the club-shaped muscle.* Laterally to the gut these two sacs are separated by a thick zone of fatty tissue, but, as it is easy to demonstrate by inflation and by injection, they are in frequent and wide communication by dorso-ventral channels situated at the lateral margins of the œsophagus.

Behind the posterior extremity of the club muscle, in the region of the gills, the ventral of these sacs becomes broken up and finally disappears, but the dorsal sinus is prolonged backwards unmodified throughout the gill region, and acquires connections with the peribranchial sacs by vertical channels which accompany the efferent branchial arteries. The contents of the latter sac, therefore, may pass quite freely into the dorsal œsophageal sinus.

The peribranchial or pleural sacs or sinuses † are large and well-defined bags covered by a fatty tissue—one to each gill. They are invariably distended with injection mass when the vessels have been filled from the ventricle of the heart, owing to the mass passing through the vascular papillæ into the sacs. The gill projects quite freely into the sac, the walls of the two structures being here and there connected by fine tough threads. The posterior wall of one sac is very closely opposed to the anterior wall of the one behind, so that there is a double partition between any two adjacent gills. This partition is quite imperforate, so that no communication is here possible between contiguous sacs.

There can be no doubt, as JOHANNES MÜLLER first pointed out, that the gills are not morphologically within the pleural sacs, but that they are related to the sacs in precisely the same manner as the abdominal and thoracic viscera are to their respective cavities. In other words, each pleural sac consists of a visceral and a parietal layer, and the gill, with its afferent and efferent ducts and arteries, is really outside it. This can be easily demonstrated by serial sections. J. MÜLLER, in fact, compares the peribranchial sinuses of Cyclostomes not with lymph sacs properly so called, but with the pleural cavities of higher animals.

The ductus œsophago-cutaneus has no sinus associated with it, but is wedged in between the last pleural sac of the left side and the pericardial cavity.

The first pleural sac extends a little distance in front of the gill it encloses at the side of the club muscle, and is overlapped behind by the second pleural sac. It is only prolonged a short distance on to its efferent gill duct, the greater part of which, therefore, is visible without removing the sinus.

The second sac spreads over the external surface of the root of its efferent gill duct for a short distance, and this tendency for the sac to extend over the efferent duct becomes greatly and suddenly emphasised behind the second efferent duct, so that only the first two ducts are visible without removing the covering sinus. The sinus system

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* *Cp.* J. MÜLLER, *Abh. Ak. Berlin*, 1834, p. 253.

† J. MÜLLER, *Abh. Ak. Berlin*, 1834, p. 264 *et seq.*

is further complicated by the overlapping of the gills, any gill, except of course the first, overlapping externally the one in front as far as the origin of its efferent gill duct. The result is that in the posterior gills those parts of the pleural sacs spreading over their efferent gill ducts course backwards side by side, and these portions of the sacs communicate freely with each other. It is hence not strictly correct to say that the gill sacs only communicate indirectly with each other through the medium of the longitudinal ventral and dorsal sinuses.

The last gill sac communicates freely above with the sinus dorsal to the œsophagus, which itself ceases to exist behind the branchial region. Posteriorly, the last gill sac terminates blindly by a somewhat irregular border.

In the mid-ventral line, and situated just above the inferior jugular vein, is a large longitudinal sinus, in which courses the cardiac aorta. Anteriorly, this sinus splits into two wide channels, which pass upwards and forwards in a curve to open into the first pair of pleural sacs. In the neighbourhood of the split another pair of channels are given off, which course straight up into the second pair of gill sacs. Similarly, four other pairs of channels arise from the median longitudinal sinus to open into the four posterior gill sacs. In the main channel and its branches are situated apparently the cardiac aorta and the afferent branchial arteries—connected with the walls of the sinus by means of numerous fine but strong threads. The exact relation of the arteries to the cavities in which they appear to lie can only be ascertained by a study of their development, but we can hardly be wrong in concluding, on *a priori* grounds, that the arteries are situated morphologically outside the cavities.

The median sinus is prolonged backwards behind the exit of the last lateral channel on to the base of the ventricle, but here its cavity becomes much broken up by numerous attachments between its visceral and parietal walls. It has no communication with the pericardial cavity, nor is there any justification for regarding it as the pericardium itself.

In *Petromyzon*, according to J. MÜLLER, the gills lie in closed sacs, and there is no ventral longitudinal sinus. The afferent gill arteries pass to the gills *between* the two abutting walls of contiguous pleural sacs, thus differing from the Myxinoids in a striking manner. Although J. MÜLLER, RATHKE, and ROBIN noticed blood in the so-called lymph spaces, it was LANGERHANS[*] who first established any connection between these spaces, which he compared with those of Amphibia, and the blood vascular system. He injected the subcutaneous sinus, and found that the injection passed first of all into other and internal lymph spaces, and finally reached the veins and heart. EWART[†] also states, independently of former writers, that the peribranchial spaces of the Lamprey normally contain blood. He did not succeed in finding any connection *via* the arteries, but was able to fill the spaces by injection from the veins. He believes the veins concerned are the internal jugulars. At about the same time SCHNEIDER[‡]

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[*] *Verhand. nat. Ges. Freiburg*, Bd. vi., 1873.

[†] *Jour. Anat. and Phys.*, vol. xii., 1877.

[‡] *Beitr. z. vergleich. Anat. u. Entwick. d. Wirbelthiere*, Berlin. 1879.

stated that the peribranchial sinuses always contained venous blood, and he investigated the connection of the lymph spaces with the veins by the injection of coloured fluid, although he states that this connection may easily be followed without any injection. He notes, as I have also done in *Myxine*, that blood may be clearly seen in the subcutaneous sinus in the living *Petromyzon fluviatilis*.

Recent writers have paid very little attention to the peribranchial spaces of the Lamprey.* GEGENBAUR, in his text-book,† does no more than quote JOHANNES MÜLLER. VOGT and YUNG ‡ state that the sacs are completely closed and contain a viscid liquid, probably lymph, which coagulates in spirit into granular yellow masses. I take it the yellow colour is due, as in *Myxine*, to a certain admixture of blood. VIALLETON does not believe the spaces to belong to the blood vascular system, and returns to the old view, as we now know quite erroneously, that the blood they contain has extravasated into them through ruptured walls. CORI, § in his important paper on the blood vascular system of the young Ammocœtes, only mentions very briefly the system of blood sinuses.

MOŽEJKO has conducted numerous experiments in the injection of the vascular system of *Petromyzon*, ‖ but, apart from the fact that he says it is possible, he does not appear to have more than casually used the method of injecting from the heart. Elsewhere ¶ he controverts VIALLETON'S statement that the peribranchial sinuses do not normally contain blood, and asserts that red blood corpuscles are found in all the lymph cavities. The sinuses cannot be injected directly *via* the arteries, but are easily filled by injection through the veins. The peribranchial sinuses, however, only communicate indirectly with the jugular veins, but in the case of some of them there is a communication *inter se*. He regards the lymph sinuses of *Petromyzon* as blood-vessels and lymphatics at the same time.

In *Bdellostoma* JACKSON remarks: ** "I have observed in several cases a marked tendency for the injected carmine gelatine to escape from the blood-vessels into the surrounding lymphatics, which are very numerous and extensive. These lymphatic spaces, especially the sub-dermal spaces in the caudal region and the peribranchial spaces around the gill pouches, are usually found more or less injected, although the blood-vessels show no signs of over-distension. The lymphatic spaces around the vessels in the gill itself are also often filled. This condition may be interpreted as indicating that the capillary walls are unusually weak and permeable, so that the injected liquid passes through them, carrying blood corpuscles with it. That this process is not normal is shown by the absence of red blood corpuscles from the lymphatic spaces in life and in uninjected specimens." In *Myxine*, as I have indicated above, the presence of red blood may easily be seen in the living animal in the subcutaneous sinus, and red

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* *Cp.* NESTLER, *Arch. f. Naturgesch.*, 1890; FAVARO, *Atti Accad. sci. Veneto-trent.-Istriana*, 1905.

† Bd. ii. p. 221.

‡ *Anat. comp. prat.*, t. ii. p. 460.

§ *Arb. zool. Inst. Wien*, t. xvi., 1906.

‖ *Z. f. w. Mikrosk.*, Bd. xxvii. p. 248, 1910.

¶ *Anat. Anz.*, Bd. xxxvi. p. 618, 1910.

** *Op. cit.*, p. 35.

blood corpuscles occur in uninjected specimens in all the so-called lymphatic spaces of the body. It has been stated that the vessels rupture and fill the lymphatics in bringing the animal up from the bottom. This may conceivably be so at Cullercoats, where *Myxine* are not usually found within the 23-fathom line, and most of my material was collected in over 25 fathoms of water; but the Californian Hag used by JACKSON occurs quite commonly in from 10 to 20 fathoms of water. If, therefore, the presence of injection mass in the lymphatics is due to rupture of the vessels, we are driven to distrust any results produced by that method. It will, however, be obvious from the preceding discussion that in this matter JACKSON is mistaken.

We have seen that in *Myxine* blood enters the pleural or peribranchial sacs *via* the vascular papillæ on the afferent and efferent arterial system, although chiefly by the former. If this be the case, there must be some corresponding connection with the venous system by which the contents of the sacs may be drawn off. Some chance injections enabled me to demonstrate this connection in a very striking manner.

Injection by the ventricle of the heart is a little difficult. The heart is tucked away under the anterior lobe of the liver, and in getting at it some vessels are certain to be cut, and the injection bleeds. I therefore determined to try an injection by the portal vein, which is very easy to get at and to ligature, and to expose which only a very slight operation is necessary. To my great surprise, the result was a complete injection of the veins of the whole body, with apparently nothing whatever in any of the arteries. The liver and gall bladder are injected first (and presumably also the anterior portal vein). Then the sinus venosus fills up from the liver, and finally the injection travels back along all the veins, which become well filled. Examination of the specimen afterwards with the dissecting microscope revealed a little injection in the auricle, still less in the ventricle, a trace in the cardiac aorta, and none in the afferent branchial arteries or in the gills. *Nevertheless the pleural sacs were full of injection, and it had also passed freely into the large sub-dermal sinus.* In this case there was and could be no question of rupture, since the injection had first to pass through the liver before reaching the sinus venosus. Therefore the fact that the pleural sacs filled up in a case where the veins were also well injected, and the possibility of injection reaching the sacs *via* the arteries is absolutely out of the question, shows that the sacs must at some place be in communication with the venous as well as the arterial system. I have not specially investigated this connection, but I believe it to be with the superior jugular veins in the neighbourhood of the heart.

A brief note by KLINCKOWSTRÖM* may be quoted in confirmation of the above:—"Auch im Innern des Körpers bestehen weit ausgedehnte Lymphräume, die sich über und unter dem Œsophagus, zwischen den äusseren und inneren Zungenmuskeln über dem Gaumen und rings um das Nasenrohr erstrecken. Wie oben erwähnt, stehen sie in weitoffener Verbindung mit den subcutanen Lymphsäcken. Auch die Kiemensäcke sind von zahllosen grösseren und kleineren Lymphräumen, die alle mit einander in

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* *Biol. Fören. Förhand.*, Bd. iv., 1891.

Verbindung stehen, durchsetzt. Zwischen diesen Theilen des Lymphsystems und dem 'Pfortaderherzen' scheint eine Verbindung zu bestehen; aber nur zwei Male war es K. gelungen diese Verbindung durch Injectionen darzulegen; bei dem einen Exemplare hatte die Injectionsmasse von den Lymphräumen aus nicht nur das Pfortaderherz selbst sondern auch einen Theil des Venensystems gefüllt."

KLINCKOWSTRÖM's injections are not as satisfactory or as conclusive as the one described above, since he injected not from the portal vein but from the lymph space. The fact that the injection reached the portal heart agrees with my results, because the mass would reach the latter *via* the anterior portal vein (= the right superior jugular).

3. The Structure of the Vascular Papillæ.

The vascular papillæ, although never entirely absent, vary very greatly both in occurrence and structure, and they may or may not open into the surrounding sinus. It seems obvious, therefore, that they must be regarded as vestigial structures, and that they stand for the vanishing point of the connection between the arteries and the lymphatics.

In figs. 2 to 5 I have represented a series of simple cases in which there was an undoubted communication between the cavity of the artery and the surrounding lymph sinus. They are all drawn from transverse sections of the arteries, but in fig. 5, owing to the greater magnification, only the papilla itself and a small portion of the arterial wall are shown. Figs. 2, 3 and 5 are sections of afferent branchial arteries, but fig. 4 is from the common carotid. The spaces occupied by red blood are indicated by the red tint.

In all cases the base of the papilla is excavated as a large space in free communication with the cavity of the artery and which therefore always contains blood. If this space communicates with the surrounding lymph sinus at all it may do so in a variety of ways. The apex of the papilla may be more or less pointed and possess a single opening only, as in fig. 3. This is unusual. On the other hand, the free end may be expanded, and its external surface indented by a series of crypts, the whole having a somewhat digitate or even grape-like appearance, with perhaps one opening or more on the summit of each finger. Care must be taken not to confuse these crypts with the blood vascular tubules which pass from the basal excavation to the apex of the papilla. The latter tubules are usually just large enough to transmit a single corpuscle at a time in preserved material, but in the living animal they can be considerably distended. Each papilla may contain only one such tubule, as in fig. 3, or several, as in fig. 5, and their relation to each other and manner of opening, when they do open, are very variable (*cp.* fig. 4). The papilla may hence be a simple structure with no more than a single opening, or a somewhat complex feature with several openings.

The afferent branchial arteries on rare occasions give off small vessels to the surrounding tissues before entering the gills, and in one injection a conspicuous twig arose from the second afferent branchial and broke up on the wall of the corresponding efferent gill duct.

I have never found the vascular papillæ entirely absent, but they may be very greatly reduced and almost all of them imperforate, in which case the peribranchial sacs contain less blood than usual. On the other hand, in those cases where the papillæ are numerous and well developed, the pleural sacs are always rich in blood.

Apart from the fact that sections of injected material demonstrate in the clearest manner that the vascular papillæ may place the cavity of the artery in communication with the surrounding "lymph" space, we find in many cases which have not been injected a papilla capped by a small blood clot. This clot in favourable cases will be found to be directly continuous with the blood coagulum in the interior of the papilla, and this in its turn with the contents of the arterial trunk itself. On the other hand, in many cases it is equally certain that the papillæ are quite closed, and represent merely small evaginations of the arterial wall. Occasionally one finds blood corpuscles in the tubules, in their external openings, and just outside those openings.

In injections the mass always passes readily into the basal cavity of the papilla, and often into the proximal ends of the tubules; but it does not always travel along the whole length of the tubule, and so to the exterior, or, if it does, the tubule, being elastic, contracts and empties itself when the pressure is relaxed. When such a papilla is examined as a whole preparation, the uninjected distal portion of the tubule is visible as the direct continuation of the injected proximal portion.

A striking feature is that the tubules leading from the large space at the base of the vascular papilla to its apex, and it may be opening there, are lined by a well-marked epithelium. This epithelium is confined to the tubule, and its extent is indicated by the dots in figs. 2 to 5. Peripherally, it does not extend beyond the external opening of the tubule, nor does it line the large blood space at the base of the papilla. The cells are shallow, but the nuclei are large and deeply staining, and reach from one extremity of the cell to the other.

The following variations in the structure of the papillæ may be recorded:—

1. The tubules traversing the distal end of a papilla may be so complex, as shown by injections, as to almost deserve to be referred to as a *rete mirabile*.

2. A papilla may consist of a pear-shaped mass, with its narrow proximal end excavated into the usual blood space in free communication with the cavity of the artery. At the expanded distal end is a large cavity with very little obvious contents, and having no communication with the exterior, but which is connected with the proximal blood space by one or more tubules. In other cases the distal cavity was lined by epithelium and possessed undoubted openings on to the exterior.

3. In some of the gelatine injections the papilla was pear-shaped, its enlarged distal extremity having a spongy consistency. From the proximal blood space a number of fine anastomosing tubules were given off, traversing the spongy mass, and some of them opening by fine pores on to the exterior.

4. A papilla may be completely injected, so that the capillaries within the contiguous walls of the artery are filled, without, however, any signs of the injection escaping from the papilla. In these cases the interior of the papilla is completely occupied by the blood space, and there is no distal spongy end.

5. In one injection the free spongy extremity of the papilla was traversed by several of the blood vascular tubules, some of which were observed to unite to form a large vessel opening on to the exterior by a small pore.

6. In another injection the stalk of the papilla contained the customary large simple blood cavity, from which there were given off distally a number of tubules, the latter combining in the distal bulbous end of the papilla to form an elaborate vascular network.

7. From the large central blood space of the papilla there may pass into the more or less solid tissue of the free end a number of *intercellular blood canaliculi.* These differ markedly from the much larger and well-defined blood vascular tubules, which may also be present. They cannot be described as blood capillaries, since they have no definite walls, but rather resemble the bile capillary.

4. Theoretical Considerations.

The development of the lymphatic system has of late years been successfully studied by several American morphologists. The most recent paper on the subject is by Huntington on the development of the lymphatic system in Reptiles.* According to this author, the systemic lymphatic channels arise by the confluence of mesenchymal spaces independently of the blood vascular system. They are not derived from veins, their cavities are independent of those of the veins, and they are lined with a " lymphatic vascular endothelium not derived from or connected with a pre-existing hæmal vascular endothelium."

On the other hand, the jugular lymph sac, both of Reptiles and Mammals, has an altogether different origin. This arises *by the fusion of a venous plexus*, directly derived from the venous channels of the pericardial area. The endothelium of the veins, therefore, is continuous with that of the lymph sinus, and the latter at first contains red blood. " It then evacuates its early blood contents, separates temporarily from the hæmal vascular system, establishes secondary connections with the systemic lymphatic vessels of the anterior part of the body and of the anterior extremity, and finally re-enters the venous system at a definite and constant point of secondary lymphatico-venous junction."

We are unfortunately ignorant of the development of the peribranchial sacs and other so-called lymph spaces in the Myxinoid fishes, but the facts disclosed by the American morphologists suggest a possible explanation, or at all events indicate a line of inquiry. If the jugular lymph sac of Reptiles and Mammals is formed by the fusing up of a venous network, and a *sinus* thereby formed, it may be that the peribranchial sacs of

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* *Anat. Rec.*, June, 1911. *Cp.* also January, 1910, and *Mem. Wistar Inst. Anat. Biol.*, No. I., 1911.

the Myxinoid are also formed by the coalescence of a vascular network. On this view, the vascular papillæ will represent the remains of the embryonic plexus. In the closed papillæ the detachment of their contributions to the sinus will have been complete, whilst the open papillæ will have retained the embryonic continuity of the two systems of spaces.

As regards *Petromyzon* there are some grounds for this view. CORI points out that the branchial sinuses are represented in earlier stages by what he calls a venous network. SCHNEIDER also has the following significant passage: "Zwischen der Epithelialschicht der Mundhöhle und der Muskulatur de Körperwand befindet sich im Ammocötes eine Schicht sogennanten adenoiden (cytoiden Binde-) Gewebes, welches von zahlreichen Capillaren durchsetzt wird. Beim Uebergang in den Petromyzon nehmen diese Capillaren an Grösse zu und verschmelzen zu einem grossen Venensinus."

The fact that all the so-called lymph spaces in Myxinoids normally contain blood, though in varying quantities, must be held to remove these spaces from the category of lymph spaces *sensu stricto.* At the same time, however, they cannot be said to lie in the direct course of the blood stream, and for this reason must be equally excluded from the blood vascular system. LANGERHANS declines to commit himself as to what system the spaces belong to, but later writers have generally referred them to the lymphatic system, and denied that blood is normally present in them. MOŽEJKO, however, takes the intermediate course, and regards the spaces as blood-vessels and lymphatics at the same time.

There is, to my mind, little doubt that as regards the vascular system the Marsipobranch fishes have reached the parting of the ways. The blood system is well developed, but not completely developed. There is still in places an ill-defined connection between the arteries and the veins. Similarly, the lymphatic system is indicated as far as its broad outlines are concerned, but it contains red blood, and has not yet acquired its independence. It is, in fact, in the act of becoming detached, as is illustrated by the great variation in the amount of blood it contains, and in the fluctuating extent to which it receives blood from the arteries *via* the vestigial vascular papillæ.

SUMMARY.

1. Red blood occurs normally, but to a variable extent, in all the so-called "lymphatic" spaces of *Myxine.* In the living animal such blood can readily be seen in the extensive sub-dermal sinus.

2. In the region of the gills, and especially in the case of the peribranchial or pleural sacs, red blood enters the spaces *from the arteries.* This has been actually observed under the microscope in certain injection experiments on the freshly killed animal. The means of communication between the arteries and the sacs are a number of perforated papillæ situated on the afferent and efferent branchial vessels. The blood so entering the sacs is drawn off again into the venous system *via* the jugular veins.

3. Only a variable proportion of the vascular papillæ are perforated. Many, if not most, of them are closed and vestigial.

4. The "lymphatic" spaces are neither true lymphatic nor true blood vascular spaces, but partake of the nature of both. We have in the Myxinoids the final stage in the separation of the blood vascular from the lymphatic system. In other words, the two systems are in the act of segregating out.

I am indebted for the expenses of this research to a grant from the Government Grant Committee.

It gives me pleasure to acknowledge the kindness of Professor A. MEEK, M.Sc., in placing the resources of his admirable laboratory at Cullercoats at my disposal, and to the assistant naturalist, Mr B. STORROW, for much valuable assistance in carrying out the injection experiments.

October 1911.

Postscript, January 1912.—By the courtesy of Dr B. MOŽEJKO of Warsaw, I have received advance proof sheets of a paper, which by this time will have been published, on the morphology of the vascular system of the Lamprey. In this paper Dr MOŽEJKO states that the contents of the gill sacs cannot be distinguished from venous blood, and he believes the sinus system to be formed during metamorphosis by the local enlargement of vascular networks. The sinuses are not present in the young Ammocœtes, and only appear shortly before metamorphosis. He concludes that the venous system of *Petromyzon* is not a venous system *sensu stricto*, but is a "systema venoso-lymphaticum," in which the venous and lymphatic channels are fused into a common system, and in which the lymphatic vessels have only partially segregated out. These conclusions are very similar to those I had already arrived at from a study of *Myxine*.

EXPLANATION OF THE PLATE.

Fig. 1. Reconstruction, from serial sections, of the gills, branchial œsophagus, and afferent and efferent branchial arteries (coloured red) of a 25 cm. Hag, seen from the left side. × 11. The muscles of the gut are not included. Afferent and efferent gill ducts are represented cut off at their origin. In the case of the common carotid, the branches of the artery are distinguished from the vascular papillæ by a cut extremity. Some of the papillæ on the afferent branchial arteries are compound, but the details cannot be shown in a diagram of this magnification. For the same reason two very small papillæ on the first afferent branchial, one on the second, and two on the fourth, are omitted.

Fig. 2. Transverse section of an uninjected afferent branchial artery bearing a vascular papilla with two openings into the pleural sac. × 50. The division between the artery and the papilla is indicated by the broken line. The extent of the epithelial lining of the tubules leading to the exterior is shown by dots. Blood vascular cavities coloured red. The drawing is diagrammatic to the extent that both openings did not appear in the same section.

Fig. 3. Transverse section of an uninjected afferent branchial artery with a vascular papillæ having only one opening (very unusual). × 50. The tubule leading to the surface and the opening itself are distinctly larger than is customary. For description see fig. 2.

Fig. 4. Transverse section of the common carotid artery in the region of the gills showing two vascular papillæ. × 50. The figure is slightly diagrammatic in so far as though both vascular papillæ appear in the same sections, the openings of the lower papilla, as figured, were in the next section but one to that drawn. The upper papilla had two openings, and two tubules which ended blindly. The lower papilla had two openings. The specimen had been injected with soluble Prussian blue. *Cp.* the description of fig. 2.

Fig. 5. Portion of an afferent branchial artery with one vascular papilla mounted entire and examined as a transparent object. × 100. Injected with carmine gelatine. Only a very small portion of the wall of the artery is shown. *Cp.* the description of fig. 2.

Reference Letters.

af. br.	Afferent branchial artery.
a. g. d.	Afferent gill duct.
a. s. ao.	Anterior or pre-branchial portion of the dorsal or systemic aorta.
au.	Auricle of the heart.
br. cl.	Branchial cloaca.
c. ao.	Ventral or cardiac aorta.
c. car.	Common carotid artery.
d. oes. ct.	Ductus œsophago-cutaneus.
ef. br.	Efferent branchial artery.
e. g. d.	Efferent gill duct.
oes.	Œsophagus—branchial portion.
s. ao.	Dorsal or systemic aorta.
s. v.	Sinus venosus.
vent.	Ventricle of the heart.

PROF. F. J. COLE ON THE MORPHOLOGY OF MYXINE.—PART IV.

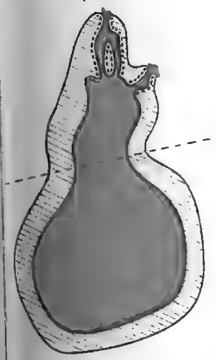


Fig. 2. × 50

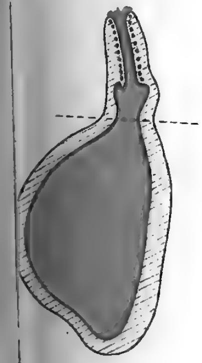


Fig. 3. × 50

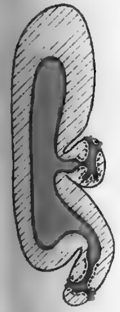
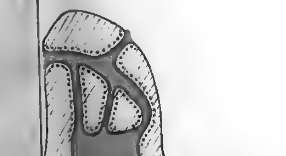


Fig. 4. × 50



ig. 5. × 100

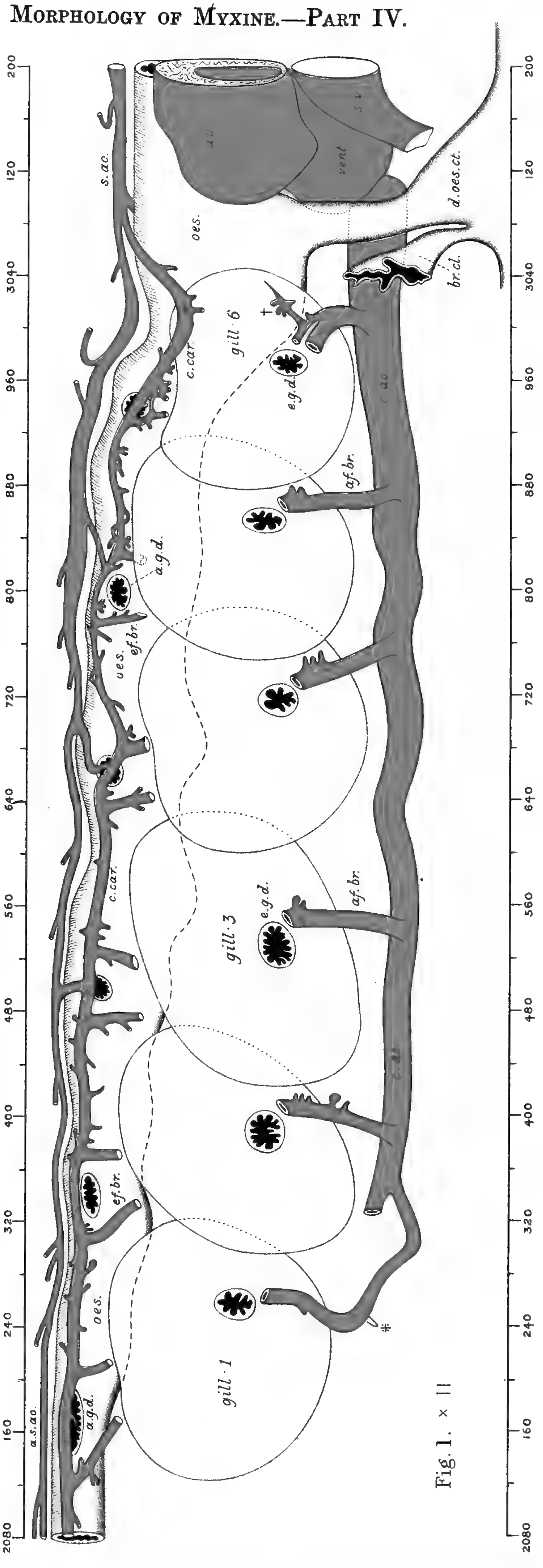


Fig. 1. × 11

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BRITISH MUSEUM
NATURAL HISTORY

XII.—The Effect of changing the Daily Routine on the Diurnal Rhythm in Body Temperature. By Sutherland Simpson, M.D., D.Sc. (From the Physiological Laboratory, Medical College, Cornell University, Ithaca, N.Y., U.S.A.) (With Thirteen Figures in the Text.)

(MS. received November 20, 1911. Read January 8, 1912. Issued separately April 4, 1912.)

CONTENTS.

I. Introduction.

It is a well-established fact that the temperature of the human body is not constant, but shows a distinct and fairly regular daily rhythm. In the classical curves of Jürgensen and Liebermeister * the minimum is reached in the early morning, some time between the hours of 2 and 6, and the maximum in the late afternoon or evening, between 4 and 8. In both there is a sharp morning rise, followed by a slight fall in the late forenoon or early afternoon, and again a further rise to the maximum, which is reached some time between the hours stated. It has been demonstrated repeatedly by many subsequent observers that this general type of curve is a more or less correct representation of the changes which the rectal temperature undergoes, in the course of the twenty-four hours, in a healthy individual leading an active life during the day and sleeping at night.

While the presence of this daily rhythm is well recognised, the causes underlying it are not clearly understood. The factors which are believed to affect the body temperature in health are muscular exercise, mental effort, ingestion of food, light, temperature of the surrounding medium, and sleep. Of these the first is the most important. Each and all of these influences are active in the body at different periods throughout the twenty-four hours, but the exact relationship existing between them and the diurnal rhythm in the body temperature has never yet been satisfactorily demonstrated.

By many it is held that the combined action of the several influences enumerated

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* Jürgensen and Liebermeister, *Handbuch der Pathologie und Therapie des Fiebers*, Leipzig, 1875.

above, although it may modify it to a considerable extent, cannot account entirely for this diurnal fluctuation. They believe that there exists in the body a fixed periodicity of which the temperature rhythm is an expression, and that this periodicity persists under all conditions, and is, to a large extent, independent of outside influences. Others are inclined to question the existence of this mysterious periodicity, and to look upon the diurnal variation as being due entirely to the action on the body of the influences already mentioned, which are known to raise or lower the temperature.

II. Previous Work on the Subject.

If these factors are alone responsible for the diurnal temperature wave, then any modification in the application of them, and particularly any change in the time within the twenty-four hour period at which one or more of them operate, might be expected to produce a corresponding change in the temperature curve, or, in the simplest and most complete case, total inversion of the daily routine should cause a complete inversion of the temperature curve.

Various attempts have been made by different investigators to produce an inverted day-and-night curve, but these have been unsuccessful in the human subject. It is true that the earlier observers, Debczynski,* Jaeger,† and Buchser,‡ claim to have succeeded, but when the conditions under which their experiments were carried out come to be examined, it is found that the methods of all three are open to criticism, and that their results are inconclusive.

More recently Mosso § (1885) and Benedict ‖ (1903), in carefully planned experiments, have studied the effect of night work and day rest and sleep on the temperature rhythm, and both have arrived at the conclusion that the normal temperature curve cannot be inverted by inverting the daily routine, for while rest and sleep during the day lower the temperature, work during the night does not appreciably raise it. The curve is modified by the altered conditions but it is not reversed.

These results then would appear to show that the daily oscillations of the body temperature are not due directly to the causes already mentioned, but that they may have a deeper significance, and may indicate a diurnal periodicity in the body comparable in character to the seasonal and lunar changes that are known to occur in certain plants and animals. That the temperature rhythm is to some extent fixed in the body is the most obvious interpretation to be put upon the failure of Mosso and Benedict to invert it, and this apparent fixity of rhythm is difficult to explain. As Benedict says: "Why the temperature of the human body reaches a minimum at 2 a.m. to 6 a.m., independent of whether the subject is sleeping soundly in the

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* Debczynski, Abstract in *Jahresb. der ges. Med.*, Bd. x., 1875, p. 248.

† Jaeger, *Deutsches Arch. f. klin. Med.*, Leipzig, Bd. xxix., 1881, p. 533.

‡ Buchser, quoted by Carter, *Jour. Nerv. and Ment. Dis.*, vol. xvii., 1890, p. 785.

§ Mosso, *Archives italiennes de biol.*, vol. viii., 1887, p. 177.

‖ Benedict, *Amer. Jour. of Physiol.*, vol. xi., 1904, p. 143.

recumbent position or whether he is awake and sitting, or even standing and walking, is a problem that calls for extended research."

Instead of altering the daily routine artificially in a fixed locality, the same result may be effected in a natural way by changing the locality, for an individual who travels round the world in these days of rapid transit from West to East, or *vice versa*, especially in high latitudes, quickly changes his daily routine. The happy idea of applying this method to the study of the question under discussion seems first to have occurred to GIBSON.* The opportunity presented itself when he had occasion to make a voyage from New Haven, Connecticut, across the American continent and Pacific Ocean to Manila in the Philippines. As a difference of eleven hours exists between the local times of these two stations, the journey involved the shifting of the daily routine, so that day and night were practically reversed.

GIBSON'S observations were made on himself and a second subject at different stages of the voyage, and on individuals in Manila who came originally from the United States and who had resided in Manila for varying periods of time. He made control experiments on his own body temperature for two days before leaving New Haven, taking readings every two hours, and so obtained the diurnal temperature curve, which proved to be of the ordinary type commonly described as normal. The same process was repeated several times during the voyage and again at Manila.

He found that the "transposition of the daily routine through a period of nearly half a day, experienced as the result of the time changes during the trip from New Haven to Manila, was accompanied by an immediate adjustment of the rhythmic temperature variation to the new régime in the case of the writer and of a second subject, so that on arrival in the islands the curves obtained were still normal in character. Subsequent residence in the Philippines for a period of about six weeks induced no alterations of any significance. Observations made during the return trip showed an apparent adjustment of the temperature rhythm day by day coincident with the shifting of the routine. After returning to New Haven the record continued to be normal, and closely resembled the earlier controls. . . . Additional observations on individuals who came originally from the United States and who have resided in Manila for varying periods of time, corroborate in part the results on the writer, in so far as the temperature rhythm was found to be of the ordinary type."

A similar experiment was made by OSBORNE† three years later, apparently without any knowledge of the previous work of GIBSON. Having first noted that his own daily maximum temperature in Melbourne occurred about 6 p.m., while on a voyage from that city to London he made some observations on his own rectal temperature with the object of seeing whether this maximum remained throughout the voyage at 6 p.m. according to Melbourne time or took place at a certain hour relative to local or ship's time. The difference in longitude between the two places is equivalent to about ten

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* R. B. GIBSON, *Amer. Jour. of the Med. Sciences*, June 1905, p. 1048.

† OSBORNE, *Journal of Physiology, Proceedings*, Jan. 25, 1908.

hours in time, and if the Melbourne rhythm had persisted, in London the curve would be practically reversed. OSBORNE found, however, that his maximum tended to follow local time, occurring about 6 p.m. by the ship's clock.

But he was only able to make five sets of observations, and in one of these the highest temperature was reached at 10.15 a.m. by ship's time, corresponding to 5.52 p.m. Melbourne time. In another only four readings were taken, at hours which did not cover the 6 p.m. by Melbourne time (2 p.m., 5.30 p.m., 6 p.m., and 11 p.m. ship's time corresponded to 0.48 a.m., 4.18 a.m., 4.48 a.m., and 9.48 a.m. Melbourne time), so that it is impossible to say whether the maximum agreed with the latter or not. The results therefore are not quite convincing. To quote his own words: "The above results, though incomplete, rather tend to prove that the time of evening maximum takes place with regard to local time and not the time of the starting-point—Melbourne. They do not, however, disprove the existence of body periodicity, nor prove that the evening maximum is determined solely by the hours of sleep, the activities of the day, and the diurnal variations of light and heat, for a true periodicity might have been present but adjusted to the new conditions owing to the very gradual manner these were introduced." *

The latest contribution to the subject comes from LINDHARD,† the medical officer of the Danish Arctic expedition to the north-east coast of Greenland in the years 1906–8. On this expedition he studied extensively, on himself and other members of the ship's company, the effects of various conditions on the rectal, mouth, and skin temperatures. Discussing the question of periodicity in relation to body temperature, he criticises the method of MOSSO and BENEDICT, as TIGERSTEDT and the present writer had done before, on the ground that when one attempts to reverse the daily routine in a single individual by arranging that he shall work during the night and rest and sleep in the day-time, one cannot disconnect this individual from the rest of society. So long as the society, of which the individual is a part, follows a fixed rotation, the latter, consciously or unconsciously, will tend towards the same mode of life. Under reversed day-and-night conditions the subject must necessarily work with artificial light in the stillness of the night, and he must sleep in the day-time through noise and other disturbing influences. The night-worker is in sympathy with a sleeping world, and his bodily activities are unconsciously affected by this circumstance.

Relating his own experience in night-watching, he calls attention to the fact that the "night time has a peculiar effect upon one's general state of mind owing to the stillness, solitariness, and various other circumstances, and this changed psychical condition reacts on all one undertakes. Every strong or sudden noise is disagreeable,

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* In a recent paper (*Report of the Danish Expedition to the North-East Coast of Greenland*, 1906–8, vol. xliv., 1910, p. 1; Reitzel, Copenhagen) LINDHARD, unaware of GIBSON's work, gives to OSBORNE the credit of being the first to adopt this method of changing the daily routine, and makes no mention at all of GIBSON's name in this connection. As a matter of fact priority, by three years, belongs to GIBSON, and besides, his observations were much more extensive and complete, and his results far more definite than those of OSBORNE.

† LINDHARD, *loc. cit.*

and involuntarily one tries to avoid all such things; the movements become gliding and noiseless, resembling those of other night animals, and are much less definite than in the day-time. A round in the night will therefore fail to raise the temperature like a corresponding walk in the day-time. And one is never sitting so still as in the night; . . . ."

The psychical factor might naturally be expected to have a greater influence on the human subject than on the lower animals, and this may account for the fact that in the monkey the body-temperature curve can be reversed by reversing the daily routine (SIMPSON and GALBRAITH *). Here, however, the case is somewhat different in another respect, since the reversed conditions were imposed on a colony of monkeys instead of an isolated individual.

Instead of experimenting on a single individual, then, the proper method would be to apply the "reversed" routine to the whole society in which the individual lives, but this is inconsistent with social life in civilised communities. Such an experiment, however, may be carried out on a high-arctic expedition during the long polar night or day, and this LINDHARD did on the members of the party. For this he preferred the winter night to the perpetual day of summer, since the "sun occasions a continual unrest, the working hours are unlimited, and a little food emancipates one from the regular meals. It will therefore be very difficult for all to adopt the same mode of life, ... Apart from this, the difference in the intensity of the light is much more pronounced in summer than in winter, just as the variations in the day-and-night temperature are much greater. During the polar night the case is different. All lamps are put out at certain fixed hours appointed by the leader of the expedition; then it is night: during the remaining hours the lamps are lit and we have day. As practically all work is done indoors, the dining hours are kept by everyone; and in the open air the light by day and at night does not vary appreciably, and the changes in temperature are comparatively small."

This experiment was carried out in January 1907, in lat. 76° 46′ N., on the whole ship's crew. The transition was made very quickly and easily. Bedtime was delayed once four hours, and then eight hours by the insertion of an extra meal, and so in two days the "reversal" was accomplished. The lamp was lit and extinguished at a fixed time as before, but twelve hours later, and all met at the table as usual at the "reversed" meal hours. Only on clear days at "noon" a little brightness in the southern sky might be missed, otherwise the change was betrayed by no external sign. All were conscious of the fact that this change had been made, but in the great majority this did not give rise to a feeling of anything unusual. "Time rolled along on its even, ordinary way. More than half of the twenty-eight members of the expedition felt, indeed, just as usual as soon as the transition had been accomplished; after five to six days only a few were a little indisposed to work, sleeping less well in the "night" and becoming sleepy at various times of the "day." The function altered

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* SIMPSON and GALBRAITH, *Trans. Roy. Soc. Edin.*, vol. xlv., part i., 1905, p. 65.

with the greatest difficulty was defæcation; for a few it took about a week before this occurred at the usual time, for one (rarely quite free, however, from indisposition) it took even till the end of the experiment." The return to the normal routine was made in the same way as the reversal. The period of complete reversal lasted eleven days.

Although readings for the seven hours of sleep were not taken, the curves of all point to reversion. In those who had difficulty in becoming accustomed to the altered routine there is delay in the adaptation of the temperature curve to the changed conditions, but ultimately "in all cases the fundamental type is evident, and the causes of the departures present are obvious. All of them tend to show that the curve of temperature variations is determined by work and mode of living, that the astronomical division of day and night is without importance in this regard, and that an inherited form is consequently out of the question, a mysterious periodicity even more so."

III. Present Investigation.

The writer happened to be present when Professor Osborne made his communication at a meeting of the Physiological Society in London on January 25, 1908, and being especially interested in the subject of body temperature, he was struck by the fact that no one had ever thought of adopting the procedure described by Osborne before. At that time it did not seem probable that the opportunity would ever present itself to the writer of repeating the work of Osborne, which was admittedly somewhat fragmentary and inconclusive, but circumstances came about which made this possible a year later.

In the summer of 1909 a journey was undertaken from Ithaca, in the western part of the State of New York, eastward to Edinburgh, and after a six weeks' stay in Scotland, westward again from Edinburgh to Winnipeg. As the local time of Edinburgh is about five hours in advance of Ithacan time and over six hours ahead of Winnipeg time, in a rapid journey between these places the daily routine would, within a few days, undergo a considerable modification although it would not be completely reversed. At that time I did not know of Gibson's work, nor, in fact, until I arrived in Edinburgh, when I had the privilege of reading his paper.

It was planned to make, as far as possible, three-hourly observations on the temperature of the rectum, mouth, and axilla during the waking hours throughout the voyage. In order to obtain the daily temperature curve in Ithaca for comparison, the observations were begun one week before starting on the journey eastward. It was found that the steepest grade on the curve took place between 6 a.m. and 9 a.m., and in this interval readings were taken more frequently. The subject (the writer himself) was forty-six years of age, measured 5 feet 10½ inches in height, weighed 205 pounds, and was of stout build. He was in perfect health throughout the whole experiment.

For the mouth and axilla sensitive and accurate clinical thermometers were used (Fahrenheit scale), graduated in fifths and capable of being read to tenths of a degree. For the rectum a special thermometer was constructed, also of the clinical type, but the bulb and about 1 cm. of the stem was encased in silver as a safeguard against accidental breakage while in use on shipboard. In this the centigrade scale was adopted; each degree was subdivided into tenths, but with a lens readings to the second decimal place could be made with approximate correctness.

The records were taken simultaneously from the left alveolo-lingual sulcus, the left axilla, and the rectum, where the thermometer was always inserted to the same depth—8 cm.,—as indicated by a fine wire fixed around the stem at this point. The thermometers, before being used, were warmed in the hand, and they were held in position for five minutes, although it is probable that a shorter time would have been sufficient for the mercury to adjust itself to the temperature of the surrounding walls.

For comparative results of this kind it is essential that the daily habits of the subject should be, as far as possible, the same throughout the whole experiment, and this was kept in mind. Three meals a day were taken at the same hours—breakfast between 8 and 9 a.m., lunch from 1 to 2 p.m., and dinner between 6 and 7 p.m. No food was taken from 7 p.m. till 8 a.m. except very occasionally, when a glass of buttermilk with a slice of bread was served for supper about 9 o'clock.

During the control period in Ithaca the days and evenings were spent, for the most part, in the laboratory,—sometimes seated at a table writing or reading, sometimes walking or standing about in the rooms doing light work. The subject got out of bed about 7 a.m., dressed, and walked about three hundred yards to breakfast, and then up a hill, which was fairly steep, about half a mile to the laboratory. The temperature was taken at 6 a.m., frequently again before arising about 7, after dressing about 8, and always at 9 a.m. in the laboratory. On warm days, instead of walking, the street car was used. Lunch was taken in the laboratory and dinner at the same dining-rooms as breakfast, after which the street car was made use of again in returning to the laboratory. Some time between 10 and 11 p.m. a walk of ten minutes down the hill brought the subject to his living-rooms, and he retired about 12, after the last set of observations for the day had been recorded. The daily bath was taken at night instead of in the morning during this period. Occasionally both in the control and other periods, when the subject chanced to wake up in the early morning, a set of readings was taken, but this practice, of course, could not be carried out regularly.

The daily routine above described is not very different from what can be followed on board ship, and as far as possible both there and in Scotland Ithacan habits were kept up. For example, before breakfast (the meals were served at the same hours as in Ithaca) a short walk was taken around the deck in imitation of the walk to the dining-rooms in Ithaca, and again after breakfast. The day was spent for the most part in reading novels in the saloon or on deck, promenading, and playing deck billiards or quoits. The muscular exercise indulged in was probably not equal to, and certainly not in excess of, that taken in Ithaca, but there was greater mental relaxation. The weather was fine from land to land and not the slightest suspicion of sea-sickness was experienced.

The eastward voyage was begun on June 25, about 11.45 p.m., when the train left Ithaca, and New York City was reached shortly after 8 o'clock next morning. The steamer (s.s. *Caledonia,* Anchor Line) sailed from New York for Glasgow about 2.30 p.m. on June 26. Four observations were made on the train and two in New York City for the sake of keeping up the continuity. Glasgow was reached about 4 p.m. and Edinburgh at 9 p.m. on July 4, the voyage thus lasting practically eight days.

The longitude of Ithaca, N.Y., is 76° 29′ W., and the local time is therefore 5 hours 5 minutes and 56 seconds—practically 5 hours 6 minutes—behind Greenwich time. The clock time at Ithaca is about 6 minutes ahead of the true local time. Eastern standard time is used at Ithaca, and this is the local time for stations on long. 75° W., which is 5 hours behind Greenwich time. My watch was adjusted for this difference, and the observations were made according to the correct local time at Ithaca. The longitude of Edinburgh is 3° 10′ W., and the local time about 12 minutes behind Greenwich time, so that the difference between Ithaca and Edinburgh local time is 4 hours 54 minutes.

On the Atlantic voyage the ship's position at noon was posted each day, and from the longitude given the local time was obtained. This was only correct for noon, however, but it was known that the time gained in a day's run east would be a little over half an hour, and, assuming that the vessel's speed was uniform, allowance could be made for the gain in the interval between each set of observations. This only amounted to a few minutes, however, and for my purpose it was immaterial whether this error was accurately corrected or not. The readings were taken usually at the hours stated, but on some occasions this was not possible and a variation of ten minutes to one side or the other was not considered sufficient to affect the results appreciably.

The figures obtained for the rectal, mouth, and axillary temperatures are given in degrees centigrade in the subjoined table, together with the temperature of the air, the local time, and, after the eastward journey was begun, the corresponding time at Ithaca, the starting-point. The remarks, necessarily brief, may be sufficient to show how the subject was employed for some time immediately preceding the observations.

TABLE I.

RECORDS OF RECTAL, MOUTH, AND AXILLARY TEMPERATURES TAKEN AT ITHACA, N.Y., ON THE JOURNEY FROM ITHACA TO EDINBURGH, AND FOR SIX DAYS AFTER ARRIVING IN EDINBURGH. THE AIR TEMPERATURE, ITHACA TIME AND LOCAL TIME ARE ALSO GIVEN.

	Ithaca Time.	Local Time.	Rectum.	Mouth.	Axilla.	Air.	Remarks.
1909 June 19	6 a.m.	...	37·1	36·3	36·2	23° C.	Awake since 5.30 a.m. Temp. taken in bed.
	9 ,,	...	37·4	36·8	36·1	24	In laboratory, half an hour after breakfast.
	12 ,,	...	37·4	36·6	36·3	26	,, writing at table.
	3 p.m.	...	37·6	37·0	36·4	25	,, moving about.
	6 ,,	...	37·9	36·8	36·3	24	,, ,,
	9 ,,	...	37·5	36·8	36·2	24	,, arranging books.
	12 ,,	...	37·2	36·5	36·1	23	In rooms; just before retiring.
June 20	6 a.m.	...	36·8	36·3	36·3	21	In bed; just awoke.
	7 ,,	...	36·9	36·2	36·3	22	,, light sleep since 6.
	8 ,,	...	37·1	36·5	36·2	22	After dressing.
	9 ,,	...	37·4	36·8	36·2	24	In laboratory; took street car.
	12 ,,	...	37·6	37·0	36·2	25	,, doing experiment.
	3 p.m.	...	37·6	36·8	36·3	26	,, ,,
	6 ,,	...	37·4	36·9	36·5	25	,, cleaning apparatus.
	9 ,,	...	37·5	36·8	36·2	26	In rooms; reading and writing.
	12 ,,	...	37·3	36·8	36·0	24	,, before retiring.
June 21	4 a.m.	...	36·8	36·3	36·3	20	In bed; just awoke.
	6 ,,	...	36·9	36·3	36·3	20	,, asleep since 5.
	7 ,,	...	37·0	36·2	36·1	21	,, light sleep since 6.
	8 ,,	...	37·2	36·8	36·2	22	After dressing.
	9 ,,	...	37·7	37·3	37·1	25	After walking to laboratory.
	12 ,,	...	37·4	36·9	36·4	28	In laboratory, writing at table.
	3 p.m.	...	37·5	37·1	35·8	29	,, ,, ,,
	6 ,,	...	37·6	36·9	36·1	29	Shopping down town.
	9 ,,	...	37·6	37·1	36·3	25	In laboratory, writing at desk.
	12 ,,	...	37·4	36·7	36·3	22	In rooms; did not retire till 1 a.m.
June 22	6 a.m.	...	36·8	36·3	36·1	19	In bed; awake since 5.
	7 ,,	...	36·8	36·5	36·3	22	,,
	8 ,,	...	37·2	36·8	36·3	...	After dressing.
	9 ,,	...	37·4	37·2	36·7	24	In laboratory, by street car.
	12	...	37·6	37·2	36·7	26	Had been walking on campus.
	3 p.m.	...	37·5	37·1	36·4	25	In laboratory; cleaning lenses.
	6 ,,	...	37·0	36·8	36·3	25	Writing near open window.
	9 ,,	...	37·6	37·1	36·6	25	In laboratory, after ride on street car.
	12	...	37·3	36·8	36·0	23	In rooms; retired at 12.30.
June 23	6 a.m.	...	37·0	36·5	36·4	...	In bed; sound asleep since 1 a.m.
	7 ,,	...	37·1	36·6	36·4	25	,, room hot.
	8 ,,	...	37·4	36·9	36·2	24	After dressing.
	9 ,,	...	37·6	36·9	36·3	26	In laboratory, by street car.
	12	...	37·6	37·0	36·5	27	,, moving about.
	3 p.m.	...	37·4	36·9	36·4	27	,, ,,
	6 ,,	...	37·7	37·1	36·7	26	,, after being down town.
	9 ,,	...	37·8	37·3	37·1	25	In rooms; walked home.
	12	...	37·4	36·9	36·7	23	,, packing trunk.
June 24	3 a.m.	...	36·7	36·2	36·1	...	In bed; asleep since 12.30.
	7 ,,	...	37·0	36·6	36·3	24	,, did not sleep well.
	9 ,,	...	37·9	37·4	37·1	27	After walk to laboratory.
	12	...	37·9	37·2	36·6	28	In laboratory; in active movement.
	3 p.m.	...	38·5	37·6	37·2	31	,, after short walk on campus.
	6 ,,	...	38·1	37·1	36·6	29	,, moving about actively.
	9 ,,	...	37·9	37·0	36·6	27	,, packing books.
	12	...	37·3	36·6	36·1	25	In rooms; reading.
June 25	2 a.m.	...	36·8	36·4	36·3	...	In bed; had been asleep.
	7 ,,	...	36·7	36·4	36·2	...	,, after sound sleep.
	8 ,,	...	36·9	36·6	36·4	25	After dressing.
	9 ,,	...	37·2	37·1	36·6	25	In laboratory, by street car.
	12	...	38·2	37·6	37·2	28	Long. 76° 29′ W. In lab.; moving about.
	3 p.m.	...	37·8	37·4	37·1	29	In laboratory; packing books and papers.
	6 ,,	...	37·7	37·4	37·0	29	,, moving about actively.

TABLE I.—*continued.*

	Ithaca Time.	Local Time.	Rectum.	Mouth.	Axilla.	Air.	Remarks.
1909							
June 25	9 p.m.	...	37·6	37·0	36·8	28° C.	In laboratory ; packing books.
	12	12	37·6	37·1	36·6	...	In train, 15 minutes after leaving Ithaca.
June 26	2.56 a.m.	3 a.m.	36·8	36·5	36·6	...	„ in bed ; feeling cool.
	6.51 „	7 „	37·3	36·8	36·8	25	„ „
	7.50 „	8 „	37·5	37·1	36·6	25	After dressing in train.
	9.50 „	10 „	37·6	37·5	36·7	28	In New York City ; half hour after breakfast.
	11.50 „	12	38·1	37·6	37·1	30	Long. 74° W. (about) ; after walk.
	2.50 p.m.	3 p.m.	37·8	37·2	36·3	26	In steamer, about 20 minutes after sailing.
	5.47 „	6 „	37·9	37·3	36·8	24	Walking deck ; before dinner.
	8.44 „	9 „	37·6	36·9	36·7	22	„ „
	11.41 „	12	37·3	36·7	36·3	25	In state-room, before retiring.
June 27	5.33 a.m.	6 a.m.	36·8	36·3	36·1	20	In bed ; open port-hole ; cool.
	6.31 „	7 „	36·8	36·4	36·5	20	„ „ „
	7.29 „	8 „	37·0	36·3	36·0	22	After dressing.
	8.27 „	9 „	37·2	37·0	36·1	21	On deck ; after breakfast.
	11.23 „	12	37·3	36·8	36·2	22	Long. 67° 21′ W. Reading on deck.
	2.19 p.m.	3 p.m.	36·9	36·7	36·6	19	On deck ; walking and reading.
	5.15 „	6 „	36·8	36·4	36·1	18	„ seated.
	8.11 „	9 „	36·7	36·5	36·1	19	In saloon after seat on deck.
	11.07 „	12	37·2	36·4	36·0	25	Before retiring ; room hot and stuffy.
June 28	3.01 a.m.	4 a.m.	36·4	36·2	36·1	...	In bed ; after short sleep.
	5.57 „	7 „	36·4	36·0	36·1	19	„ after sound sleep ; room cool.
	6.56 „	8 „	36·8	36·3	35·7	19	Short walk on deck.
	7.54 „	9 „	37·0	36·8	36·3	20	After breakfast.
	10.50 „	12	37·2	36·4	36·1	19	Long. 59° 12′ W.
	1.46 p.m.	3 p.m.	36·9	36·5	36·3	19	Seated on deck reading.
	4.42 „	6 „	37·0	36·9	36·1	16	In saloon, after walk on deck.
	7.37 „	9 „	37·2	36·8	36·2	16	„ reading.
	10.32 „	12	36·8	36·3	35·8	23	Before retiring.
June 29	5.24 a.m.	7 a.m.	36·6	36·2	36·1	19	In bed ; port-hole open.
	6.22 „	8 „	36·9	36·5	36·0	19	After dressing.
	7.20 „	9 „	37·2	37·0	36·4	20	After breakfast and short walk.
	10.16 „	12	37·1	36·3	36·1	11	Long. 50° 38′ W. Fog.
	1.12 p.m.	3 p.m.	36·9	36·7	36·3	10	On deck ; fog ; feel chilled.
	4.08 „	6 „	36·9	36·8	36·5	10	„ walking ; foggy.
	7·04 „	9 „	37·0	36·6	36·2	20	In saloon ; reading.
	10.00 „	12	36·4	36·2	35·9	21	Before retiring ; feeling very cold.
June 30	12.56 a.m.	3 a.m.	36·2	36·0	36·1	...	In bed.
	3.52 „	6 „	36·3	36·1	36·1	20	„
	5.49 „	8 „	36·5	36·3	36·0	18	After dressing.
	6.48 „	9 „	36·9	36·7	35·8	20	After breakfast ; cold north wind.
	9.44 „	12	36·9	36·6	35·6	10	Long. 42° 47′ W. Reading ; feeling cold.
	12.40 p.m.	3 p.m.	36·9	36·7	36·3	11	Playing deck billiards.
	3.36 „	6 „	36·8	36·7	36·2	10	On deck walking ; cold wind.
	6.32 „	9 „	37·4	36·6	36·2	21	In saloon since dinner, reading.
	9.28 „	12	37·3	36·3	35·8	20	Before retiring ; saloon had been stuffy.
July 1	3.21 a.m.	6 a.m.	36·9	36·4	36·4	22	In bed ; port-hole closed ; room stuffy.
	4.19 „	7 „	36·9	36·5	36·5	20	„ „ open.
	5.17 „	8 „	37·2	36·7	36·0	18	After dressing and walk on deck.
	6.15 „	9 „	37·4	37·0	36·5	23	After breakfast.
	9.11 „	12	37·6	36·8	36·6	19	Long. 34° 32′ W. Deck billiards.
	12.07 p.m.	3 p.m.	37·4	37·0	36·6	18	On deck reading ; clear ; sunshine.
	3.03 „	6 „	37·5	37·1	36·6	17	In saloon after walk.
	5.59 „	9 „	37·6	36·5	36·2	21	„ reading.
	8·54 „	12	37·2	36·7	36·1	22	Before retiring.
July 2	2.45 a.m.	6 a.m.	36·9	36·3	36·3	21	In bed ; slept well.
	3.44 „	7 „	36·9	36·3	36·2	19	„
	4.42 „	8 „	37·1	36·5	35·9	20	After dressing.
	5.40 „	9 „	37·3	36·8	35·9	18	After breakfast.
	8.35 „	12	37·3	36·2	35·8	17	Long. 25° 17′ W. Fog.
	11.30 „	3 p.m.	37·3	36·5	36·3	17	On deck ; playing quoits.
	2.25 p.m.	6 „	37·2	36·8	36·1	16	„ „ „
	4.20 „	9 „	37·4	36·7	36·2	21	In saloon ; reading.
	8.15 „	12	37·5	36·6	36·0	24	Before retiring ; after concert in saloon.

TABLE I.—*continued.*

	Ithaca Time.	Local Time.	Rectum.	Mouth.	Axilla.	Air.	Remarks.
9091							
July 3	2.05 a.m.	6 a.m.	37·0	36·3	36·1	22° C.	In bed.
	4.01 ,,	8 ,,	37·3	36·5	35·9	22	After dressing.
	4.59 ,,	9 ,,	37·5	36·6	36·2	23	After breakfast; no walk.
	7.54 ,,	12	37·7	36·8	36·4	15	Long. 15° 00′ W. On deck; billiards.
	10.49 ,,	3 p.m.	37·6	36·6	36·1	16	On deck; walking; fine breeze.
	1.44 p.m.	6 ,,	37·4	36·9	36·6	15	,, reading.
	4.39 ,,	9 ,,	37·4	36·8	36·6	21	In saloon; reading.
	7.34 ,,	12	37·2	36·2	36·0	14	On deck looking for Tory Island light.
July 4	12.28 a.m.	4 a.m.	36·8	36·1	36·2	...	In bed; retired at 1.30 a.m.
	2.23 ,,	7 ,,	37·0	36·4	36·4	19	,, no sleep since 5.
	3.21 ,,	8 ,,	37·3	36·6	35·8	19	After dressing and short walk.
	4.19 ,,	9 ,,	37·4	37·1	35·9	...	After breakfast.
	7.14 ,,	12	37·7	36·9	36·2	16	Long. 5° W. (about). Reading.
	10.11 ,,	3 p.m.	37·8	37·0	36·6	17	Long. 4° 20′ W. Standing on deck.
	1.11 p.m.	6 ,,	37·6	36·9	36·4	...	In Queen Street Railway Station, Glasgow.
	4.06 ,,	9 ,,	37·4	37·1	36·5	...	Long. 3° 10′ W. (about). Edinburgh.
	7.06 ,,	12	37·1	36·8	36·5	19	In rooms in Musselburgh.
July 5	2.06 a.m.	7 a.m.	37·0	36·4	36·2	21	In bed.
	3.06 ,,	8 ,,	37·4	36·9	36·0	20	After dressing; no walk.
	4.06 ,,	9 ,,	37·5	37·1	36·2	21	After breakfast.
	7.06 ,,	12	37·4	36·7	36·4	19	In rooms; reading.
	10.06 ,,	3 p.m.	37·6	37·0	36·6	20	In Edinburgh; after walk.
	1.06 p.m.	6 ,,	37·5	36·6	36·2	18	After shopping.
	4.06 ,,	9 ,,	37·3	36·9	36·4	21	In rooms; reading.
	7.06 ,,	12	37·2	36·9	36·5	19	Before retiring.
July 6		No observations made.					
July 7	11.06 p.m.	4 a.m.	36·9	36·1	36·0	...	In bed; slept since 12·30.
	1.06 a.m.	6 ,,	36·8	36·2	36·2	18	,, ,, 5.
	2.06 ,,	7 ,,	37·0	36·2	36·1	17	,, awake since 6.
	3.06 ,,	8 ,,	37·3	36·3	35·9	18	After dressing.
	4.06 ,,	9 ,,	37·4	37·0	36·0	19	After breakfast.
	7.06 ,,	12	37·5	37·1	36·4	21	Packing books.
	10.06 ,,	3 p.m.	37·6	37·0	36·6	18	,, ,,
	1.06 p.m.	6 ,,	37·4	36·9	36·4	17	After short walk.
	4.06 ,,	9 ,,	37·3	36·8	36·2	16	,, ,,
July 8	7.06 ,,	12	37·2	36·8	36·4	20	Reading before retiring.
	12.06 a.m.	5 a.m.	36·6	35·9	35·8	18	In bed.
	2.06 ,,	7 ,,	36·8	36·2	36·1	19	,, light sleep since 5.
	3.06 ,,	8 ,,	37·1	36·7	36·1	19	After dressing.
	4.06 ,,	9 ,,	37·3	37·1	36·0	20	After breakfast; cold.
	7.06 ,,	12	37·5	36·8	36·3	19	Packing books.
	10.06 ,,	3 p.m.	38·0	37·0	36·4	21	,, ,,
	1.06 p.m.	6 ,,	37·6	36·8	36·3	22	Writing at table.
	4.06 ,,	9 ,,	37·4	36·6	36·1	18	After seat in garden.
	7.06 ,,	12	37·3	36·6	36·0	19	Before retiring; packing books.
July 9	1.06 a.m.	6 a.m.	36·9	36·3	36·0	20	In bed; sound asleep since 1 a.m.
	2.06 ,,	7 ,,	37·0	36·3	36·3	20	,, no sleep since 6.
	3.06 ,,	8 ,,	37·2	36·4	36·0	19	After dressing.
	4.06 ,,	9 ,,	37·6	36·9	36·1	19	Reading newspaper.
	7.06 ,,	12	38·0	37·2	36·3	21	Packing trunks.
	10.06 ,,	3 p.m.	37·7	37·1	36·6	18	After short walk.
	1.06 p.m.	6 ,,	37·6	37·1	36·6	17	,, ,,
	4.06 ,,	9 ,,	37·6	36·9	36·3	21	Reading; room stuffy.
	7.06 ,,	12	37·3	36·6	36·0	20	Before retiring; packing trunks.
July 10	11.06 ,,	4 a.m.	36·8	36·4	36·3	...	Asleep since 12.30.
	1.06 p.m.	6 ,,	36·8	36·4	36·3	18	,, 4.30.
	2.06 ,,	7 ,,	36·9	36·5	36·4	19	Just before getting up.
	3.06 ,,	8 ,,	37·2	36·7	36·0	20	After dressing.
	4.06 ,,	9 ,,	37·5	36·8	36·2	21	After breakfast and short walk.
	7.06 ,,	12	37·5	36·7	36·1	23	Working in house.
	10.06 ,,	3 p.m.	37·3	36·8	36·4	22	Reading for half hour.
	1.06 p.m.	6 ,,	37·6	36·9	36·5	24	After walk on beach.
	4.06 ,,	9 ,,	37·7	37·0	36·4	26	Working at table.
	7.06 ,,	12	37·3	36·7	36·1	24	Before retiring.

After arriving in Edinburgh the observations were continued, with one day's interruption (July 6), till July 10, the daily routine being not much different from the same in Ithaca. From July 17 till August 10 the time was spent in the Orkney Islands, somewhat over 200 miles farther north than Edinburgh, but practically in the same longitude, and here another series was taken from August 3 to 9 inclusive.

On August 5 I walked around one of the islands, a distance of about twelve miles, over rough ground, temperature records being taken at intervals of one and a half hours, and a glance at the chart (fig. 3) will show the effect on the body temperature. On August 8 I remained in bed the whole day, and abstained from food entirely from 9 p.m. August 7 till 8 a.m. August 9, at the same time making an effort to restrain muscular action as far as possible. As these records are important for comparison with others taken subsequently under somewhat similar circumstances in Winnipeg and in Ithaca, they are given below together with the room temperature, which was practically the same as that of the outside air, since all the windows of the sleeping-room were open. Readings were taken every hour.

The journey westward was begun on August 14, when the train left Edinburgh for Glasgow at 6 a.m. The steamer (s.s. *Ionian*, Allan Line) sailed from Glasgow about 10 a.m. and from Greenock about 2 p.m. the same day. The weather was fine, and the voyage uneventful until we ran into fog and ice off the Newfoundland coast, when we were compelled to go dead slow or to drift for almost two days (August 20 and 21). On the evening of the 21st we entered the Straits of Belle Isle, and from that time onwards it was full speed ahead until Quebec was reached about 9 p.m. on August 23. That night was spent on board ship moored at the quay, and at 7.30 a.m. we left Quebec and steamed up the St Lawrence to Montreal, where we disembarked about 7 p.m. on August 24. That night and the following day was spent in Montreal, and at 10.30 p.m. on August 25 the train to Winnipeg was taken, where it arrived at 9.20 p.m. on August 27.

During the whole journey from Glasgow to Winnipeg the observations were kept up without interruption on steamship and train until noon August 30, three days after arrival in Winnipeg.

On August 29, the second day in Winnipeg, I repeated the routine of August 8 in the Orkneys, remaining in bed the whole day without food and voluntarily inhibiting muscular movement as far as possible. The light was partly obscured by the close proximity of a brick wall to the single window of the room I occupied, and this, together with the fact that no person visited me, was particularly favourable for my purpose, which was to secure as completely as possible bodily and mental quiescence. The rectal, mouth, and axillary temperatures were recorded hourly together with the temperature of the room (see Table II.).

On the return journey from Winnipeg to Ithaca several stops were made on the way and the observations were discontinued until September 10, the day after arriving

TABLE II.

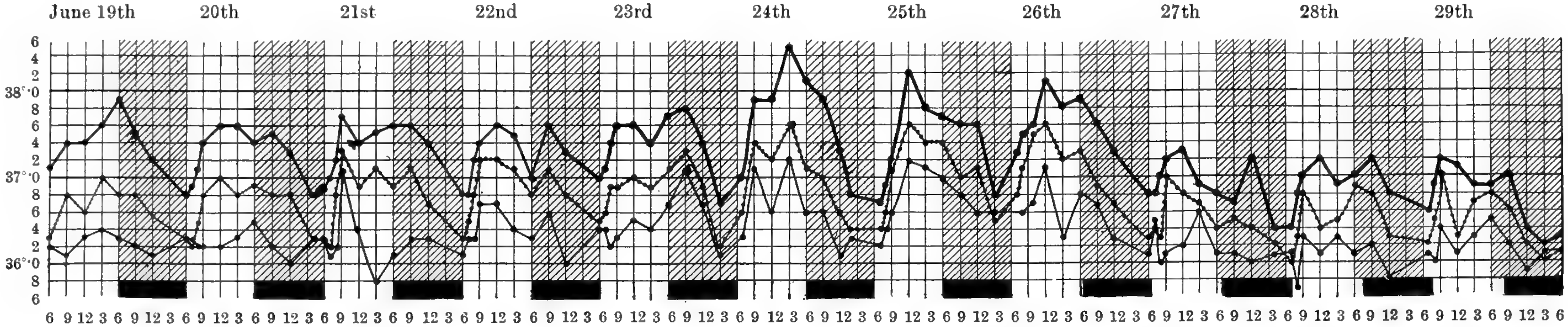
Records of Rectal, Mouth, and Axillary Temperatures taken in the Orkney Islands (Scotland), Winnipeg, and Ithaca, N.Y., while resting in Bed, and on Three Occasions (August 8 and 29 and September 26) at the same time abstaining from Food.

August 8, Orkney Islands.					August 29, Winnipeg.					September 12, Ithaca, N.Y.					* September 26, Ithaca, N.Y.					* October 3, Ithaca, N.Y.				
	Rectum.	Mouth.	Axilla.	Air.		Rectum.	Mouth.	Axilla.	Air.		Rectum.	Mouth.	Axilla.	Air.		Rectum.	Mouth.	Axilla.	Air.		Rectum.	Mouth.	Axilla.	Air.
5 a.m.	36·9	36·4	36·3	12	6 a.m.	36·8	36·1	36·1	12	6 a.m.	36·9	36·3	36·3	16	6 a.m.	37·0	36·3	36·3	6	6 a.m.	36·8	36·2	36·2	8
7 „	36·8	36·2	36·2	14	7 „	36·8	36·2	36·0	12	7 „	36·95	36·3	36·2	17	7 „	37·05	36·3	36·3	7	7 „	36·85	36·1	36·1	9
8 „	36·95	36·3	36·1	14	8 „	36·9	36·1	36·1	11	8 „	37·0	36·4	36·2	...	8 „	37·1	36·3	36·3	...	8 „	36·9	36·2	36·1	10
9 „	37·2	36·7	36·5	15	9 „	37·1	36·3	36·1	13	9 „	37·15	36·5	36·0	...	9 „	37·1	36·4	36·3	...	9 „	36·8	36·1	36·0	10
10 „	37·1	36·4	36·5	16	10 „	37·1	36·2	36·1	15	†10 „	37·2	36·6	36·2	...	10 „	37·0	36·3	36·3	8	†10 „	37·05	36·4	36·1	10
11 „	37·0	36·3	36·3	17	11 „	37·0	36·3	36·0	...	11 „	37·2	36·6	36·4	18	11 „	37·05	36·4	36·2	10	11 „	37·05	...	...	11
12	37·05	36·5	36·3	17	12	37·0	36·1	36·0	...	12	37·05	36·6	36·5	19	12	37·1	36·2	36·2	14	12	37·05	36·3	36·2	11
1 p.m.	37·05	36·2	36·4	16	1 p.m.	37·0	36·2	36·2	16	1 p.m.	37·1	36·6	36·6	...	1 p.m.	37·05	36·3	36·4	...	1 p.m.	37·1	36·4	36·3	11
2 „	37·1	36·4	36·3	16	2 „	36·9	36·1	36·0	...	2 „	37·15	36·9	36·5	20	2 „	37·0	36·4	36·4	...	2 „	37·1	36·2	36·3	12
3 „	37·05	36·3	36·2	17	3 „	36·9	36·1	36·2	...	3 „	37·05	36·5	36·4	...	3 „	37·05	36·4	36·2	19	3 „	37·3	36·7	36·2	12
4 „	37·0	36·5	36·3	16	4 „	36·9	36·2	36·2	17	4 „	37·1	36·6	36·4	...	4 „	36·9	36·4	36·2	22	4 „	37·15	36·4	36·1	11
5 „	37·1	36·2	36·4	16	5 „	36·9	36·4	36·2	...	5 „	37·15	36·5	36·4	...	5 „	36·95	36·5	36·3	20	5 „	37·1	36·4	36·3	10
6 „	37·05	36·4	36·3	16	6 „	37·0	36·3	36·1	...	6 „	37·0	36·8	36·7	21	6 „	37·0	36·3	36·3	14	6 „	37·05	36·4	36·4	10
7 „	36·95	36·4	36·5	15	7 „	37·05	36·5	36·3	18	7 „	37·05	36·9	36·7	22	7 „	37·0	36·2	36·3	13	7 „	37·25	36·8	36·3	10
8 „	36·8	36·2	36·0	15	8 „	37·0	36·4	36·2	...	8 „	37·1	36·6	36·5	...	8 „	36·95	36·2	36·2	12	8 „	37·25	36·4	36·3	10
9 „	36·8	36·0	36·1	14	9 „	36·95	36·3	36·1	...	9 „	37·0	36·7	36·6	20	9 „	36·9	36·2	36·2	11	9 „	37·2	36·3	36·2	10
10 „	36·8	36·0	35·9	14	10 „	36·9	36·5	36·4	18	10 „	37·05	36·7	36·6	...	10 „	36·8	36·0	36·1	10	10 „	37·1	36·3	36·2	9
11 „	36·8	36·1	36·1	14	11 „	36·9	36·1	36·0	17	11 „	37·05	36·4	36·3	...	11 „	36·8	36·0	36·0	10	11 „	37·0	36·1	36·2	9
12	36·7	35·8	35·8	13	12	36·85	36·2	36·1	16	12	37·0	36·3	36·3	19	12	36·75	36·0	36·0	8	12	36·95	36·0	36·1	9

* On September 26 and October 3 the bed was in the open air on the verandah.

† On September 12 breakfast was taken shortly after 9 a.m., lunch between 1 and 2, and dinner between 6 and 7 p.m. On October 3 breakfast and dinner were taken at the same hours as on September 12, but lunch came between 2 and 3 p.m. The effect of the meals can be seen on the mouth temperature.

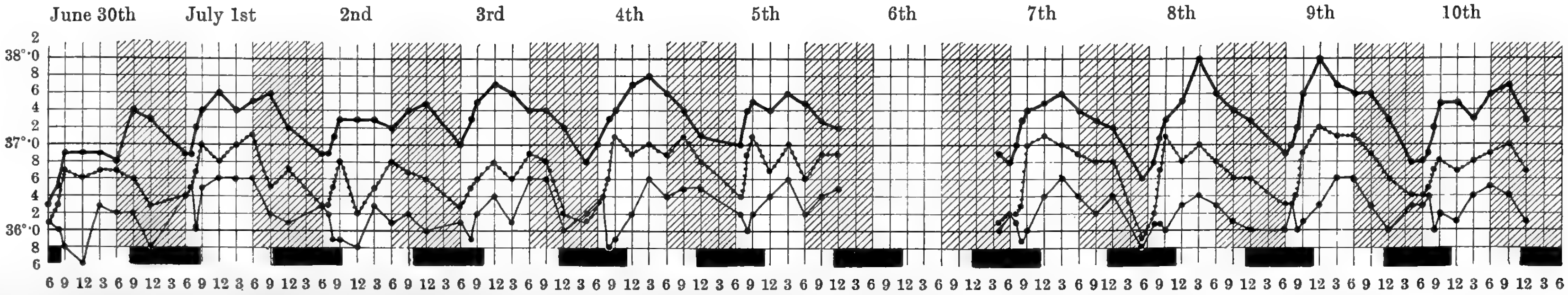
Figs. 1–5 show the records of the rectal, mouth, and axillary temperatures taken, from June 19 till September 14, 1909, in Ithaca, during a voyage from Ithaca to Edinburgh, in Scotland, on a voyage from Edinburgh to Winnipeg, and again in Ithaca. The heavy continuous line indicates the rectal temperature in degrees centigrade, the light continuous line the axillary temperature, and the dotted line the mouth temperature. The division of the twenty-four hours into night and day is indicated graphically by the alternate light (6 a.m. to 6 p.m.) and dark (6 p.m to 6 a.m.) bands at the bottom of the chart according to Ithaca local time. The hatched and intermediate clear segments show night (6 p.m. to 6 a.m.) and day (6 a.m to 6 p.m.) by train and ship's local time, and the alternate light and dark bands at the top the same by Edinburgh time. It will be observed that the dark and hatched bands coincide from June 19 to 25 and from September 10 to 14, but on the voyage eastward the train and ship's local time moves forward and on the voyage westward it moves backward in relation to Ithaca time; the gradual change in the relative positions of these bands is meant to show this. The figures at the bottom of the chart represent hours, and at the left-hand side degrees centigrade.



Control period in Ithaca, June 19 to 25.

Voyage eastward from Ithaca to Edinburgh, June 26 to July 4.

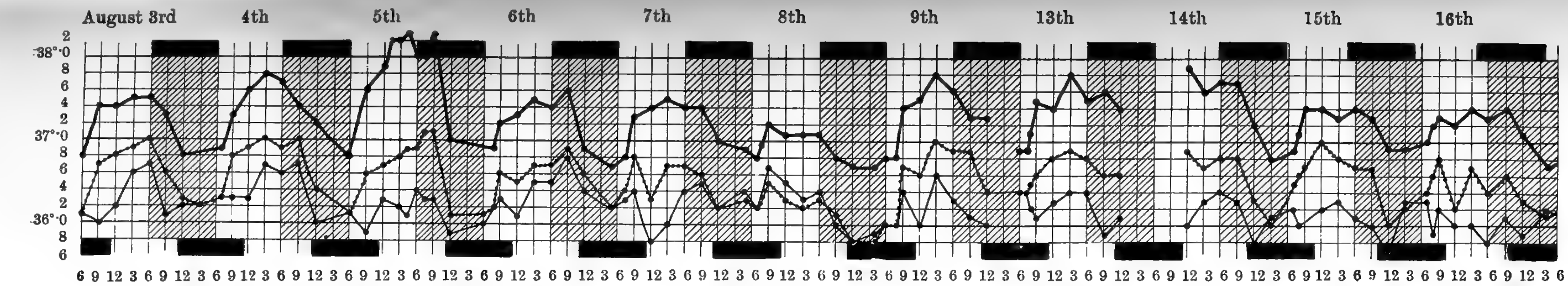
FIG. 1.



Voyage eastward from Ithaca to Edinburgh, June 26 to July 4.

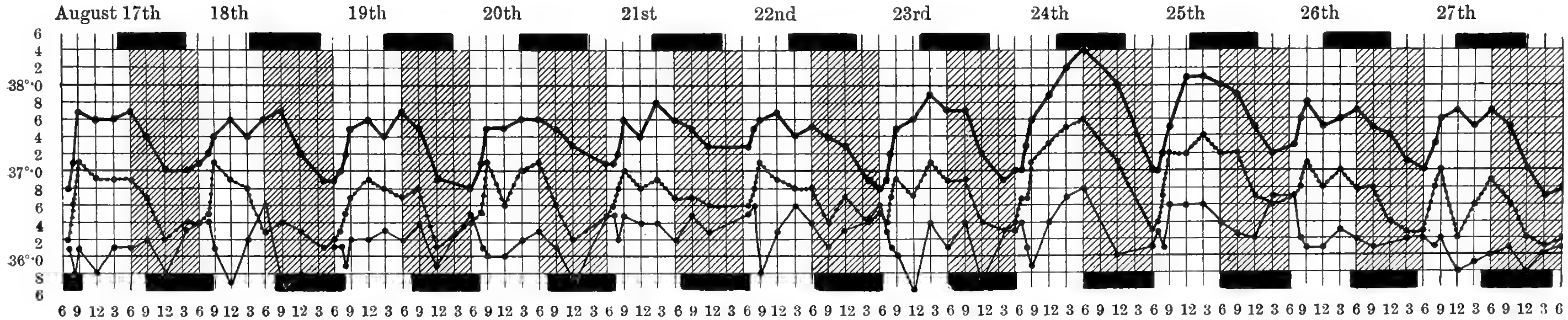
Edinburgh from July 5 to 10.

FIG. 2.



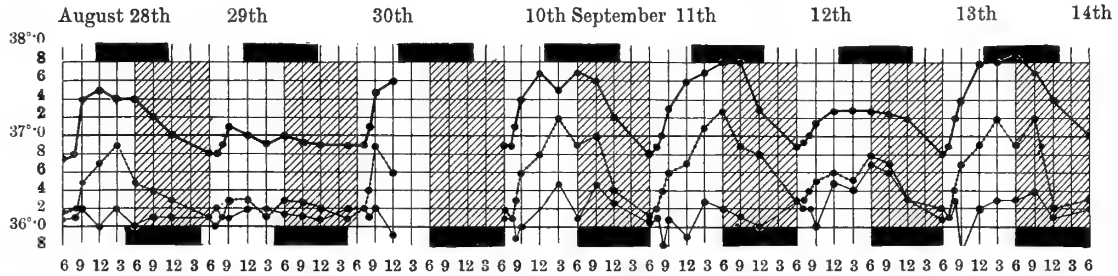
Orkney Islands (same longitude as Edinburgh), August 3 to 9. Edinburgh, August 13. Voyage westward from Edinburgh to Montreal, August 14 to 24.

FIG. 3.



Voyage westward from Edinburgh to Montreal, August 14 to 24. Montreal, August 25. Train journey from Montreal to Winnipeg, August 25 to 27.

FIG. 4.



Winnipeg, August 28 to 30. Ithaca, September 10 to 14.

FIG. 5.

in Ithaca, when they were resumed again for four consecutive days till 6 a.m. on September 14. On September 12 and 26 and October 3 the three twenty-four hour periods were spent at rest in bed, as on the former occasions in Winnipeg and Scotland. On September 12 and October 3 the three ordinary meals were taken, but on September 26 food was abstained from (see Table II.).

IV. Results and Discussion.

The results of this continuous series of observations from June 19 till September 14, with the interruptions as indicated, are presented in the accompanying temperature charts (figs. 1 to 5). The thick continuous line represents the rectal temperature, the dotted line the mouth temperature, and the thin continuous line, usually the lowest in position, the axillary temperature. The division of the twenty-four hours into night and day periods is indicated graphically by the alternate light (6 a.m. to 6 p.m.) and dark (6 p.m. to 6 a.m.) bands at the bottom of the chart according to Ithaca local time. The hatched and intermediate clear segments extending through the whole width of the chart shows night (6 p.m. to 6 a.m.) and day (6 a.m. to 6 p.m.) by ship and train local time, and the alternate light and dark bands at the top the same by Edinburgh time. This division is somewhat arbitrary, since from June 19 till September 21 the sun rises before and sets after 6 o'clock, so that the dark and hatched bands on the chart are more extensive than the natural night period, but the attempt to construct a chart in which these should coincide exactly with the dark periods for the different latitudes in which the observations were made was found to involve too much labour and was abandoned. In the Orkneys a newspaper could be read outside the house at 10 p.m. and again at 2 a.m., the actual dark period at that season of the year being of very short duration. As it stands this feature of the chart is only meant to show in a graphic way the relative differences between the local time on the journey and that of Ithaca and Edinburgh. From June 19 to 25 it will be observed that the dark and hatched bands coincide, and also from September 10 to 14; but on the voyage eastward the ship's local time moves forward, and on the voyage westward it moves backward in relation to Ithaca time.

The figures at the left side of the chart represent degrees centigrade, those at the bottom hours of the day, and those at the top days of the month. Twelve o'clock noon occurs at the middle of the clear band and 12 o'clock midnight at the middle of the hatched band, each space between the vertical lines representing an interval of three hours.

A careful scrutiny of this chart will bring to light some interesting facts, and the first and most obvious of these is that the body-temperature curves of no two days are alike. If inherent rhythmicity were a predominant feature, one would expect to find a closer resemblance between the curves on different days, whereas they all seem to be controlled to a very large extent by the conditions imposed on the body. This is well seen on June 24, 25, and 26, when the external temperature was high and muscular movement only slightly more active than on the four preceding days. It shows what a powerful influence even very moderate exercise has on the body temperature in hot weather. On the 24th at 3 p.m. the rectal temperature reached 38°·5 C., and at 7 a.m. the following day it was 36°·7 C., giving a range of almost 2° C., about double the average for the previous five days.

After getting to sea on the homeward journey cold, foggy, depressing weather, such as is usually found on the banks of Newfoundland, was experienced for the first four days, and its influence is at once evident on the temperature curve. The maximum falls about 1° C. between the 26th and 27th, and the diurnal range is also greatly reduced. The lowest point was reached at 3 a.m. on September 30, when the rectal thermometer stood at 36°·2. From June 30 till the end of the voyage the weather was clear, bright, and warm, with sunshine throughout the greater part of the day, and here again the effect on the body temperature is at once visible.

The influence of severe muscular exercise with a moderate external temperature is well seen on August 5, when a long walk was taken over rough ground; the rectal temperature was maintained over 38° C. for several hours, while the air temperature averaged about 11° C., with a cool breeze blowing. Again the influence of a high air temperature with moderate muscular exercise is illustrated by the rectal temperature curves of August 22, 23, and 24. On the 22nd the ship was in the lower reaches of the Gulf of St Lawrence, just through the Straits of Belle Isle, and not far from ice. As she steamed up the Gulf and into the river the air temperature rose rapidly until it reached the neighbourhood of 31° C. near Montreal on the 24th.

On the train sleep was poor, and the minimal rectal readings were high on August 26 and 27, probably on this account, while the effect of a sound sleep following a period of fatigue is seen on the morning of the 28th, when at 3 o'clock the body temperature (rectal) sank to 36°·7 C., a point lower than had been reached on any previous occasion during the westward journey with one exception, 4 a.m. August 17. The contrast between the curves of August 5 and 29 shows the effect of muscular exercise, the external temperature being not much different on the two occasions.

Proceeding now to the discussion of the main question (to throw some fresh light on which the present investigation was undertaken), viz. whether the temperature curve is controlled by purely local and external conditions, or shows evidence of an innate periodicity independent of these, I believe that we shall find the evidence to be mostly on the one side. If the temperature rhythm were fixed in the observer's body we should expect to find that as he proceeded eastward, gaining time daily, the morning (6 to 9) rise would begin later and later each successive day until the end of the journey, and when Edinburgh was reached, where 11 a.m. corresponds with 6 a.m. at Ithaca, this rise should show itself between 11 a.m. and 2 p.m. In this relation we shall consider the rectal temperature only, since this is influenced to a smaller degree by accidental external disturbances than either the buccal or axillary temperature. A careful examination of the chart (figs. 1 and 2) will show that no such delay is apparent in the diurnal curve. The sharp morning rise is not any less abrupt on July 5 than it is, for example, on June 20.* The curve appears to obey local time and not Ithaca time.

In order to get rid of accidental variations which might affect the body temperature on any one day, the average curve for each of the following periods is taken:—A, six days in Ithaca, immediately before setting out on the eastward journey, from June 19 to 25 (omitting one day—24th—when the rectal temperature was distinctly above the usual level, due to a combination of muscular exercise and high external temperature); B, the first four days (June 27 to 30), and C, the last four days (July 1 to 4), of the voyage from New York to Edinburgh; D, five days immediately following arrival in Edinburgh (July 5 to 10, omitting 6th); E, five days in the Orkney Islands about one week before starting westward (August 3 to 13, omitting 5th, 8th, 10th, 11th, and 12th); F, the first six (August 15 to 20), and G, the last six days (August 22 to 27, omitting 24th) of the journey from Scotland to Winnipeg; H, one day and a half at Winnipeg (August 28 till noon on 30th, omitting 29th); and lastly, I, the four days immediately following the return to Ithaca from Winnipeg (September 10 to 14, omitting 12th). In these average curves the rectal temperature only is considered. (See Table III.)

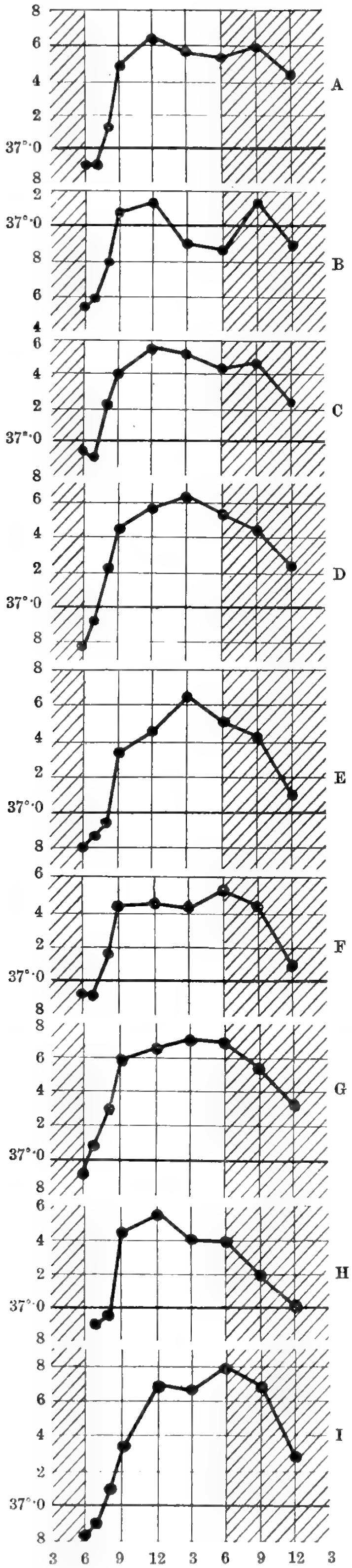


FIG. 6.—Average temperatures for different periods.

From an examination of these nine mean curves (charts A to I, fig. 6) it will be seen that although there is considerable variation in their general characters, the most constant features, viz., the rise between 6 a.m. and 9 a.m., and the fall from 9 p.m. to midnight, are fairly regular. Compare, for example, A, the Ithaca control, and C, the mean of the last four days of the journey eastward. Except for the slightly smaller range of C, due probably to the less active life led on board ship, they very closely resemble each other. The first maximum is reached at

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* On two or three occasions in the control period at Ithaca the rapid rise from 8 a.m. to 9 a.m. is associated with a walk up a rather steep hill after breakfast in hot weather and shortly before the 9 o'clock observation was made. This is apt to give a wrong impression when comparing the curves at Ithaca with those obtained subsequently.

noon and the second at 9 p.m., the same hours in both cases. The ascent from 7 a.m. to 9 a.m. is slightly less steep in C than in A, which might be explained by the fact that on two or three occasions in Ithaca the 9 a.m. temperature was taken very soon after a walk uphill in hot weather, but the descent from 9 p.m. to midnight is, on the other hand, somewhat more sudden. If the Ithaca temperature habit had been fixed in the body, there should be some evidence of delay in the rise of the curve C and also in its fall, but there is none. These curves A and C resemble each other more nearly than any other two, except probably D (Edinburgh) and G (the last half of the voyage westward), where the time difference is again four to five hours.

TABLE III.

Average Rectal Temperature for Nine Periods as stated in the Text.

	June 19–25.	June 27–30.	July 1–4.	July 5–10.	Aug. 3–13.	Aug. 15–20.	Aug. 21–27.	Aug. 28–30.	Sept. 10–14.
6 a.m.	36·92	36·55	36·95	36·79	36·80	36·93	36·97	...	36·83
7 "	36·90	36·60	36·90	36·94	36·87	36·92	37·12	36·90	36·90
8 "	37·16	36·80	37·22	37·24	36·93	37·15	37·33	36·95	37·10
9 "	37·45	37·07	37·40	37·46	37·35	37·47	37·60	37·45	37·37
12	37·63	37·12	37·57	37·58	37·43	37·48	37·67	37·55	37·70
3 p.m.	37·58	36·90	37·52	37·64	37·65	37·45	37·72	37·40	37·66
6 "	37·55	36·87	37·42	37·54	37·52	37·55	37·70	37·40	37·80
9 "	37·60	37·07	37·45	37·46	37·43	37·47	37·58	37·20	37·70
12	37·42	36·90	37·25	37·26	37·10	37·07	37·32	37·00	37·30

It might be supposed that after a five weeks' residence in Scotland the body would gradually accommodate itself to the changed conditions, and a Scottish temperature rhythm be established. This would be present in the mean of the observations made in the Orkney Islands—curve E; and if this type had been carried westward, then at Winnipeg, where the Scottish daily routine had been moved backwards by more than six hours, we would expect to find that the curve for Winnipeg (H) should show an upward tendency earlier, according to Winnipeg local time, and also decline earlier than the Orkney curve (E). It does appear that the fall sets in sooner, but the Winnipeg type represents only a single day, and some accidental variation might account for the early decline. The morning rise does not come in any sooner than in Scotland.

In making such comparisons, however, it is essential that the conditions with regard to external temperature, meals, mental activity, and particularly muscular movement shall be as nearly as possible similar at the two places, and this will be best secured if the subject remains at rest in bed, and at the same time abstains from food while the observations are being made. The effects of external factors will then be reduced to a minimum, and any inherent temperature rhythm present in the body may be expected to show itself. Assuming that the Ithaca rhythm has been replaced by a Scottish rhythm in the course of a six weeks' residence in Scotland, then if the latter had persisted in the body to any appreciable extent one would expect to find that the records obtained at Winnipeg on August 29—with the subject resting in bed and fasting, as in the Orkneys on August 8—when plotted out should give a curve different from that found in Scotland: the morning rise as well as the late evening fall should appear some six hours earlier in the Winnipeg than in the Orkney curve. Such, however, is not the case. The morning ascent, to be sure, is slightly less abrupt in the Winnipeg curve, but this may be accounted for by the fact that here the subject was allowed to remain quite undisturbed, whereas on August 8 he was persistently invited to partake of some breakfast by kind but injudicious friends.

There is no evidence of any persistence of the Ithaca control type of curve in Scotland, nor of the Scottish type in Winnipeg. In the westward as in the eastward journey there appears to be an immediate adjustment of the temperature rhythm to the changing daily routine, so that in this respect the results agree entirely with those obtained by Gibson.

V. Effect of Muscular Rest and Activity on Body Temperature.

After plotting out the curves for the rectal-temperature readings taken on August 8 and 29, I was struck with the marked effect which complete rest in bed has on the diurnal body-temperature variation, and to test this further, I made experiments under nearly similar conditions on myself on three occasions after returning to Ithaca (September 12 and 13, 26 and 27, and October 3 and 4) and twice on two other individuals (November 27, 28, and 29, and January 29, 30, and 31).

On September 12 I stayed in bed all day, *i.e.* from 12.15 a.m. till 7 a.m. on the 13th, and, as on August 8 and 29, endeavoured to make as few movements as possible, but on this occasion I had the usual three meals, taken in bed in the recumbent position—breakfast at 9.30 a.m., lunch at 1.30 p.m., and dinner at 6.30 p.m. The temperature of the room rose steadily from about 16° C. at 6 a.m. to 22° C. at 7 p.m., and then fell to 19° C. at midnight. Such changes in the outside temperature, however, in the case of a person in bed and covered with blankets, are of little importance, except as affecting the temperature of the mouth (fig. 9).

On September 26 the same experiment was repeated, with this difference, that no food was taken from 9.30 p.m. on the 25th till 8 a.m. on the 27th. The bed on this occasion was outside on the verandah, and the air-temperature range was from 6° C. at 6 a.m. to 22° C. at 4 p.m., after which it fell regularly till midnight, when the thermometer stood at 8° C. (fig. 10).

On the following Sunday (October 3) I again remained in bed on the verandah, but had breakfast at 9 a.m., lunch at 2.30 p.m., and dinner at 6.30 p.m. The air temperature was about 10° C., and varied little throughout the day (fig. 11).

Wishing to ascertain how this modification of the daily routine would affect the diurnal temperature variation in other individuals, I prevailed on Miss A. B. and Mr X. Y., workers in the laboratory, to make similar experiments on themselves, and

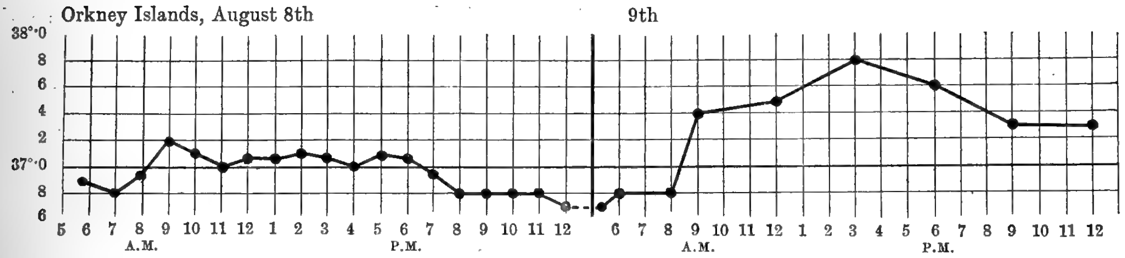

FIG. 7.—Effect of muscular inactivity and fasting on the rectal temperature.

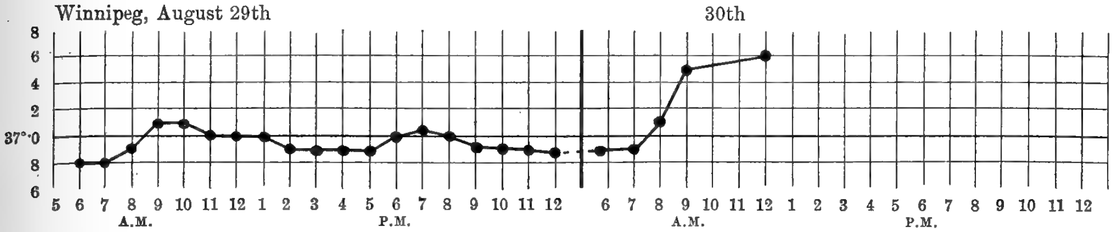

FIG. 8.—Effect of muscular inactivity and fasting on the rectal temperature.

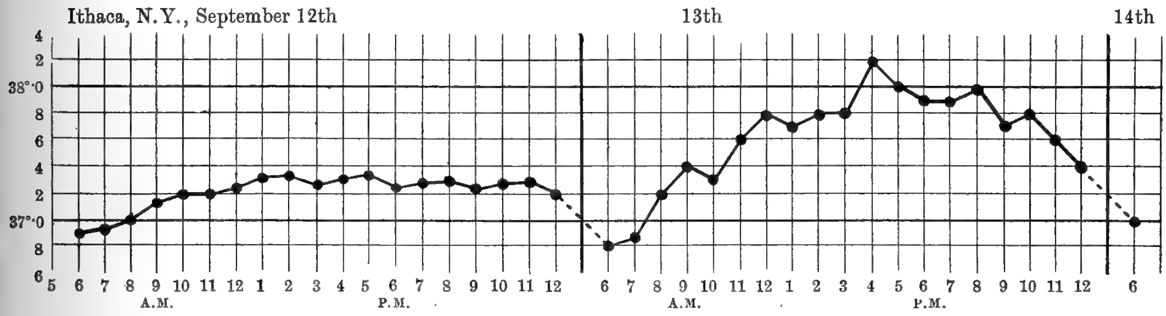

FIG. 9.—Effect of muscular inactivity on rectal temperature.

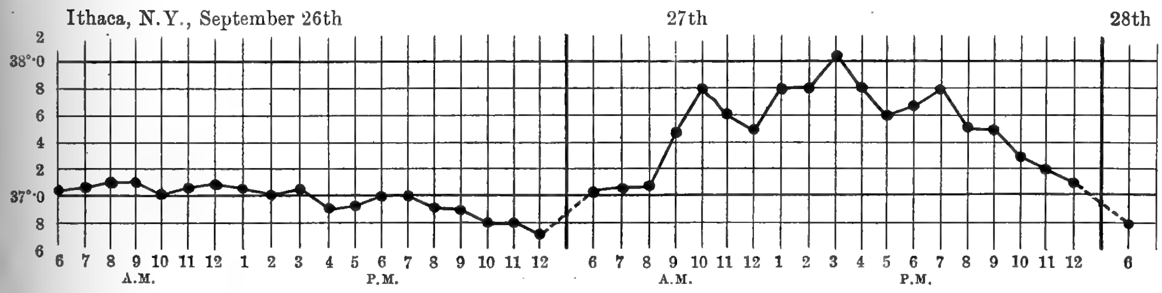

FIG. 10.—Effect of muscular inactivity and fasting on rectal temperature.

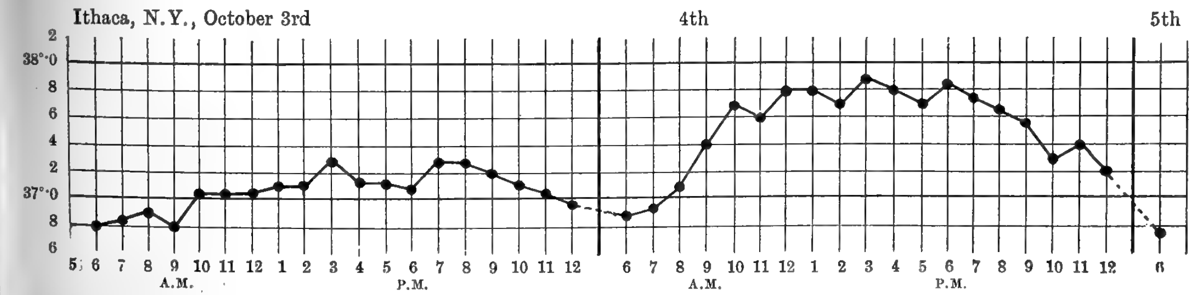

FIG. 11.—Effect of muscular inactivity on rectal temperature.

I would take this opportunity of expressing my indebtedness to both for their ready consent to pass through this, to healthy young people, somewhat trying ordeal.

Miss A. B. (age 27, weight 116 lbs., height 5 ft. 7½ ins., and of slender build) made observations at irregular hours on November 27 and 29, while engaged in her ordinary work at the University, to obtain curves on days of activity for comparison, and on the 28th took readings every hour, keeping bed from 10.15 p.m. on the 27th till 6 a.m. on the 29th, at the same time abstaining from food, "except a glass of milk and some crackers between six and seven in the evening." When examining her figures I found that twice there were somewhat sudden elevations in the temperature (at 3 p.m. and 6 p.m., fig. 12), which then quickly dropped again, and on writing to her to find out the cause of these, her reply was: ". . . I read some, slightly propped up in bed. The rises in temperature came at the periods when I was disturbed by callers. I tried to keep my room at the same temperature as I had it at night—heat off and window open. I remember that during the afternoon I was very restless, even when alone." It is quite evident to me that she had difficulty in restraining her muscular movements to the same extent that I did, and this is shown in her temperature chart for that day (fig. 12).

Mr X. Y. (age 27, weight 134 lbs., height 5 ft. 8½ ins., and sparely built) also continued his experiment for three days. On January 29 and 31, 1910, in his rooms and while at work in the laboratory, he made observations every two hours, and on the 30th every hour from 5 a.m. till 10 p.m. Like Miss A. B., he kept bed from 10 p.m. on the 29th till 6 a.m. on the 31st, but he had three meals at his usual hours—breakfast at 8 a.m., dinner at 1 p.m., and supper at 6.30 p.m. Besides, he was reading most of the time, and this implies a fair amount of muscular exertion, since in the recumbent posture a book is not easily held in front of one in such a position that it can be read. In this experiment, although the curve is distinctly modified when compared with that of the day before or the day after (fig. 13), the temperature range is considerably greater than in either the case of Miss A. B. or that of the writer. It may be mentioned in passing that neither of these (A. B. nor X. Y.) was a good subject for this experiment, since both are naturally energetic and somewhat restless individuals.

In the literature of this subject which I have consulted several temperature charts are presented from healthy individuals "resting in bed" during the day, and most show a very distinct diurnal variation. For example, in Pembrey's article on "Animal Heat" in Schäfer's *Text-book of Physiology* (vol. i. p. 800), a curve, copied from Ringer and Stuart,[*] is given which "shows the daily fluctuations of temperature in a boy 12 years old; the thermometer—a non-registering one—was kept in the closed axilla throughout the time, and the readings were taken every hour. The boy was in good health, and was kept in bed during the observations," which extended over fifty hours. The range for each of the twenty-four hour periods is almost 2° C. (from about 36° to about 38°). I cannot help thinking that this must have been a particularly

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[*] Ringer and Stuart, *Proc. Roy. Soc.*, Lond., vol. xxvi., 1877, p. 187.

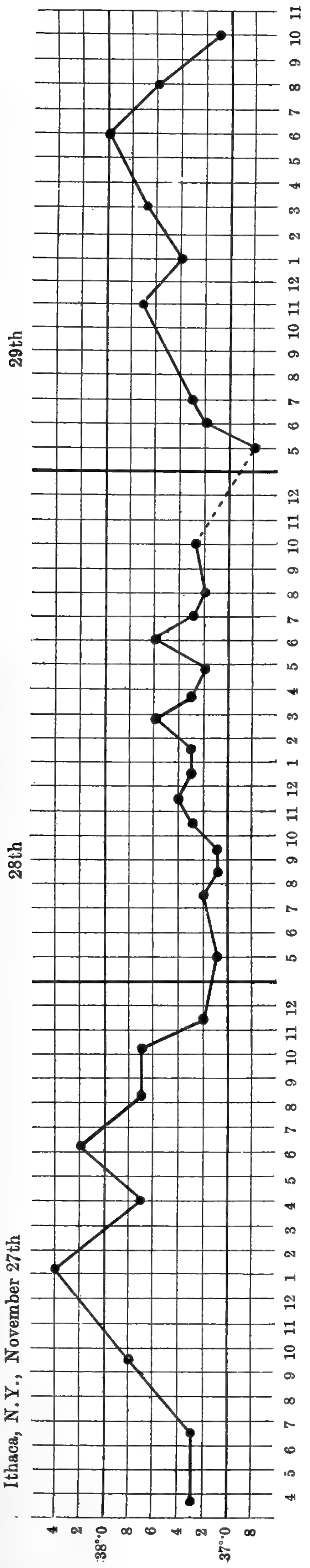

FIG. 12.—Temperature chart of Miss A. B., resting in bed and fasting on November 28.

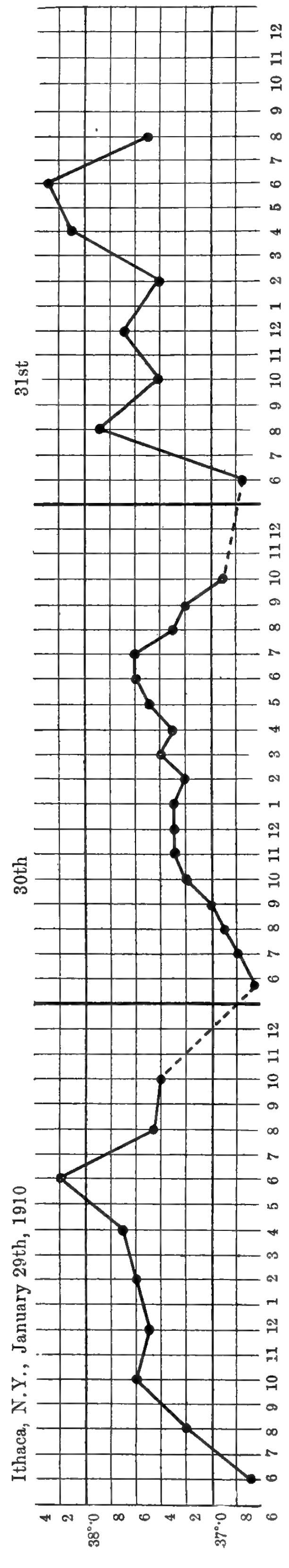

FIG. 13.—Temperature chart of Mr X. Y., resting in bed and fasting on January 30.

restless boy. The fact that the temperature was taken in the axilla need not necessarily vitiate the results when the subject remained in bed all the time, although it would have been more satisfactory if the records had been obtained from the rectum.

Again, in a recent paper by Bardswell and Chapman,* a curve is given showing the average daily variation in the rectal temperature of nine healthy individuals (seven men and two women, all between the ages of 20 and 35 years) who were kept in bed during the period of observation, which varied in different cases from twenty-four to forty-eight consecutive hours. The ordinary meals were taken at 8.30 a.m., 1 p.m., and 7 p.m. During the night the individuals were aroused sufficiently to allow of the temperature being recorded, and sleep was very little interfered with. Readings were taken every two hours throughout the twenty-four. The minimal temperature occurred between midnight and 4 a.m., the average for the nine individuals being 3 a.m. The average minimal temperature observed was 36° C., the lowest being 35°·8 and the highest 36°·3. "From the minimal level the temperature rises gradually until the period of sleep is completed (the average waking temperature being about 36°·4 C.), and thereafter it rises rapidly until at 10 a.m. the temperature is 36°·9 C. From 11 a.m. till 6 p.m. the temperature remains practically steady between 36°·9 and 37°·1, the highest point usually being reached between 4 and 6 p.m. After 6 p.m. the temperature begins to fall again, but only gradually. When the period of sleep is reached the fall continues rapidly until at about 2 a.m. the temperature curve is again at its minimal level." In this average curve the range from 6 a.m. till midnight, which corresponds with the waking periods in our experiments, is about 0°·8 C. This is greater than is found in any of our curves except that of Mr X. Y.

Johansson,† on the other hand, by enforcing muscular rest and at the same time fasting, was able to reduce the temperature range to 0°·4 C. in the twenty-four hours including the sleeping period. Hörmann‡ also found in the case of an insane woman who remained in bed and took no food for three days that the diurnal fluctuations in the vaginal temperature were almost abolished.

"Rest in bed" is, of course, a relative phrase, and may have a different meaning for different individuals, but to remain in bed during the waking hours and voluntarily inhibit all muscular movements except when these are absolutely necessary, and at the same time prevent one's self from falling asleep, is a task not easily accomplished. As a matter of fact, this experiment is not likely to be carried out properly by any subject who is not himself particularly interested in it.

Muscular contraction is the most potent factor in elevating the body temperature, and sleep in lowering it. Benedict§ found that a change in body-position from sitting

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* Bardswell and Chapman, *Brit. Med. Jour.*, May 13, 1911, p. 1107.

† Johansson, *Skandinavisches Archiv für Physiologie*, viii., 1898, p. 85.

‡ Hörmann, *Zeitschrift für Biologie*, xxxvi., 1898, p. 319.

§ Benedict, *Amer. Jour. of Physiology*, vol. xi., 1904, p. 167.

to standing was sufficient to produce almost immediately an appreciable rise in the rectal temperature, and *vice versa* when the change is from standing to sitting. This rise he attributes to the muscular work involved in maintaining the body in the erect attitude. However, there appears to be considerable variation amongst different individuals in the temperature response to muscular exercise. In the observations of LEONARD HILL and MARTIN FLACK,* made on healthy athletes in a three-mile race, they found in one case at the end of the race the extraordinary high figure of 105° F. (40°·56 C.) for the rectal temperature. As a rule they found that "the longer the effort the higher the body temperature rose," within the limits of the race of course. "Thus W. V. F. was 101°·1 F. after ¼ mile, 102°·0 after ½ mile; H. 102°·8 after 1 mile, and 103°·6 after 3 miles; H. P. 102°·8 after 1 mile, 103°·8, and 105°·0 after 3 miles. The temperature did not rise in all individuals. Thus J. F. P. showed no rise after 1 mile, or after seven laps of the three-mile race." From systolic blood-pressures taken at the same time they attribute the high temperatures, in part at least, to the influence of cutaneous vaso-constriction.

For the same individual, however, the same amount of exercise taken within the same time limits will produce roughly the same rise in rectal temperature. Thus BARDSWELL and CHAPMAN,† from experiments conducted on themselves and other healthy persons, found that the rise of temperature produced by definite amounts of exercise were so consistent and constant that they were able at will to raise their temperatures from the normal to any point up to 103° F. (39°·5 C.) simply by "prescribing to ourselves varying degrees of muscular effort. By dint of constant observation we were able to guess to within a point or two what our temperature would be at any time of the day and after any kind of exercise."

The effect of food on raising and maintaining the body temperature can be seen by a glance at the five curves of the writer, taken on the resting days (figs. 7–11). Three meals were taken on two of these days, viz. September 12 and October 3, and on these days the rectal temperature is distinctly higher, and on October 3 also less regular, than on the three fasting days. There does not appear to be any immediate effect following the meal, but the general level of the curve is higher by about three-tenths of a degree centigrade after the first meal on September 12 than on the three days when no food was taken, and this difference is maintained throughout the day. On the fasting days the decline also sets in earlier.

In the case of Miss A. B. the curve is somewhat distorted (fig. 12) by the comparatively high figures at 3 p.m. and 6 p.m., but that these are due to accidental disturbances is indicated by the low temperature before and after these hours. The probable cause of these disturbances she explains in her note. Apart from that and from the fact that the general level is somewhat higher, the curve does not differ materially from those of the writer, taken on the three resting and fasting days.

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* HILL and FLACK, *Jour. of Physiol., Proceedings*, xxxvi., 1907, p. xi.

† BARDSWELL and CHAPMAN, *loc. cit.*

From the preceding remarks will be seen the importance of making full allowance for the elements of muscular exercise particularly and of food in all investigations similar to that undertaken by the writer. The ideal experiment would be to eliminate muscular exercise and food entirely, but this, of course, cannot be done (except at comparatively long intervals) and the body still be maintained in perfect health. It is to be regretted that a similar resting and fasting experiment was not made in the control period before leaving Ithaca for Scotland, and again immediately on arriving in Edinburgh. Any inherent diurnal rhythm which might be present would not, under these conditions, be masked by external influences, but I think the proof is sufficiently clear that there is no such rhythm. When the external conditions were as nearly as possible the same in the three localities mentioned, viz. the Orkneys, Winnipeg, and Ithaca, the curves are practically identical in character, and there is no indication of a Scottish rhythm being carried in the body to Winnipeg. In each of these curves (figs. 7 and 8) there is a slight morning rise and evening fall. The former comes in the period between sleep and full wakefulness, and the latter appears when daylight is replaced by artificial light, which again induces a feeling of drowsiness.

During natural sleep the temperature of the body falls markedly, and much more so in the deeper sleep induced by narcotic drugs such as morphine, alcohol, etc. This is due in part to a diminution in muscular tonus which leads to a lessened heat-production, and in part to the fact that sleep is accompanied by a cutaneous vaso-dilatation allowing of an increase in heat-loss. Any condition which diminishes the activity of the heat-regulating mechanism, situated somewhere in the central nervous system, will tend to induce a state of poikilothermism, and then the temperature will fall if the temperature of the environment is lower (as it almost always is in temperate climates) than that of the body. Any tendency to somnolence, therefore, will be marked by some fall in the body temperature.

If the curves of August 8 (Orkney) and August 29 (Winnipeg) be compared (figs. 7 and 8), it will be seen that in the former both the morning rise and the evening fall are more distinct than in the latter. As explained previously, this is probably due to the fact that the subject was more quiescent on August 29. If the Scottish temperature rhythm had been carried in the body to Winnipeg, the morning rise and the evening fall should begin some six hours earlier; the former, therefore, would not come into the Winnipeg curve at all, and the rectal temperature would be already high when the first observation was made at 6 a.m., while the latter would begin about 12 (noon) or 1 p.m. instead of 6 or 7 p.m. As a matter of fact, a slight fall is noticeable in the Winnipeg curve at 1 p.m., but this is succeeded by a rise later which should not be if this corresponded with the Scottish evening fall. These two curves are remarkably alike in every respect. There are minor differences, but these are not greater than one might expect to find in any two similar curves taken in the same locality on consecutive days.

VI. THE RELATIVE VALUES OF RECORDS FROM RECTUM, MOUTH, AND AXILLA, AS INDICATING CHANGES IN BODY TEMPERATURE.

As is correctly pointed out by LINDHARD, the term "body temperature" is a misnomer. There is in reality no such thing. Most of the heat of the body is produced in the muscles and in the organs of digestion, notably the liver, and from these it is conveyed by the blood to the other organs of the body. If by body temperature we mean the temperature of the warmest organ in the body, it will probably be found in the muscle or group of muscles which happens to be most active at that particular moment, and this will change from time to time according to circumstances. We may correctly speak of the rectal temperature, the mouth temperature, or the temperature of the axilla as the temperature of these localities at any particular time, but not of the body temperature. However, since the heat produced in the muscles, etc., is distributed so rapidly by the blood-stream that the temperatures of the deeper parts of the body away from the radiating surfaces do not differ at any one time probably by more than some fraction of a degree centigrade in health, the term body temperature may still be conveniently used as indicating the average temperature of the deeper and well-protected parts of the body.

Clinically the temperature is usually taken in one of three situations—the rectum, mouth, or axilla, and of these it is recognised that the rectum is the best, since it is better protected against the rapid loss of heat than either the mouth or axilla, and consequently the readings are not so liable to be affected by external and accidental circumstances. The temperature of the rectum is always higher than that of the mouth and axilla and nearer the so-called body temperature. The mouth temperature is being used less and less by physicians and the axillary temperature scarcely at all, on account of the belief that these are unreliable as an indication of the changes in the temperature of the deeper parts, *i.e.* the body temperature.

An examination of the charts (figs. 1 to 5) will show the relationship existing between the temperatures of these localities under different conditions. In the morning, before getting out of bed, the readings for the mouth and axilla are practically the same throughout the whole experiment, *i.e.* for the same day they are almost identical, both being distinctly below the rectum. After the subject arises the mouth temperature follows more or less closely the changes in the rectal temperature, the two curves running parallel to a considerable extent. The most constant deviation from the parallel is found between 9 a.m. and noon, when the mouth falls while the rectum rises, and this is easily explained. The 9 a.m. reading was taken shortly after breakfast, and the local effects of mastication and of warm food act on the mouth temperature alone. The rise thus produced quickly subsides, so that the next reading, at noon, is lower.

The relationship between the curves of the axilla and rectum are much less constant. The temperature of the axilla almost invariably falls when the subject gets out of bed, while that of the mouth and of the rectum rises. The mouth and axilla curves separate at that point and do not meet again until the following morning. On the resting days, when the subject remained in bed, the figures for the mouth and axilla are practically identical at every observation, and the two curves run fairly parallel with that of the rectum. In the case of a patient confined to bed then, are the mouth and axillary temperatures as unreliable as they are held to be? The temperature of the mouth particularly, and also of the axilla, is affected by the temperature of the surrounding air, rising and falling with it, and when this is fairly regular, as it usually is in a sleeping-room, the parallelism between the mouth and axillary curves and that of the rectum appears to be on the whole pretty constant. With the subject outside in the open air and exposed to atmospheric changes, the case, of course, is different.

The above remarks, it must be remembered, are meant to apply only to the case of the person who was the subject of this experiment. There may be, and there probably are, great variations amongst different individuals in this relation. For example, in a sparely built person the walls of the buccal chamber will be thinner, and it will be more difficult to convert the axilla into a closed cavity than in a stout individual, so that the temperature of both localities will be more susceptible to changes in the surrounding air in the former than in the latter.

With regard to the question of individual differences in the response of the mouth and skin temperatures to muscular activity I was interested to find, in reading over the report of LINDHARD,[*] that his results were different from mine. He says: "With regard to the mouth temperature, its relation to the work of the muscles is quite inconstant. As a rule it does not rise during work. On working indoors, it is almost constant; on working in the open air it always falls, but in a single case I have found it so much raised while staying indoors soon after working in the open air, that the rise must without doubt be ascribed to the work. On the other hand, I have seen that even energetic exercise indoors was not able to prevent the mouth temperature, raised by the meal, from falling. . . . For the temperature of the skin pretty much the same holds good as for the mouth temperature; as a rule I have not been able to notice any rise occasioned by muscular work."

In order to test this matter further in the case of my own temperature I have lately made a few experiments, the results of which are given in tabular form below. These observations were made in September, when the outside temperature was fairly high, and again in November, when the weather was colder. The readings were taken first in the recumbent posture just before getting out of bed[†] in the morning, then in the sitting position half an hour later, after dressing but before breakfast, again after breakfast, and finally immediately after a walk of about three-quarters of a mile up a pretty steep hill and then two flights of stairs to a room in the laboratory. The same clothing was worn and the same muscular energy expended on each day in approximately the

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[*] LINDHARD, *loc. cit.*, p. 18.

[†] The bed was outside on the verandah.

same time, so that the only variable factor was the air temperature. On the last two occasions breakfast was taken in the laboratory after the walk instead of before. The readings are given in degrees centigrade.

TABLE IV.

EFFECT OF MUSCULAR ACTION ON THE RECTAL, MOUTH, AND AXILLARY TEMPERATURES.

		Rectum.	Mouth.	Axilla.	Air.	Remarks.
1911 Sept. 7	8 a.m.	37·22	36·55	36·52	17	In bed ; slight perspiration.
	8.30 „	37·32	36·89	36·31	19	After breakfast ; before dressing.
	9.30 „	37·42	36·76	36·30	21	Street car to laboratory.
Sept. 8	7.45 „	37·12	36·56	36·45	17	In bed ; raining.
	8.30 „	37·41	36·52	36·0	20	After dressing.
	9 „	37·38	36·78	35·91	20	After breakfast.
	9.30 „	37·82	37·25	36·64	15–20*	After 17 minutes' walk.
Sept. 9	8 „	37·26	36·86	36·70	19	In bed ; heavy rain.
	8.30 „	37·41	37·04	36·70	20	After breakfast ; before dressing.
	9 „	37·54	36·92	36·72	20	After dressing.
	9.45 „	37·90	37·24	37·04	19–20*	Walk 16 minutes ; perspiring.
Sept. 10	9 „	37·16	36·62	36·60	20	In bed.
	9.30 „	37·18	36·78	36·70	21	After breakfast ; in bed.
	10 „	37·51	37·00	36·54	21	After dressing.
Sept. 11	7 „	37·03	36·62	36·62	18	In bed ; feeling cold.
	7.30 „	37·20	36·60	36·18	21	After dressing ; before breakfast.
	8 „	37·25	36·91	36·38	21	After breakfast.
	8.45 „	37·72	37·12	36·78	18–21*	Walk 15 minutes ; perspiring freely.
Sept. 12	7.30 „	37·41	37·00	36·90	20	In bed ; slight lumbago.
	8 „	37·60	37·10	36·64	23	After dressing ; before breakfast.
	8.30 „	37·75	37·45	36·72	22	After breakfast.
	9 „	38·15	37·65	37·30	18–22*	Walk 16 minutes ; perspiring.
Sept. 13	7.30 „	37·00	36·46	36·46	10	In bed ; cold weather.
	8 „	37·32	36·48	35·66	17	After dressing ; before breakfast.
	8.30 „	37·36	37·08	36·28	17	After breakfast.
	9 „	37·78	37·12	36·74	9–19*	Walk 15 minutes ; slight perspiration.
Sept. 14	6 „	36·70	36·03	36·00	2	Just after awoke ; feeling cold.
	7.30 „	36·78	36·28	36·12	4	In bed ; feeling cold.
	8 „	36·92	36·31	35·52	17	After dressing ; before breakfast.
	8.30 „	37·05	36·50	35·89	17	After breakfast.
	9.30 „	37·40	36·61	36·15	5–16*	Car to laboratory after business in town.
Nov. 1	7.15 „	36·94	36·18	36·20	3	In bed ; feeling warm.
	7.45 „	37·25	36·38	35·76	20	After dressing.
	†8.30 „	37·57	36·21	36·26	2–22*	Walk 15 minutes, talking on way, before breakfast.
	9 „	37·42	36·52	36·26	24	After breakfast, in warm room.
Nov. 3	7.30 „	36·81	36·48	36·36	1	In bed.
	8 „	37·12	36·50	35·82	19	After dressing.
	8.30 „	37·58	36·71	36·5	1–21*	Walk 15 minutes to laboratory before breakfast.
	9 „	37·41	36·68	36·5	21	After cold breakfast.

With regard, then, to the effect of muscular work on the mouth temperature, my results do not agree with those of LINDHARD. On every day except one, the effect of a not very long walk was to raise the mouth temperature as well as the rectal, and usually the rise was very distinct. On all but two of these days the walk was begun very shortly after finishing a hot breakfast, when the mouth temperature was artificially

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* A thermometer was carried in the hand during the walk, and the lowest air temperature reached was noted ; this is indicated by the first figure, and the second gives the temperature of the room in the laboratory, where the observations were made *immediately* on entering it.

† On this occasion I walked to the laboratory in company with a friend, with whom I was conversing all the way. On all the other days I breathed through the nose and kept the mouth closed.

raised, and still, as a result of the exercise, it rose higher. During the walk the mouth was kept closed except on November 1, and that is the only occasion on which the temperature fell. The outside temperature has much to do with this, of course, and it is probable that in many of LINDHARD's experiments it was below zero. He does not give the air temperatures, but when his observations were made indoors it is not likely that the atmosphere was as cold as that to which I was exposed in my walks on November 1 and 3, when the temperature was only one or two degrees above the freezing-point, and a cold wind blowing at the same time. LINDHARD found in his own case and in other members of the crew that as a rule the mouth temperature did not rise during work. "On working indoors it was almost constant; on working in the open air it always falls." The only explanation of the difference in the results is that it depends on individual peculiarities, or rather, on mouth peculiarities. The thinner the walls of the buccal chamber the greater and more rapid will be the dissipation of heat and the more difficult will it be to raise the temperature. The relative vascularity of the parts is probably also of importance.

In my case the temperature of the axilla also rose during the walk, or at any rate did not fall. On November 1 and 3 it remained constant.

VII. SUMMARY.

To determine whether the diurnal variation in body temperature is due to the combined effects of the various influences which are known to act upon it, such as muscular exercise, the ingestion of food, sleep, etc., or is present independently of these, the daily routine of the individual who is the subject of the experiment may be reversed artificially by causing him to work during the night and rest and sleep during the day, or it may be modified in another way, viz. by rapidly changing his longitude in a journey from west to east, or *vice versa*. If the temperature of the body is dependent on the influences mentioned, then a total reversal of the daily routine, or any modification of it, should produce a corresponding change in the diurnal temperature curve.

On a voyage from Ithaca, in the western part of New York State, to Edinburgh, during six weeks' residence in Scotland, and again on the return journey from Edinburgh to Winnipeg, continuous three-hourly observations (and hourly from 6 a.m. to 9 a.m.) were made by the writer on his own temperature (rectum, mouth and axilla), except between midnight and 6 a.m., with a view to ascertain whether the temperature rhythm obeyed local (ship's) time or Ithaca time. To get the Ithaca rhythm as a control, observations were made in that city for one week before the journey began. If a temperature periodicity were fixed in the body independently of external conditions, then the curve should correspond to Ithaca time and not to local time as he travelled from west to east, or *vice versa*. For example, since Edinburgh local time is five hours in advance of Ithaca local time, the morning rise which began at 7 a.m. in Ithaca should have been delayed till 12 (noon) in Edinburgh, if the Ithaca rhythm were fixed in the body of the subject. This was found not to be the case. In the eastward voyage, which occupied eight days, there was an immediate adjustment of the temperature rhythm to the changed routine day by day, and the same was found to occur on the westward journey from Edinburgh to Winnipeg, between which stations there exists a difference of over six hours in time.

It was also found that the temperature curve can be almost obliterated by remaining in bed and enforcing muscular rest during the whole twenty-four hour period, at the same time abstaining from food. This was practised in Scotland, in Winnipeg, and in Ithaca. Any temperature rhythm inherent in the body might be expected to show itself under these conditions, and, if persistent, to be carried from one locality to the others. This was found not to be the case. The curves obtained at the above-mentioned stations, with time differences as already indicated, resemble each other very closely, and differ only in minor details.

The results of the present investigation, therefore, give strong support to the conclusions of GIBSON, LINDHARD, and SIMPSON and GALBRAITH, viz. that the diurnal variation of body temperature, in man as in other animals, is determined by the conditions imposed on the body, such as rest and activity, and is not an expression of any inherent periodicity established in the body.

XIII.—On the Carboniferous Flora of Berwickshire. Part I. Stenomyelon Tuedianum Kidston. By R. Kidston, LL.D., F.R.S., and D. T. Gwynne-Vaughan, M.A., Professor of Botany, Queen's University, Belfast. (Plates I.–IV.)

(MS. received January 8, 1912. Read January 8, 1912. Issued separately April 13, 1912.)

INTRODUCTION. By R. KIDSTON.

My first knowledge of *Stenomyelon Tuedianum* was derived from a microscopical preparation in the collection of the late Mr C. W. PEACH, A.L.S., which, through the kindness of his son, Dr B. N. PEACH, F.R.S., subsequently came into my possession.* The specimen was labelled as having been found "near Berwick."

During the investigation of the fossil flora of Berwickshire, in company with Mr A. MACCONOCHIE of the Scottish Geological Survey, a special effort was made to secure additional specimens of this plant, as the original material, as far as known to me, was quite inadequate for a satisfactory description of the species. It was ascertained that the specimen in Mr PEACH's collection had been received from the late Mr ADAM MATHESON, Jedburgh, a geologist who took much interest in the fossils of his neighbourhood, and whom I believed to be the author of an anonymous pamphlet—apparently a reprint from a local newspaper—describing some fossil stems found at Norham Bridge. A perusal of this paper led me to infer that his specimen of the fossil, here described as *Stenomyelon Tuedianum*, had also come from the same locality, an opinion which subsequent events showed to be correct.

The matrix containing Mr MATHESON's fossil was an impure fine clay, apparently with a fair proportion of iron, and one showing features which were possible of recognition in the field; but though a careful search for a similar bed was made in the neighbourhood of Norham Bridge, no trace of such could be found *in situ*. Subsequently, in 1901, we discovered some small blocks of the desired rock lying on the side of the road near the north end of Norham Bridge. It was ascertained that the material came from a cutting made in the road while putting in a drain some time before; the surface of the road in the neighbourhood of the drain was therefore carefully examined, and in a small block which had been used for refilling the cutting the specimen was discovered which has enabled us to give a detailed description of the species.

We are also indebted to the original material for additional points of interest.

Subsequently, in 1903, Dr D. H. SCOTT, F.R.S., informed me that some sections of *Stenomyelon* had been presented in 1859 to the Botanical Museum, Royal Botanic Gardens, Edinburgh, by Mr ADAM MATHESON; and from a copy of a letter referring to these specimens which has been kindly forwarded to me by Dr SCOTT, who had received

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* Slide No. 2105.

it from Professor I. BAYLEY BALFOUR, F.R.S., it would appear that Mr MATHESON only found one specimen of *Stenomyelon*, and that this had been got at Norham Bridge, which the study of the anonymous paper already mentioned had led me to infer.

In addition to the parts of the original specimen received from Mr MATHESON by Professor BALFOUR and Mr C. W. PEACH, in 1900 I received a few fragments attached to glass slips from Miss MATHESON, daughter of the original discoverer of *Stenomyelon Tuedianum*. Some additional specimens, also mounted for microscopical examination, were given me by Mr JAMES VEITCH, Jedburgh, to both of whom I take this opportunity of recording my sincere thanks.

DESCRIPTION OF *STENOMYELON TUEDIANUM*, KIDSTON. By R. KIDSTON and D. T. GWYNNE-VAUGHAN.

Owing to the imperfect preservation of the softer tissues of the specimen it is not possible to determine the true outline of the stem, for in all cases the thin-walled tissues of the cortex are completely disintegrated and destroyed. As a result, the stem has become flattened, and those tissues of the cortex that remain form wing-like projections on two opposite sides of the stele. One of these extensions is seen in its entirety, but of the other only a part is preserved. In some of the sections it is quite narrow, having a regular and very wing-like appearance (figs. 1–2), while in others it is much wider, and is irregularly crushed in at its margin (fig. 3). The xylem of the stele has not suffered any damage, and is almost circular in section. We are of the opinion that the present appearance of the fossil does not imply that the stem of the living plant actually possessed wings, but it will be shown that the leaves were arranged in three rows, and it is therefore quite possible that the stem possessed three more or less prominent decurrent ridges.

Description of the Stem.

The xylem mass of the stem contains both primary and secondary xylem, and as a whole measures 8–9 mm. in diameter. The primary xylem forms a bluntly triangular or three-lobed central mass, which measures 3–4 mm. from the extremity of one lobe to that of another (figs. 6–10). It consists of tracheæ alone, except for a few occasional cells of parenchyma near its periphery. There are also three bands of parenchymatous tissue in the primary xylem which extend from the middle of the sides of the triangle so as to separate the three lobes more or less completely from one another. These parenchymatous stripes, although always quite narrow, vary somewhat in breadth, and they also form a few small irregular bays projecting into the tracheal masses of the lobes. Sometimes, but rarely, the three stripes are continuous to the centre, and then the lobes of the xylem are completely separate from one another. More often one or the other of them is interrupted by a wider or narrower bridge of tracheæ, so that two of the lobes are connected. In spite of these occasional fusions, the three lobes of the primary xylem very clearly retain their individuality throughout all the sections, as may be seen by comparing the above-mentioned figures,—so much so indeed that they may be regarded as practically independent of one another.

These three lobes are obviously in relation to the leaf-traces, one of which, as will be shown later, departs from the extremity of each lobe in turn. It is clear, therefore, that the divergence must have been $\frac{1}{3}$. The sequence in which fusion occurs between any two of the lobes is possibly also related to the order of the leaf-trace departure, but our series of sections was not sufficiently extensive to settle this point.

The elements of the primary xylem are fairly large, attaining a diameter of 160μ. In longitudinal section they are seen to be typical elongated tracheæ with finely pointed ends, and beautiful porose pitting on all their vertical walls (fig. 12). Towards the extremities of the lobes the tracheæ become somewhat smaller, and their pitting becomes typical scalariform (fig. 13). There appear to be no protoxylem strands proper to the stem itself, but in the neighbourhood of the departing leaf-traces a pair of definite exarch protoxylem strands are usually to be seen (fig. 11, *prx.*). These are evidently decurrent from the leaf-trace, and lower down in the stem they fuse to a single strand (fig. 10, *prx.*).

The secondary xylem evidently appears first opposite the side bays of the triangle of the primary xylem, and when the bays are filled up it crosses over in front of the angles, so that the outline of the whole xylem mass, which was at first triangular, eventually becomes circular. The earlier elements of the secondary xylem are narrower than those formed later (fig. 11 and figs. 6–10), and its tracheæ are usually separated from those of the primary xylem by a few cells of parenchyma. Often, however, primary and secondary tracheæ are found to be in direct contact. The tracheæ of the secondary xylem are arranged in very regular radial rows, which are separated by the medullary rays into wedges of from 2–5 elements in width (fig. 11). The medullary rays widen out considerably towards the periphery, and in this region secondary medullary rays also make their appearance. The rays are all very long vertically, and are from 1–6 cells broad (fig. 14). A few specially wide medullary rays occur on the inside of the departing leaf-trace (fig. 10, M.R.). In radial section the cells of the rays have the ordinary brick-like appearance, with the long axis radial (fig. 15). All the tracheæ of the secondary wood exhibit porose pitting, but the pits are confined to the radial walls; the tangential walls are quite smooth, being entirely without pits (fig. 14).

No trace was found of any tissue resembling phloem, neither around the stele of the stem nor in relation to the leaf-traces in the cortex. However, patches of a very curious tissue have been preserved in the immediate neighbourhood of the stele, which are clearly parts of a zone that in life completely and closely surrounded it. The inner portion of this tissue consists of small cells with very dark contents. They are rectangular in form, and are arranged in very regular radial series. In longitudinal section they have exactly the same appearance as in transverse, only their long axes are vertical instead of being tangential (fig. 16, *i.z.*). There can be no doubt that the cells arose from the activity of a cambium of some kind, and the general appearance and structure of the tissue indicates it is best regarded provisionally as a deep-seated and probably thick-walled periderm. A certain amount of phloem and other soft tissues may have existed between this zone and the xylem, but if so they have entirely disappeared. In any case such tissues could not have been very extensive, for, after making every allowance for crushing and imperfect preservation, the dark-celled zone fits very closely into the xylem,—so much so indeed at some points as almost to suggest that it might have arisen from the same cambium.

Towards the outside of this dark-celled zone its elements become larger and irregularly polygonal in outline, the radial arrangement being in consequence lost (fig. 16, *o.z.*). In addition, large groups of similar cells form rounded bosses, projecting at irregular intervals beyond the general level of the outer surface of the zone (fig. 16, *b.*). The same type of cell also forms a number of scattered sphærical masses in the cortex of the stem (fig. 17). The central cells of these masses, and also those of the bosses, are smaller than the others, and form a sort of nucleus from which the larger cells radiate more or less distinctly, appearing as though, during their development, they had been pulled out by the growth of the surrounding tissue. Their cell walls are very imperfectly preserved, but it is very probable that they were of a sclerotic nature. It is clear that the masses they form were during life quite hard and resistent, for whenever they have been pressed against a mass of xylem, it is the latter, and not the former, that has given way and become crushed. The "sclerotic nests," as they may be called, are scattered without order throughout the inner cortex of the stem, and do not seem to bear any relation to the leaf-traces. In structure and appearance they are quite similar to the sclerotic nests described by Dr SCOTT in the pith of *Calamopitys Beinertianum.**

The outer cortex of the stem is of the "Sparganum" type (fig. 18). That is to say, it contains a number of rather short radiating bands of fibrous sclerenchyma, running vertically almost without anastomosis (fig. 19, *from the petiole*). The tissue between these sclerotic bands is a rather firm-walled parenchyma. Some of its cells have dark-coloured contents, and may perhaps be regarded as resin sacs.

The Departure of the Leaf-trace.

The leaf-traces depart from the ends of the lobes of the primary xylem in a perfectly protostelic manner. Our series enabled us to follow one such departure from start to finish. First the extremity of one of the xylem lobes is seen to become more and more prominent (figs. 6–7, *l.t.*^{2}). Then the protrusion is gradually nipped off as a fairly large roundish leaf-trace (figs. 8–9, *l.t.*^{2}). As the trace passes out it carries with it some of the secondary xylem on its abaxial side, and at the same time it also obtains a certain amount of secondary xylem of its own on the adaxial side (figs. 9–10). The depar-

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* SCOTT, "On the Primary Structure of certain Palæozoic Stems with the Dadoxylon type of Wood," *Trans. Roy. Soc. Edin.*, vol. xl. p. 342, pl. i. figs. 3–4, 1902.

ture of the trace leaves no gap in the secondary xylem, which closes in immediately behind it.

The leaf-trace continues to possess a certain amount of secondary xylem for some time after it has become free from the xylem of the stem, although that on the adaxial side is very scanty and soon disappears. It was possible also to recognise in our sections the leaf-trace that immediately preceded the one just described (figs. 6–7, *l.t.*,^{1} and 18). In this trace the primary xylem had just divided into two approximately equal portions, which are at first still surrounded by a certain amount of secondary xylem common to both. Even after they have become completely separate, the secondary wood on the abaxial side is retained for a considerable time (fig. 7, *l.t.*^{1}).

There is no doubt that all the traces occurring in the space formerly occupied by the cortex were derived by the continued subdivision of primary leaf-traces such as those just described. Several leaf-traces, both large and small, were observed in actual division (fig. 21). It is therefore certain that all the vascular strands given off from the stele are primary leaf-traces, which in their passage through the cortex divide repeatedly to supply the petioles. There is also clearly an entire absence of any meristeles proper to the stem such as those occurring in *Sutcliffia insignis.*[*]

The xylem of the leaf-traces consists mainly of porose tracheæ without any xylem parenchyma. The tracheæ at the periphery are markedly smaller than those at the centre, and are scalariformly pitted (figs. 20, 21, 22, and 23, *from the petiole*). The scalariform tracheæ are present in greatest number towards the side of the trace on which the protoxylem is situated. The traces usually show a single very distinct and definite protoxylem, except just below a point of division of the trace where there are two (figs. 21–22). In the immediate neighbourhood of the stele the protoxylems appear to be exarch, but at some distance out they are distinctly immersed, and are represented by small cavities situated some little distance within the periphery of the xylem (figs. 20, 21, and 22). Owing to the shifting and displacement of the leaf-traces due to collapse of the cortex, it is impossible to determine their proper orientation with regard to the periphery of the stem. Most probably, however, the protoxylems pointed to the outside. No indication of phloem could be discovered in relation to any of the leaf-traces.

Description of the Leaf.

In the sections of the block which contained the stem there also occurred several other fragments of vegetable tissue. Most of these were portions of leaf lamina, and one of these was found to be in organic connection with an axis which is no doubt the petiole, rachis, or midrib of *Stenomyelon* (fig. 1, L., and text fig. 1). As seen in longitudinal section, the connection between the lamina and the rachis of the petiole extended over a considerable distance, which suggests that the leaf was a simple and not a divided one,

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[*] SCOTT, "On *Sutcliffia insignis*, a new type of *Medulloseæ* from the Lower Coal Measures," *Trans. Linn. Soc.*, vol. vii. p. 49, 1906.

and from the portion of the leaf contained in the block it is evident that it was continued below into a round or oval petiole, which bore the curious emergences described later on (text fig. 1).

The leaf is very large compared with the stem that occurs alongside of it, and it is possible that it belonged to another and perhaps a larger stem (fig. 1, L.). In the section only about one-half of the total circumference of the midrib or rachis was present, and it contained only four vascular strands. These are of exactly the same type as the leaf-traces in the cortex of the stem, but they are on a distinctly larger scale. (Compare fig. 25 with figs 20, 21, and 22, which are all of the same magnification.) The small peripheral elements are more numerous in the strand of the leaf, and in longitudinal section there is a greater proportion of scarlariform to porose elements. Some of the scalariform elements are almost as wide as the porose, but transitional types of pitting are to be observed (fig. 23). The protoxylems are slightly immersed, and in one case two were present, indicating an approaching division (fig. 25). In the three strands that were sufficiently well preserved to show the protoxylems they were on the side of the xylem nearest the periphery of the midrib or rachis. The outer cortex is of the "Sparganum" type (figs. 28 and 19). It attains a greater development than that seen in the stem,—the sclerotic strands being much more numerous and more irregular in form. The dark-coloured resin sacs that occur between the fibrous strands in the stem are present in greater number in the midrib, and they also occur in its more central parenchyma. The "Sparganum" cortex does not reach up to the extreme periphery of the petiole, but there is a narrow zone of homogeneous parenchyma lying to the outside of it (figs. 31 and 4, *par.*). At certain points this tissue is prolonged into a number of curious emergences (figs. 30, 31, and 4). They vary greatly in their form and length, some being quite short and blunt

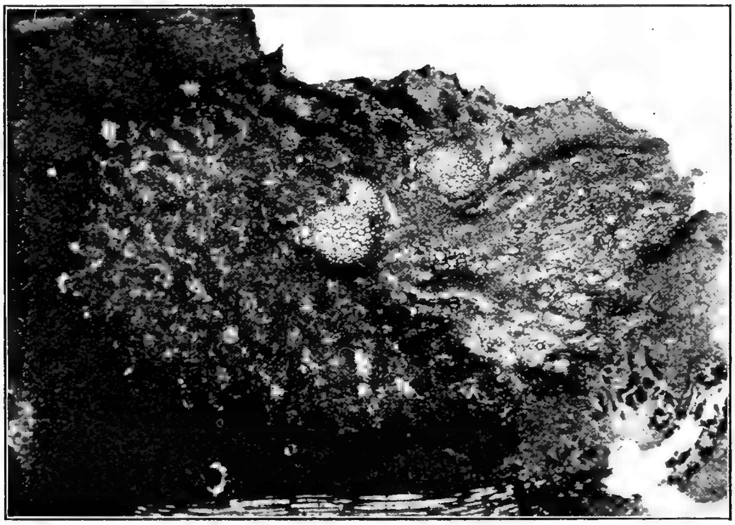

FIG. 1.—*Stenomyelon Tuedianum.* Free petiole showing vascular strands, "Sparganum" cortex, and emergences. ×8½. (Slide No. 2095.)

(fig. 31), while others are narrow, greatly elongated, and somewhat swollen at the end (figs. 30 and 4). They do not seem to be produced by any crushing or folding of the outer tissues. It is possible, however, that they may represent transverse sections of longitudinal ridges. The epidermis of the midrib is well preserved as a definite layer of rather small cells.

Judging from a fragment present in the original block found by Mr MATHESON, the lamina of the leaf must have been of considerable thickness (fig. 24). The epidermis is quite distinct, but no stomata could be distinguished in it. There were indications of a hypodermal zone of sclerotic strands on both sides of the leaf, and resin sacs were very plentiful in the mesophyll. In the fragment in question the vascular bundles lie in single row, but in others less well preserved they appear to be irregularly scattered.

Remarks on other Stems of STENOMYELON.

A few other stems were present in Mr MATHESON's material which in all essential points resemble the specimen already described, but they exhibit a few features of special interest, to which it is necessary to refer.

In one of these stems the primary xylem at first sight gives the impression of being parenchymatous (figs. 26–27). We were able to satisfy ourselves, however, that this is not the case. The apparent parenchyma cells are really tracheæ that have undergone a certain amount of decay. In this section also the three lobes of primary xylem appear to be quite separate from one another, but this, again, is probably due to decay (fig. 26).

In another stem (fig. 29) the secondary thickening has only just begun. It is present in greatest quantity opposite the sides of the triangle of primary xylem, and has not yet crossed over in front of all the lobes.

Again, an unusually small stem was found in which the primary xylem only measures 2·5 mm. at its greatest width (fig. 5), while the secondary xylem is much more extensive than it is in the stem shown in fig. 29, which is photographed at the same magnification. This indicates that, apart from secondary thickening, the primary axes of *Stenomyelon* were of different sizes, which might perhaps suggest that the plant was branched.

CONCLUSION.

The stem of *Stenomyelon* possesses so many features peculiar to itself that in the present state of our knowledge it is unsafe to enter into any speculation as to its relationship to other members of the *Cycadofilices*. It is perhaps best to let it remain among that nebulous group in which it has been already provisionally placed by Dr SCOTT.* At the same time it should be noted that the absence of independent meristeles in the

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* *Studies in Fossil Botany*, 2nd ed., part ii. p. 498, 1909.

cortex of the stem separates it widely from *Sutcliffia insignis*, with which one might be tempted to compare it.

Locality.—Road Cutting at north end of Norham Bridge, Berwickshire.

Horizon.—Calciferous Sandstone Series.

Diagnosis.

Stenomyelon Tuedianum, Kidston, gen. et spec. nov.

Stem monostelic, primary xylem without xylem parenchyma, divided more or less distinctly into three lobes by as many radiating and interrupted bands of parenchyma. Primary tracheæ porose on all walls. The protoxylems of the leaf-trace decurrent as exarch strands on the extremities of the lobes. Secondary thickening occurs. Secondary tracheæ, with porose pits on radial walls only. Medullary rays numerous. Stele closely invested by a zone of sclerotic periderm. Leaf-traces depart successively from the extremities of the lobes and repeatedly divide in the cortex. Leaf-trace protoxylems become immersed. Outer cortex of the " Sparganum " type.

DESCRIPTION OF PLATES I.–IV.

Plate I.

Stenomyelon Tuedianum, Kidston.

Fig. 1. General view of the specimen, showing a stem, *st.*, and a portion of a leaf, L. × 2½. (Slide 2093.)

Fig. 2. Transverse section of the stem, showing the cortex flattened into a thin wing. × 2½. (Slide 2089.)

Fig. 3. Transverse section of the stem, showing a thicker and indented cortex. × 2½. (Slide 2097.)

Fig. 4. Transverse section of outer cortex of midrib of leaf, showing two long emergences; *par.*, parenchymatous cortex. × 13. (Slide 2094.)

Fig. 5. Transverse section of the small stem in Mr Matheson's original block. × 9. (Slide 2107.)

Fig. 6. Transverse section of stem, showing the beginning of the departure of a leaf-trace, *l.t.*^{2}. × 9. (Slide 2088.)

Fig. 7. Do., *lt.*^{1}, the trace of the proceeding leaf already divided into two. × 9. (Slide 2092.)

Plate II.

Fig. 8. Transverse section of stem, showing leaf-trace just free from primary xylem. × 9. (Slide 2095.)

Fig. 9. Do., leaf-trace passing through secondary xylem. × 9. (Slide 2096.)

Fig. 10. Transverse section of stem, showing leaf-trace free from secondary xylem; M.R., specially large medullary rays below the leaf-trace; *prx.*, single protoxylem at summit of lobe. × 9. (Slide 2098.)

Fig. 11. Transverse section of a lobe of the primary xylem with two decurrent leaf-trace protoxylems, *prx.* × 35. (Slide 2091.)

Fig. 12. Longitudinal section of central tracheæ of primary xylem. × 110. (Slide 2101.)

Fig. 13. Longitudinal section of periphery of primary xylem, showing small scalariform elements. × 110. (Slide 2099.)

Plate III.

Fig. 14. Tangential section of secondary xylem, showing medullary rays and unpitted surface of the tangential tracheal walls. × 110. (Slide 2099.)

Fig. 15. Radial section of secondary xylem, showing porose tracheæ and medullary rays. × 110. (Slide 2100.)

Fig. 16. Radial section at the periphery of the stele, showing its periderm; *i.z.*, inner zone; *o.z*, outer zone of the same; *b.*, the bosses; *xy.*^{2}, secondary xylem. × 30. (Slide 2099.)

Fig. 17. Longitudinal section of the inner cortex, showing the sclerotic nests. × 30. (Slide 2101.)

Fig. 18. Transverse section of the cortex of the stem, showing the "Sparganum" zone; *l.t.*,^{1} same leaf-trace as in fig. 7. × 10. (Slide 2088.)

Fig. 19. Tangential section through the "Sparganum" zone of the midrib. × 17. (Slide 2102.)

Fig. 20. Transverse section of a leaf-trace in the cortex of the stem, showing a single protoxylem, *prx.* × 36. (Slide 2096.)

Fig. 21. Do. The trace in division. × 36. (Slide 2097.)

Fig. 22. Do. Below the point of division there are two protoxylems. × 36. (Slide 2090.)

Fig. 23. Longitudinal section of the xylem of a leaf-trace in the midrib, showing porose, scalariform, and transitional pitting. × 110. (Slide 2100.)

Plate IV.

Fig. 24. Transverse section of the lamina of a leaf. × 13. (Slide 678.)

Fig. 25. Transverse section of a vascular bundle in the midrib near a point of division; *prx.*, protoxylem. × 36. (Slide 2094.)

Fig. 26. Transverse section of a stem in Mr Matheson's block, with false appearance of parenchyma in the primary xylem. × 9. (Slide 678a.)

Fig. 27. Portion of the same. × 30. (Slide 678a.)

Fig. 28. Transverse section of "Sparganum" cortex of the midrib, *cf.* fig. 19; *scl.*, sclerotic cortex; *par.*, parenchymatous cortex. × 15. (Slide 2094.)

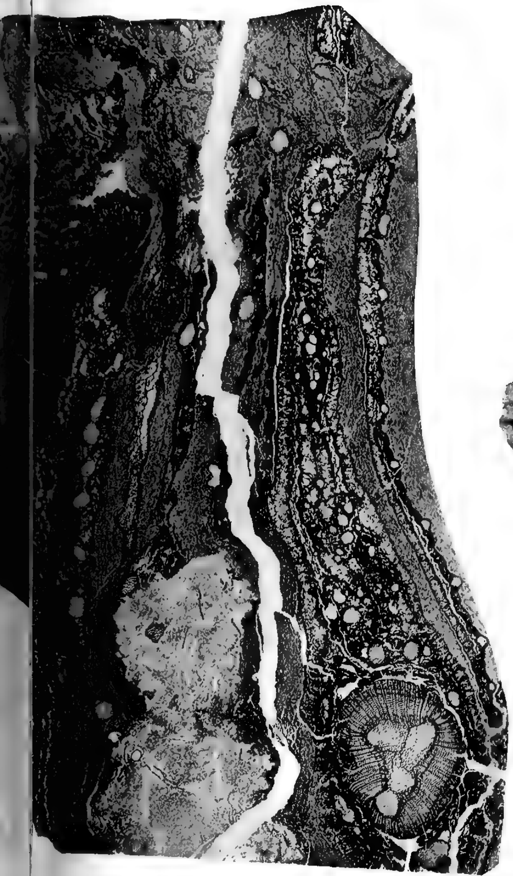
Fig. 29. Transverse section of a stem in Mr Matheson's block, showing the beginning of secondary thickening. × 9. (Slide 2105.)

Fig. 30. Transverse section of outer cortex of midrib, showing a long emergence. × 13. (Slide 2093.)

Fig. 31. Transverse section of outer cortex of midrib, showing several short emergences; *scl.*, sclerotic cortex; *par.*, parenchymatous cortex. × 13. (Slide 2095.)

(All the figured specimens are in the collection of Dr R. Kidston.)

KIDSTON AND GWYNNE-VAUGHAN.—PLATE I.



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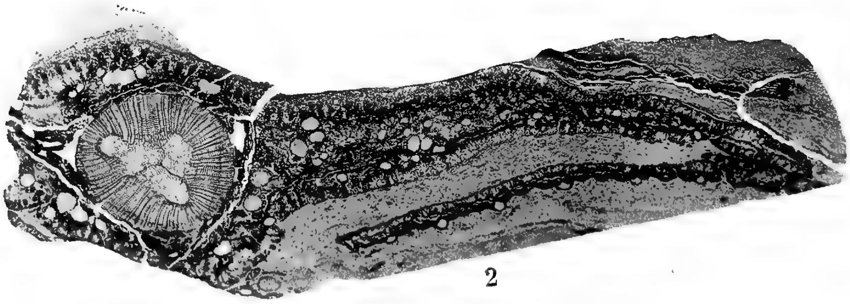

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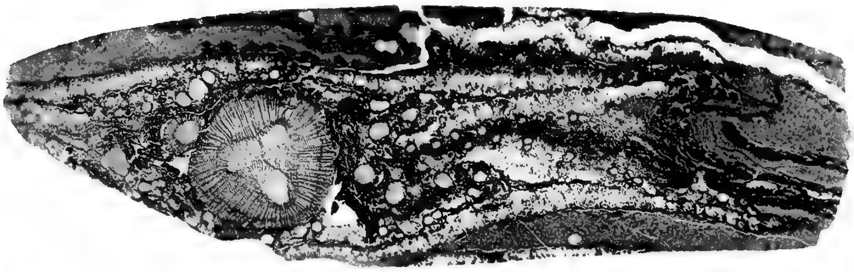

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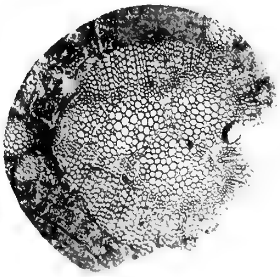

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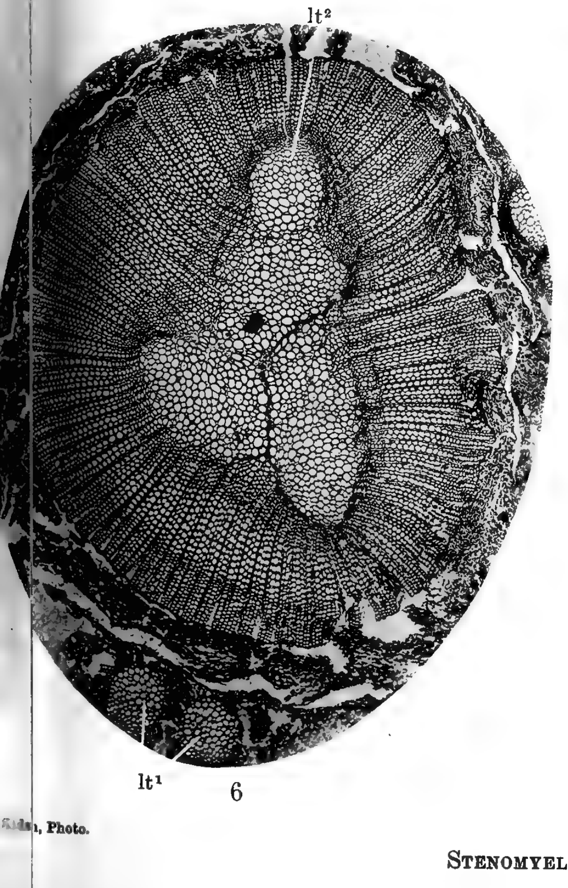

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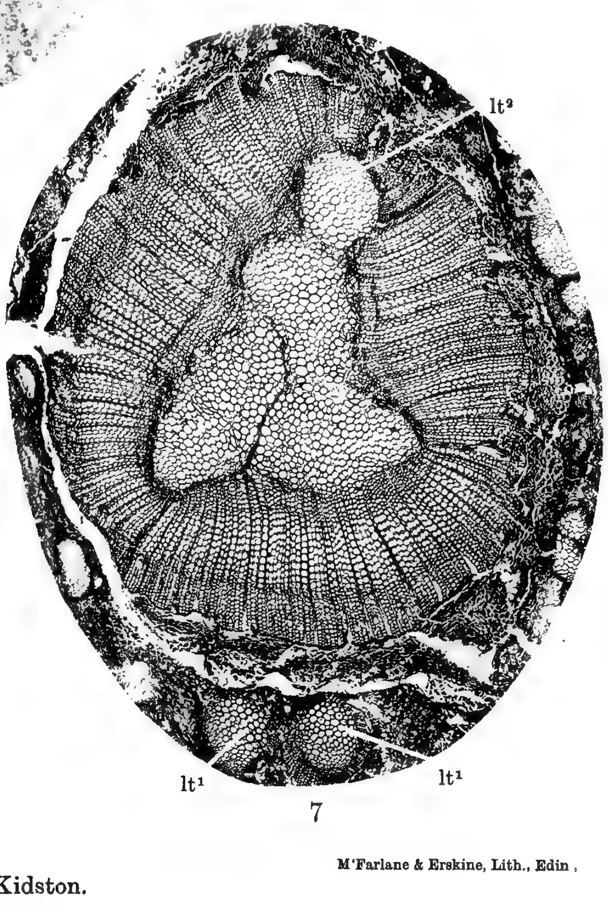

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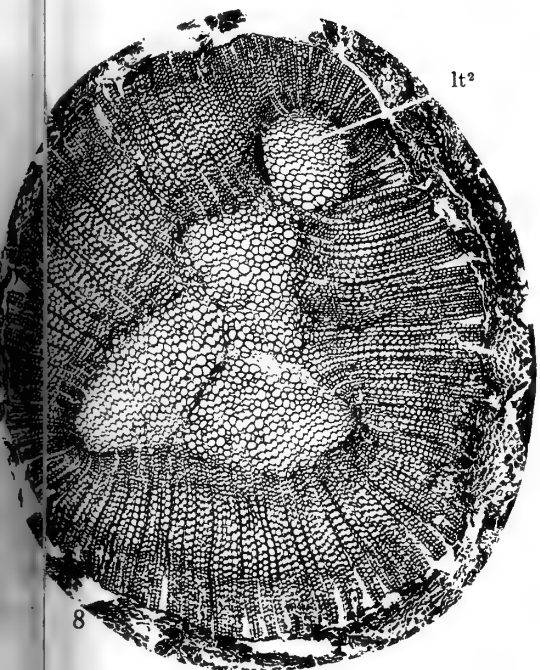
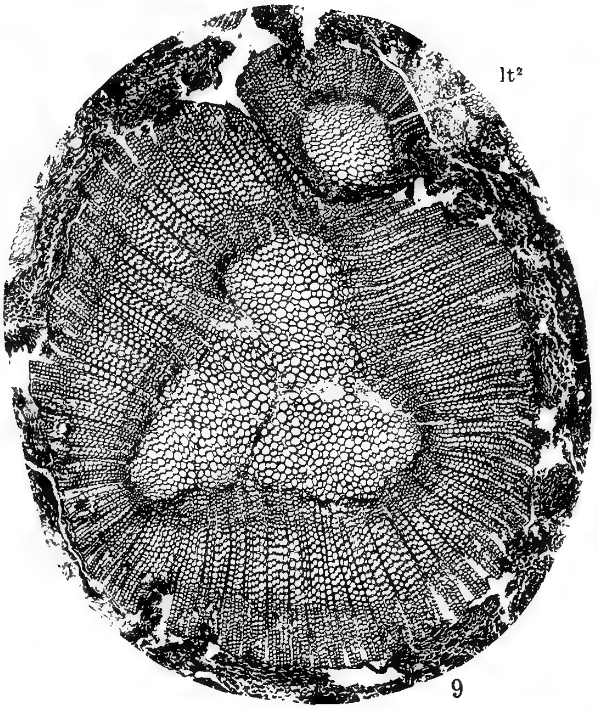
M'Farlane & Erskine, Lith., Edin.

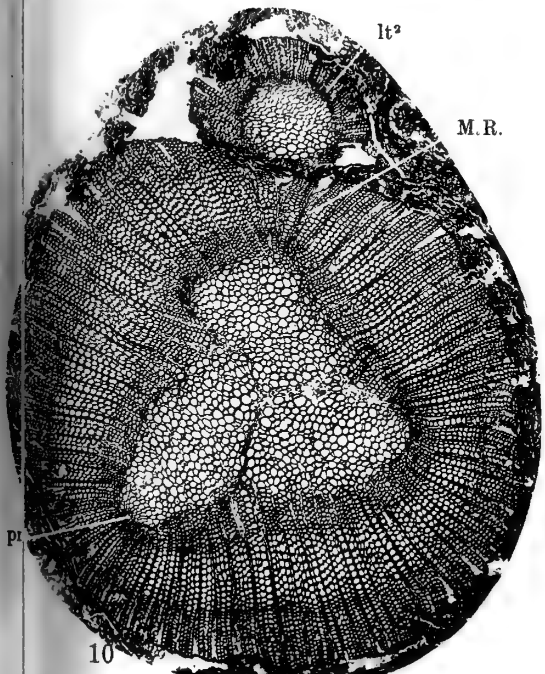
STENOMYELON TUEDIANUM, Kidston.

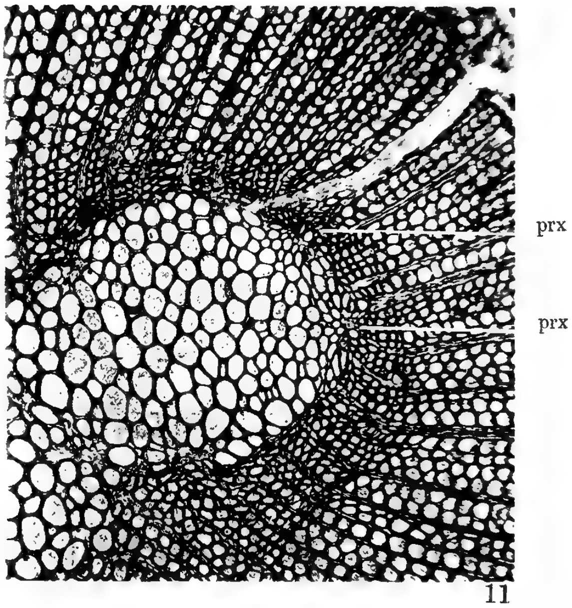
BRITISH MUSEUM NATURAL HISTORY

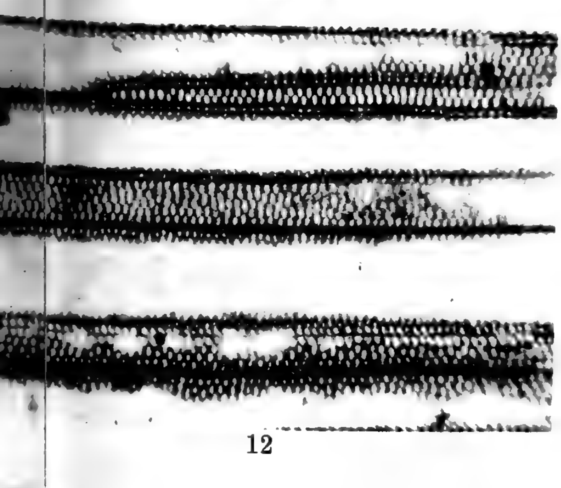
KIDSTON AND GWYNNE-VAUGHAN.—PLATE II.

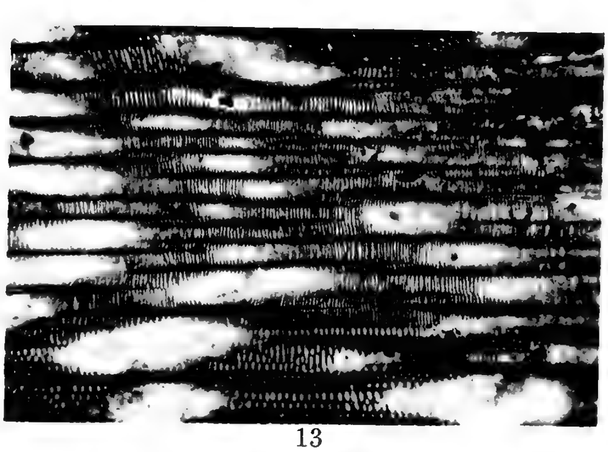












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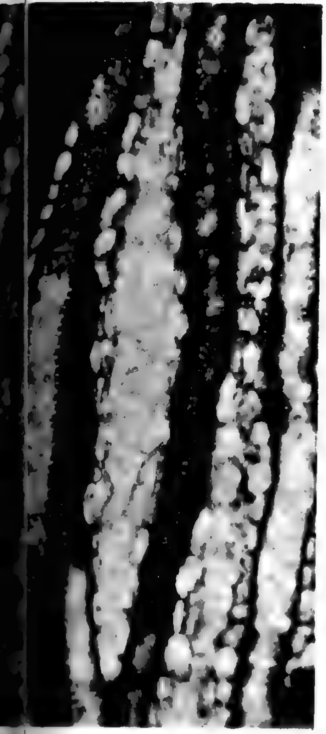
STENOMYELON TUEDIANUM, Kidston.

KIDSTON AND GWYNNE-VAUGHAN.— PLATE III.



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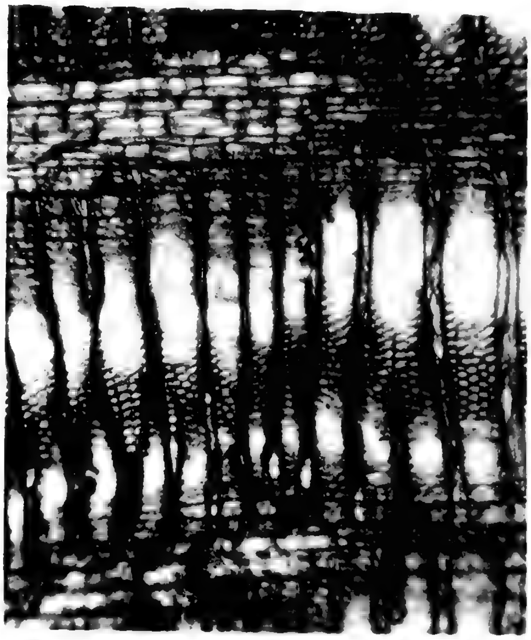

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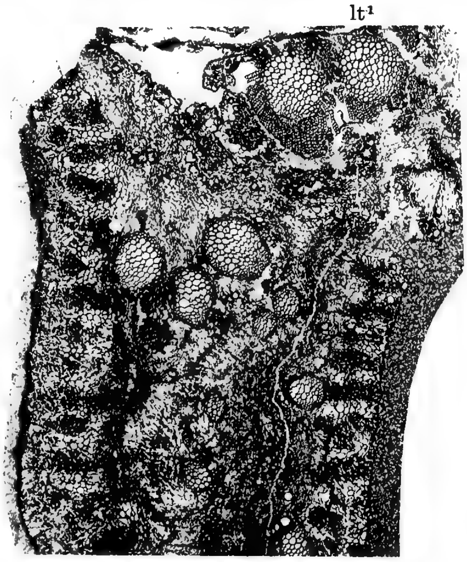

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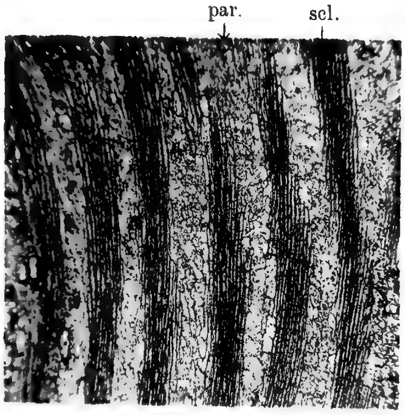

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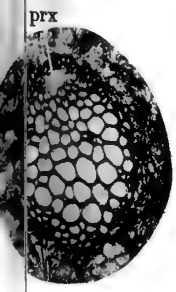

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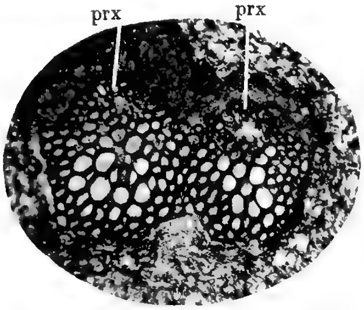

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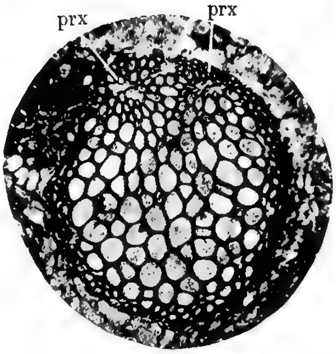

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STENOMYELON TUEDIANUM, Kidston.

M'Farlane & Erskine, Lith., Edin.

BRITISH MUSEUM
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KIDSTON AND GWYNNE-VAUGHAN.—PLATE IV.

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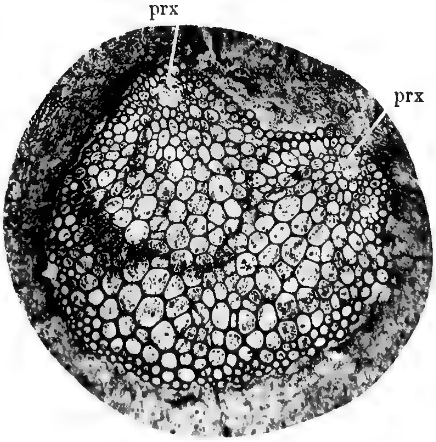

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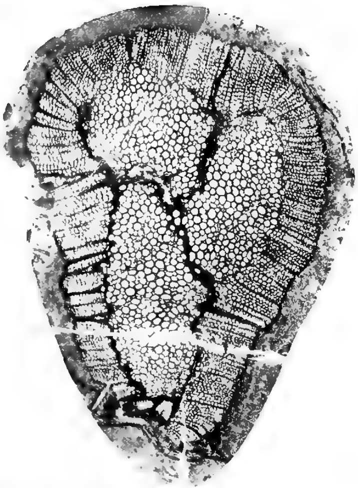

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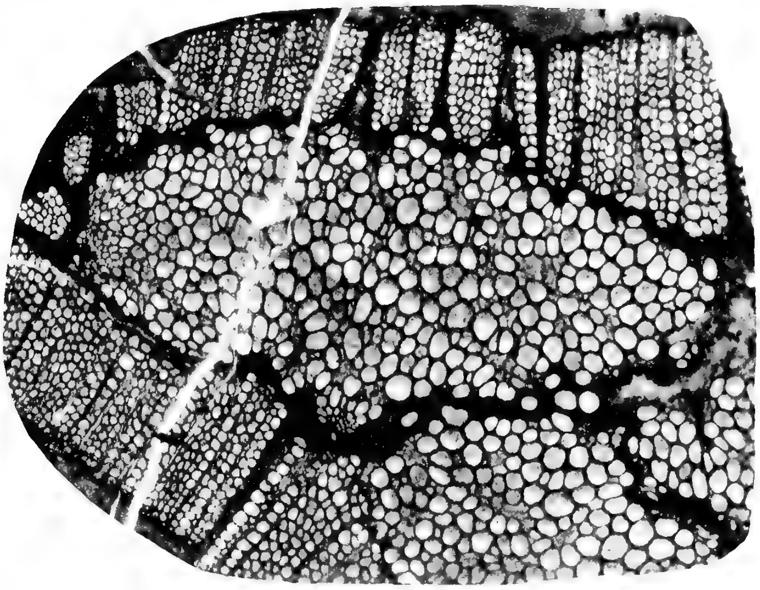

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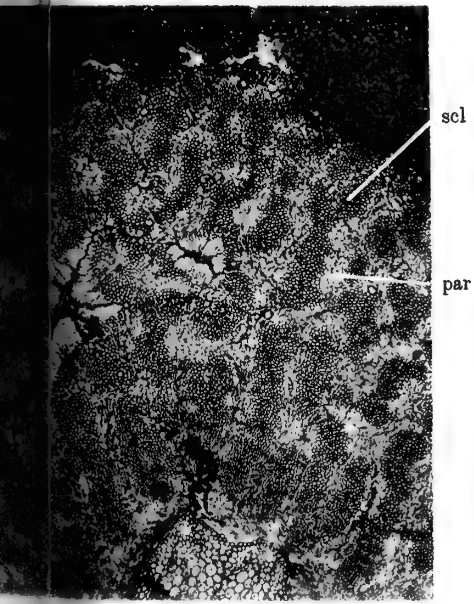

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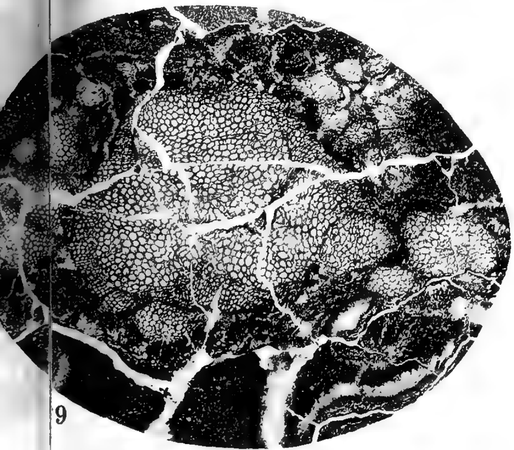

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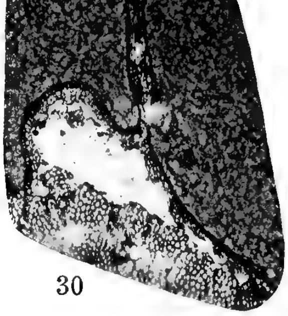

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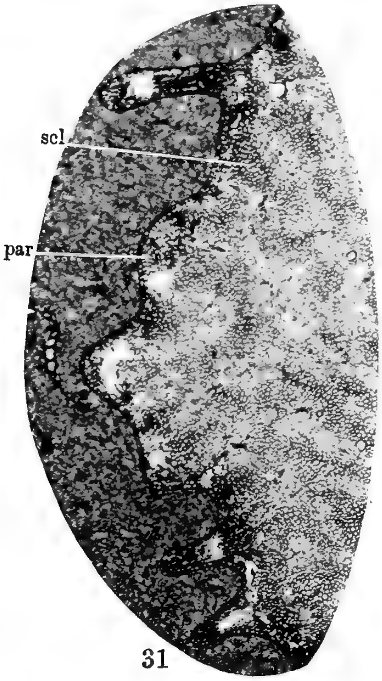

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Photo.

STENOMYELON TUEDIANUM, Kidston.

M'Farlane & Erskine, Lith., Edin.,

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XIV.—The Cephalopoda of the Scottish National Antarctic Expedition.

By **William Evans Hoyle**, M.A., D.Sc.

(MS. received January 8, 1912. Read February 19, 1912. Issued separately May 28, 1912.)

The Cephalopoda collected by the *Scotia* may, with a few trifling exceptions, be separated geographically into three divisions, coming respectively from South Africa, South America, and the Antarctic.

A. South Africa:

- *Euprymna* sp.
- Sepiolid (undetermined).
- *Loligo reynaudi.*
- *Sepia australis.*
- *Hemisepius typicus.*

B. South America:

- *Polypus brucei,* n. sp.
- *Polypus tehuelchus.*
- *Desmoteuthis* sp.

C. Antarctic Regions:

- *Stauroteuthis* sp.
- *Moschites charcoti.*
- *Onychoteuthis ingens.*
- *Bathyteuthis abyssicola.*
- *Galiteuthis suhmi.*

In addition were collected:—

Between the Cape and Tristan da Cunha:

- *Histioteuthis* sp.

Equatorial Atlantic:

- *Tremoctopus quoyanus.*

A considerable number of the horny mandibles of Cephalopods were obtained from the stomachs of various mammals and birds, but the small amount of authentically named material available does not justify an attempt to identify them. The animals referred to and the localities were:—

Ross' Seal.—Station 165, 6th February 1903.

Weddell's Seal.—Station 326, Jessie Bay, South Orkneys, May 1903; Station 325, South Orkneys, 21st September 1903.

Albatross.—Station 437, 3rd April 1904.

Sooty Albatross.—Station 376, lat. 64° 38′ S., long. 35° 13′ W. 23rd February 1904.

Emperor Penguin.—Station 248, lat. 69° 46′ S., long. 20° 58′ W. 21st February 1903.

SYSTEMATIC LIST.

Cirroteuthidæ.

Stauroteuthis sp.

Locality.—Station 295, Weddell Sea. Lat. 66° 40′ S., long. 40° 35′ W. 10th March 1903. 2425 fathoms. One specimen [H 956].*

This is probably either *S. meangensis* or *S. hippocrepium*, but in the mutilated condition of the body and the absence of the internal cartilage it is impossible to speak with certainty. It is just possible that it might be one of the species of *Cirroteuthis*, but this is less likely.

A number of fragments and a few fairly complete examples of Crustacea were found in the gizzard of this specimen, and an account of them has been published by Dr Thomas Scott.† The most remarkable appears to be *Pontostratiotes abyssicola*, G. S. Brady, which seems never to have been met with since the unique type was obtained by the *Challenger* in mud from 2200 fathoms in lat. 37° 29′ S., long. 27° 31′ W. This is of interest as furnishing corroborative evidence of the deep-sea habits of the Cirroteuthidæ. By a clerical error Dr Scott gives the date of capture as 1908 instead of 1903.

A water-colour drawing of this specimen, made on the Expedition, shows that the coloration very closely resembles that of *Stauroteuthis hippocrepium*, as depicted in the *Albatross* Report;‡ the colour of the body is, however, more deeply purple. As compared with *Cirroteuthis umbellata*, Fischer,§ the arms are dull red instead of deep purple (though this may be owing to the oral aspect of the arms being depicted in one case and the aboral in the other), and the body is purple instead of pale reddish.

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* The numbers in square brackets refer to my own register of specimens examined.

† *Ann. and Mag. Nat. Hist.* (8), vol. v. pp. 51–54, pls. ii., iii., Jan. 1910.

‡ Hoyle, *Bull. Mus. Comp. Zool.*, vol. xliii., No. 1, pl. i. fig. 1, pl. ii. fig. 1, 1904.

§ Joubin, "Céphalopodes de la 'Princesse Alice,'" pl. i., 1900 [1901].

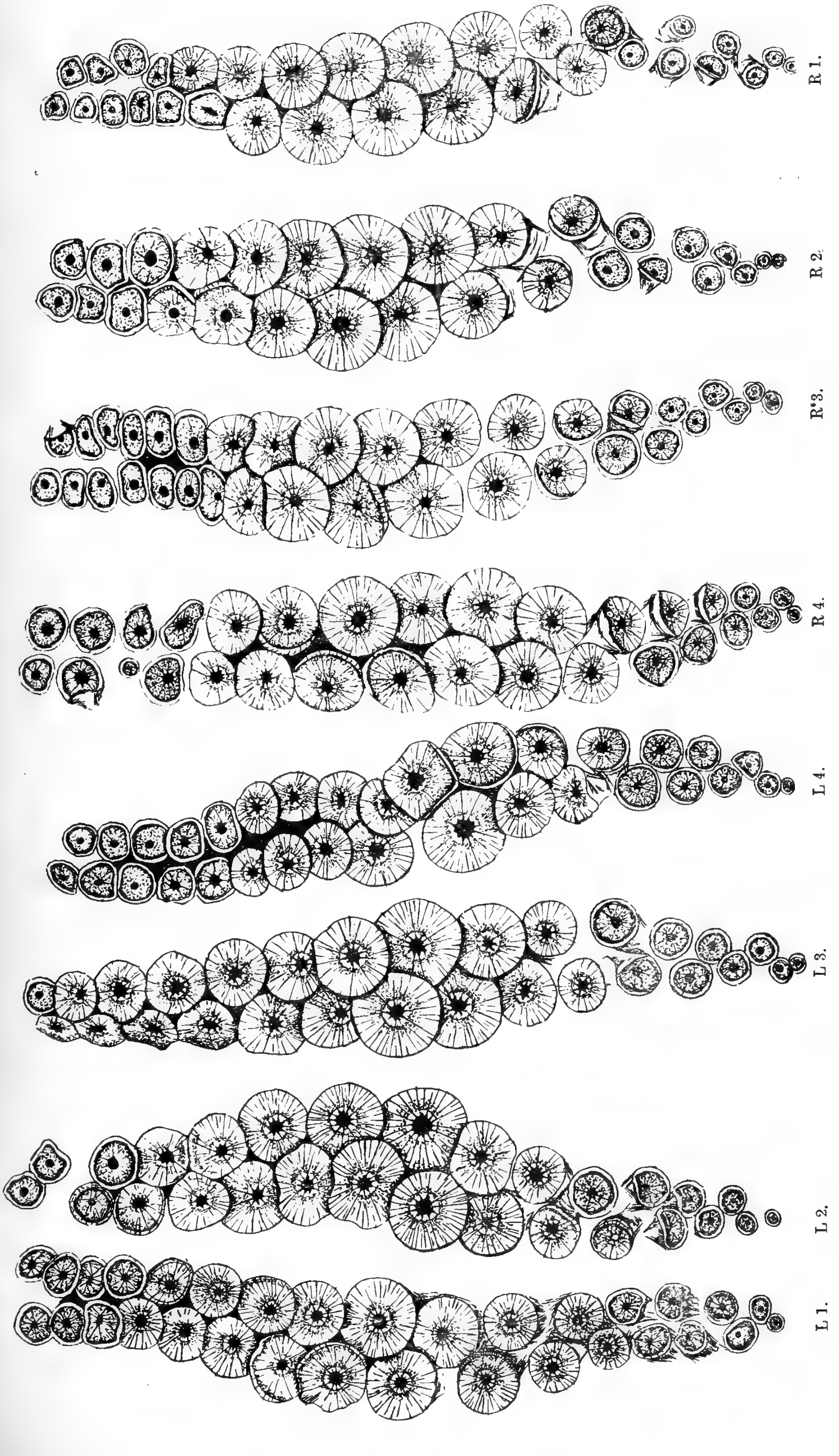

Fig. 1.—Oral aspect of the arms of *Polypus brucei*, to show the arrangement of the enlarged suckers. Natural size.

TREMOCTOPODIDÆ.

Tremoctopus quoyanus, d'Orbigny, 1835.

Locality.—Tow-net, Station 59, Equatorial Atlantic. Lat. 2° 30′ S., long. 32° 42′ W. 12th December 1902. Surface. One specimen, ♀ [H 1366].

Previous Records.—Atlantic and Pacific Oceans.

POLYPODIDÆ.

Polypus brucei, n. sp.

Locality.—Station 346, Burdwood Bank, off Tierra del Fuego. 1st December 1903. One specimen, ♂ [H 924].

The Body is a flattened ovoid, with a very shallow groove along the middle line ventrally. The *mantle opening* extends fully half way round the circumference of the body, terminating immediately below and behind the eyes. The *siphon* is short and broad, and extends less than half way from the margin of the mantle to the edge of the umbrella.

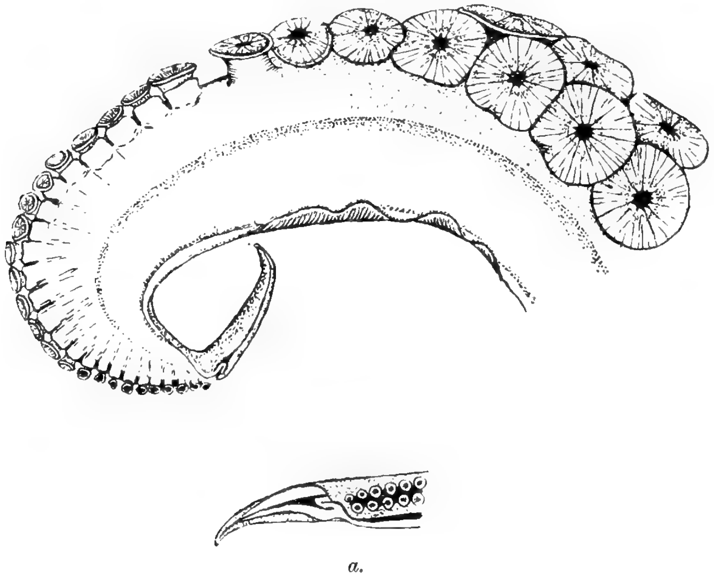

FIG. 2.—The hectocotylised arm of *Polypus brucei*. *a*, oral aspect of the extremity. Natural size.

The Head is somewhat narrower than the body, and the *eyes* are but slightly prominent.

The Arms are somewhat unequal, and about four times as long as the body; their order of length is 1, 2 = 3, 4. The *umbrella* is well marked and its arrangement very characteristic. On the dorsal aspect of each arm it is attached as far as a point about one-third up the arm, whilst on the ventral aspect its attachment can be followed to about within 1 cm. of the extreme tip of the arm. The *suckers* (fig. 1) on all the eight arms are enlarged for the second quarter of the arm; after about the first twelve suckers they enlarge very rapidly for about six suckers, and then gradually diminish. The third arm on the right side is hectocotylised (fig. 2), and is considerably shorter than its fellow on the opposite side. The seminal groove is well marked, but is neither very broad nor very deep; the modified extremity is unusually long and narrow, and, instead of the usual transverse ridges, shows a double row of small papillæ along its bottom.

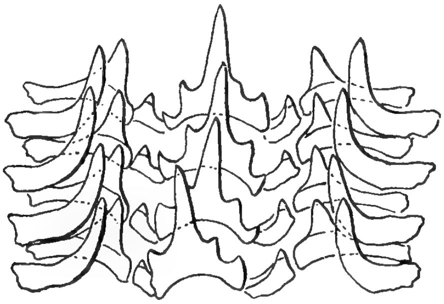

FIG. 3.—Radula of *Polypus brucei* [H 924]. × 25.

The Surface shows a considerable amount of wrinkling, due apparently to the action of preservative fluids, but was most probably smooth when the animal was alive. There is no trace of any warts or tubercles.

The Colour is dull purplish above, changing gradually into a pinkish stone colour below.

The Radula is shown in fig. 3.

Dimensions in Millimetres.

End of body to mantle margin	58
End of body to eye	75
Breadth of body	60
Breadth of head	50
Eye to edge of umbrella	60
Length of hectocotylus	17
Breadth of hectocotylus	3
Diameter of largest sucker on arm	15

	Right.	Left.
Length of first arm	270	275
Length of second arm	185*	250*
Length of third arm	200	260
Length of fourth arm	255	255

* Mutilated.

This species is evidently nearly related to *P. megalocyathus* (Gould) from the same geographical region. It differs, however, in the absence of the extremely marked constriction between the head and umbrella, as well as of the membrane along the sides of the body, and in the fact that the enlarged suckers are found in all the arms. It is impossible to ascertain whether this last peculiarity occurs in GOULD's species, but his comparison with *P. fontanianus,* in which only the lateral arms have enlarged suckers, would lead one to suppose that such was the case in his species also.

I have much pleasure in dedicating this species to my friend Dr W. S. **BRUCE**, the leader of the expedition.

Polypus tehuelchus, d'Orbigny, 1835 ?

Locality.—Station 118, Falkland Islands. Lat. 51° 49′ S., long. 57° 51′ W. Shore collection. 6th February 1904. One specimen, ♂ [H 1696].

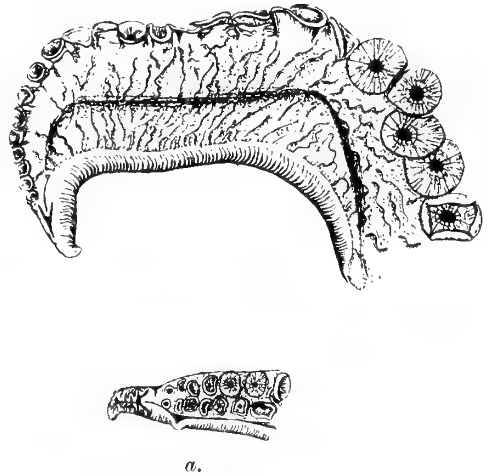

FIG. 4.—Hectocotylised arm of *Polypus tehuelchus.* *a*, oral aspect of the extremity. Natural size.

Port Stanley, Falkland Islands. February 1904. One specimen, ♀ [H 926].

Previous Records.—East coast of Patagonia, 40° S.; Strait of Magellan; Punta Arenas; Nicaragua; St Thomas, Danish West Indies.

The skin of the upper part of the body, and especially of the head, is very much wrinkled, but this is probably due to the action of reagents, as no traces of definite papillæ can be found. The animal was most likely smooth in the natural state. The hectocotylised arm of the male (fig. 4) has a very well-developed seminal groove, especially at the proximal end, where the membrane forming it stands out very distinctly from the surface of the arm. The tip is comparatively short and broad, measuring 6 × 3 mm., and of quite normal form; the terminal groove is small and narrow; its margins are deeply folded (perhaps owing to reagents), and there are no transverse ridges across its bottom. The radula is shown in fig. 5.

I believe this specimen to be correctly identified, but there is some little doubt owing to its colour being neither so dark above nor so pale below as is indicated in D'ORBIGNY's description and figure.

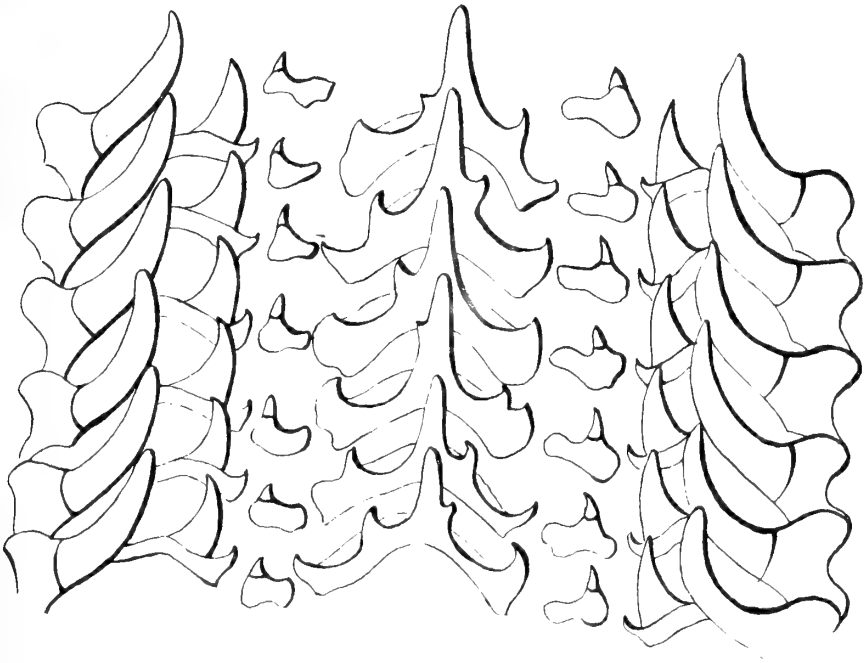

FIG. 5.—Radula of *Polypus tehuelchus*, ♂ [H 1696]. ×52.

Moschites charcoti (Joubin), 1905.

Locality—Station 325, Scotia Bay, South Orkneys. 7th August 1903. 10 fathoms. One specimen, ♂ [H 929]. Same locality. 30th May 1903. 9–10 fathoms. Temperature about 28°. One specimen, ♀ [H 936].

FIG. 6.—Hectocotylised arms of *Moschites charcoti*. *a*, oral aspect of the extremity. Natural size.

Previous Records.—Booth-Wandel Island. Lat. 65° 05′ S. Among algæ on the beach. 3rd September 1904.

The hectocotylised arm (fig. 6) is short and stout; the ridge bounding the seminal groove is very well marked, and is continuous with the margin of the umbrella. The groove itself is broad and deep, the extremity measures 7 × 5 mm.; the longitudinal groove is triangular in form, and has four transverse ridges in its bottom.

The radula is shown in fig. 7.

According to coloured drawings made on the Expedition, the male of this species is dull stone colour above, deepening to brown in the centre of the back; the female is much paler, with a pinkish tinge above, almost white below. The colours would, however, probably undergo change according to the varying state of contraction of the chromatophores.

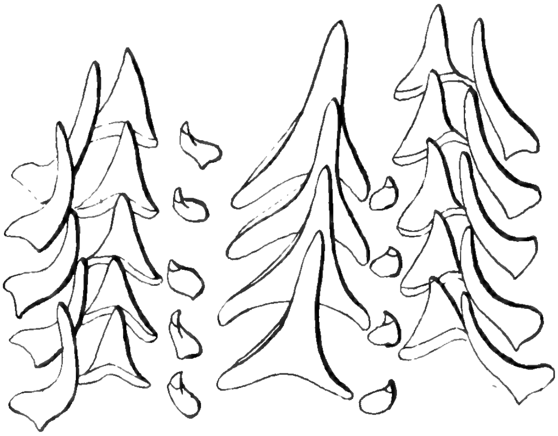

FIG. 7.—Radula of *Moschites charcoti*, ♂ [H 924]. ×50.

SEPIOLIDÆ.

Euprymna sp.

Locality.—Station 482, Saldanha Bay, Cape Colony. 19th May 1904. 8–10 fathoms. Trawled. One specimen, too young to determine [H 934].

Sepiolid gen. et sp. ?

Locality.—Entrance to Saldanha Bay, Cape of Good Hope. 21st May 1904. 25 fathoms.

A head and arms, much macerated [H 1367].

LOLIGINIDÆ.

Loligo reynaudi, d'Orbigny, 1845.

Locality.—Station 480, eight miles north of Dassen Island, Cape Colony. 35 fathoms. Between 2 and 2.30 p.m., 18th May 1904. One specimen, ♀ [H 927].

Twenty-six young specimens, thirteen ♂, twelve ♀, one damaged [H 930]. One somewhat damaged specimen, ♀, probably of this species [H 1372].

Previous Records.—Cape of Good Hope; False Bay, Cape Town.

It is quite possible that some of the young specimens recorded as females may be males in which the secondary sexual characters were as yet undeveloped.

SEPIIDÆ.

Sepia australis, Quoy and Gaimard, 1832.

Locality.—Station 480, eight miles north of Dassen Island, Cape Colony. 35 fathoms. 18th May 1904. One specimen, ♀ [H 932].

Previous Records.—Cape of Good Hope, Agulhas Bank; North Queensland; New South Wales.

This is not *S. australis*, d'Orbigny: that author changed QUOY's name to *S. capensis*, and gave the name *S. australis* to a quite different form.

The tentacular club (fig. 8) shows three suckers much larger than the others, which diminish in size towards the tip, the third being about half the diameter of the first.

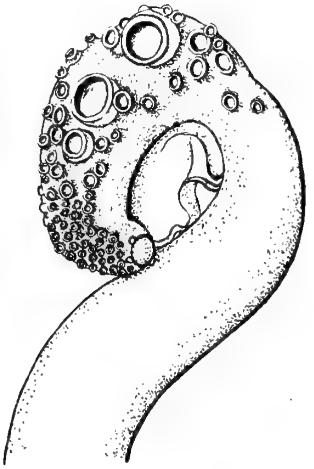

FIG. 8.—Tentacular club of *Sepia australis* [H 932]. ×7·5.

Hemisepius typicus, Steenstrup, 1875.

Locality.—Station 482, Saldanha Bay, Cape Colony. 19th May 1904. 8–10 fathoms; trawled. Two specimens, ♀ [H 933 and 1380].

Previous Record.—Table Bay, Cape Town.

ONYCHOTEUTHIDÆ.

Onychoteuthis ingens, Smith, 1881.

Locality.—Off the South Orkney Islands. Lat. 60° 10′ S., long. 42° 35′ W. 6th February 1903. From the stomach of a Ross' seal: a number of half-digested fragments [H 925].

Station 325, Scotia Bay, South Orkneys. 1st January 1904. One specimen [H 928].

A drawing of the radula is given in fig. 9, as its form differs in a few details from that shown by SMITH.*

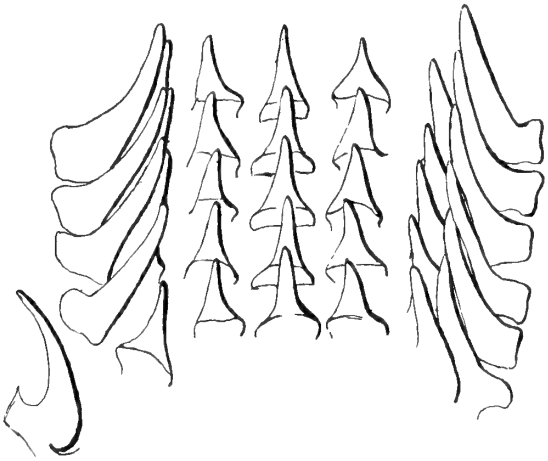

FIG. 9.—Radula of *Onychoteuthis ingens* [H 925]. × 25.

HISTIOTEUTHIDÆ.

Histioteuthis sp. juv.

Locality.—Station 468, South Atlantic. Lat. 39° 48′ S., long. 2° 33′ E. 29th April 1904. 2645 fathoms. One specimen [H 940].

The specimen is somewhat damaged. The interbrachial membrane is slightly developed. One arm shows the pigmented organ at the extremity, which, so far as I am aware, is characteristic (in this family) of the genus *Histioteuthis*, although it is not alluded to in the diagnosis either of PFEFFER or CHUN. In many respects it resembles the *Challenger* specimen called *Histiopsis atlantica*, which was also from the same region, but is pale and semi-transparent, whilst that was opaque and dull reddish in colour.

BATHYTEUTHIDÆ.

Bathyteuthis abyssicola, Hoyle, 1885.

Benthoteuthis megalops, Chun, "Cephalopoden," *Wiss. Ergebn. deutsch. Tiefsee Exped.*, p. 185, pls. xxiv.–xxvii.

Locality.— Station 416, off Coats Land. Lat. 71° 22′ S., long. 18° 15′ W. Surface to 2300 fathoms. 17th March 1904. One specimen [H 938].

Previous Records. — Southern Ocean, lat. 46° 16′ S., long. 48° 27′ E.; off Martha's Vineyard, U.S.A.; off Cape Mala, Gulf of Panama; off Cape Agulhas; Equatorial Indian Ocean.

Professor CHUN has adopted VERRILL's name *Benthoteuthis megalops* for this species, on the ground that "sheet 50 of the *Trans. Connect. Acad.*, vol. vi., in which VERRILL's description is contained, bears (p. 399) the note 'April 1885.'" If my friend is content to accept this method of determining dates of publication, he may turn to sheet 34 of the *Narrative of the Challenger Expedition*, vol. i., first part, in which HOYLE's description is contained, and he will find that it bears

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* *Proc. Zool. Soc.*, 1881, pl. iii., fig. 1 *b*.

(p. 265) the date "1884." I was fully aware of both these dates when I prepared the *Report on the "Challenger" Cephalopoda*, but as a matter of fact neither of them is a date of publication. Sheet 50 of VERRILL's *Third Catalogue of Mollusca . . . of the New England Coast* was not published by itself, but along with sheets 51–56, in a wrapper which bears the words, "Newhaven, April to June 1885." Therefore, under the most favourable construction, it cannot possibly have appeared before June, and careful inquiries which I made at the time led me to the conclusion that it did not make its appearance till July. I may further add that in the twenty-five years which have elapsed since the statement was published its accuracy has never been impugned.

CRANCHIIDÆ.

Galiteuthis suhmi, Hoyle, 1886.

? *Procalistes suhmii*, Lankester, *Quart. Journ. Micr. Sci.*, vol. xxiv. p. 311, 1884.
Taonius suhmi, Hoyle, *Ceph. Challenger Exped.*, p. 192, pl. xxxii. figs. 5–11, 1886.
Taonidium suhmi, Pfeffer, *Synopsis Oegopsid. Ceph.*, p. 192, 1900.
Galiteuthis armata, Joubin, *Ann. Sci. Nat. (Zool.)*, sér. 8, vol. vi. p. 279, 1898.
Galiteuthis (Taonidium) suhmii, Chun, "Cephalopoden," *Wiss. Ergebn. deutsch. Tiefsee Exped.*, p. 382, pl. lix., 1910.

Locality.—Station 422, Weddell Sea. Lat. 68° 32′ S., long. 12° 49′ W. 23rd March 1904. Vertical net; surface to 600 fathoms. One specimen [H 935].

Previous Records.—South of Australia, lat. 47° 25′ S., long. 130° 22′ E.; Mediterranean; Equatorial Atlantic in the Guinea Current.

This specimen has a mantle length of 45 mm., and is, therefore, considerably larger than that described by CHUN (34 mm.); but nevertheless I could find no trace of the modification of the tentacular suckers into hooks as depicted by him (pl. lix. figs. 6, 7); still, the other characters agree so well that I have no doubt that it belongs to the same species as his.

If it could be proved satisfactorily that the embryo described by LANKESTER really belonged to this species, his name would take precedence; but at present it seems advisable to keep the name *Procalistes suhmii* for it, and to call the more mature specimens by the name adopted by CHUN.

Desmoteuthis sp.

Locality.—Station 98, off Rio Grande, South America. Lat. 34° 2′ S., long. 49° 7′ W. 28th December 1902. Mantle and fin, cast up by a petrel. Too fragmentary to determine. [H 1368.]

I have not thought it necessary to encumber this Report with full bibliographical references; these will be found in my *Catalogue of Recent Cephalopoda* and its two Supplements.* The drawings have been made by Miss I. M. DAVENPORT, B.Sc., under my supervision.

NATIONAL MUSEUM OF WALES, CARDIFF,
6th January 1912.

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* *Proc. Roy. Phys. Soc. Edin.*, vol. ix., 1886; vol. xiii., 1897; vol. xvii., 1909.

XV.—On Branchiura sowerbyi Beddard, and on a new species of Limnodrilus with distinctive characters. By J. Stephenson, M.B., D.Sc. (Lond.), Major, Indian Medical Service; Professor of Biology, Government College, Lahore. *Communicated by* Professor Ewart. (With Two Plates.)

(MS. received October 25, 1911. Read December 4, 1911. Issued separately *May* 23, 1912.)

On a recent occasion, looking into a small shallow pool near Lahore, I saw here and there on its bottom a reddish appearance, which a closer examination showed to be due to innumerable worms, implanted by one extremity in the mud, and waving their free ends in the water. These were the *Limnodrilus* described below. A quantity of the mud taken for further examination yielded, though in very much smaller numbers, three other Oligochætes, viz. *Branchiura sowerbyi*, *Lahoria hortensis*, and a species of *Dero*.

Branchiura sowerbyi was originally described by Beddard (2) from specimens found in mud from the "Victoria regia tank" in the Royal Botanical Society's Gardens, Regent's Park. Its most distinctive feature is the possession of a double series of finger-like gills on the posterior part of the body, one row being placed along the mid-dorsal, the other along the mid-ventral line. *Lahoria hortensis* was originally described by me (9) from a small pond in the Lawrence Gardens at Lahore; it is not common; and, not having met with it for two years, I had begun to think that it had disappeared. It belongs to the Naididæ; like *Branchiura sowerbyi*, it possesses two rows of gill-processes, but these are either limited to, or best developed on, the anterior part of the body, and are dorso-lateral in position. *Dero* is well known as a Naid which possesses a small number of gill-processes at the posterior end of the body round the anus. *Limnodrilus* is remarkable in possessing a cutaneous capillary plexus in the posterior part of its body,—better marked in this, apparently, than in most of the other species of the genus; and this feature, and the constant waving movements of its tail, have doubtless a respiratory significance.

There were here, therefore, living together, four genera of Oligochætes, with peculiar and specialised respiratory arrangements; and, by a curious coincidence, three of them were among the very few known Oligochætes which possess gills.

The coincidence, however, does not end here. Beddard, in his paper on *Branchiura sowerbyi*, relates that the mud which provided him with this form also contained three or four examples of *Chætobranchus semperi*, a gilled Naid previously described from Madras by Bourne (4). *Branchiura sowerbyi* has been recorded twice since then (1892) (*v. inf.*), but *Chætobranchus* has apparently not been seen again. *Lahoria*, however, resembles *Chætobranchus* very closely in many ways,* the chief difference

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* Michaelsen (7) indeed includes it in the genus *Branchiodrilus*, Mchlsn. (= *Chætobranchus*, Bourne). I have discussed the question in my original paper (9); the point depends on the value to be attached to "cephalisation,"

being the absence in *Lahoria* of gills and dorsal setæ on the segments from the second to the fifth, and their presence on these segments in *Chætobranchus*. It is thus noteworthy that the coexistence of *Branchiura sowerbyi* and *Chætobranchus* in artificial surroundings in England should be paralleled by the coexistence of *Branchiura sowerbyi* and *Lahoria* under natural conditions in India.

The pond in which the worms were found was one of a series occurring in a small nullah on the outskirts of Lahore. The surface drainage of the jail runs into this nullah, so that, unlike most small ponds in this neighbourhood, it is probably seldom altogether dry. At times, *e.g.* after rain, there is a continuous stream of water along the nullah.

Methods.—The best method for the observation of the living animals is the employment of the binocular microscope with comparatively low powers; this is the easiest way of obtaining a conception of the complicated relationships of the blood-vessels, and the mode of their contraction.

The setæ are best studied by killing the animals by a narcotic (methyl alcohol, chloretone) and leaving them in the water for a few hours till they become soft and are just beginning to disintegrate. A worm is then carefully placed on a slide in glycerin and the coverglass lowered; the weight of the coverglass is sufficient to cause a specimen in this condition to flatten out completely, and the setæ, retaining their arrangement, can then be viewed in one plane.

Parts of the genital system, and especially the chitinous penis sheath of the *Limnodrilus*, can be isolated by teasing under the binocular microscope.

Serial sections (5–10μ) were stained with Heidenhain's iron-hæmatoxylin followed by eosin, and with Delafield's hæmatoxylin.

Branchiura sowerbyi Bedd.

Since the original discovery of this worm by BEDDARD it has been recorded by L. PERRIER (8), who has found it in different years at several places in the Rhone at Touron (Ardèche), and by MICHAELSEN (6) in a warm-water tank of the Botanical Gardens at Hamburg. PERRIER does not give any anatomical description of his specimens, while MICHAELSEN states that, apart from the genital apparatus, which he describes in detail, his specimens agree essentially with BEDDARD's.

I do not propose to give a complete description of the worm. My own specimens

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i.e. the differentiation of a certain number of the anterior segments of the body,—especially their differentiation by the absence from them of the dorsal series of setæ. The presence or absence of this cephalisation has hitherto, I think, always been regarded as of generic importance, and the extent anteriorly of the dorsal setæ is always mentioned in the generic diagnoses of the Naididæ; and so BOURNE, BEDDARD (3), and MICHAELSEN (5) all give the distribution of the dorsal setæ (as far forwards as the second segment) as a generic character of *Chætobranchus*.

It is, I think, very possible, as I have myself suggested, that cephalisation will lose much of the importance hitherto assigned to it. But until the question has been further discussed, and until authorities are agreed with respect to this far-reaching alteration in our ideas as to specific and generic characters in the Naididæ, it seems better to abide by the more general opinion on this point.

were none of them mature sexually, so that a comparison with BEDDARD's and MICHAELSEN's specimens is in this respect impossible. I wish, however, to refer in some detail to the setæ, the gills, the body-wall, the cœlom and its partitions, the circulatory and nervous systems; and to bring out certain points which are new, or in which my specimens appear to differ from those described by BEDDARD.

Seven specimens of this worm were obtained. In length they were, when extended, two inches or less, *i.e.* considerably longer than those examined by BEDDARD; one, much the smallest, measured only about two-thirds of an inch. They were fairly stout, in breadth about a millimetre or more, very contractile, with both ends tapering to a blunt point. In colour they were a pinkish grey, with whiter and more translucent margins.

The *prostomium* is bluntly conical; the *number of segments* 74–116.

The *setæ* are of three kinds, single and double-pointed needles, and hair-setæ; the needles of both forms occur in both dorsal and ventral bundles, the hair-setæ only in the dorsal.

The needle-setæ (fig. 1) are mostly forked in the anterior part of the body, single-pointed needles being relatively few; in the posterior bundles the reverse is the case, the single-pointed being here the more numerous. In the double-pointed setæ the outer point, *i.e.* that on the outer side of the curve of the shaft, is the smaller; intermediate forms between the single- and double-pointed setæ are met with, in which the outer point is still smaller, or, it may be, scarcely recognisable. The single-pointed setæ and the intermediate forms are not produced from the forked setæ by wear, since, especially in the posterior part of the body, the formation of new setæ may be observed, and many of these have single points from the beginning. In length these needle-setæ are about 120μ, in breadth 6–7μ; they have the usual double curve; the nodulus, not mentioned by BEDDARD, is distal to the middle of the shaft (distal to nodulus : proximal to nodulus : : 2 : 3); and the seta ends internally by tapering somewhat, not as shown by BEDDARD in a broad square end.

The hair-setæ are a little longer (130–164μ) and much slenderer than the needles; they are straight, and show no other distinctive marks; they are confined to the dorsal bundles of the anterior part of the body, being absent from the whole of the gill-region; there is never more than one in each setal bundle.

The setal bundles begin both dorsally and ventrally in the second segment, and cease some distance in front of the hinder end of the animal, the last ten segments or so being devoid of setæ. There may be as many as six needle-setæ in a ventral bundle; five, four, or fewer are also met with. In the dorsal bundles the most that I have observed is five needles and one hair-seta.

The *gills* correspond in their appearance to the description given by BEDDARD. They are not ciliated, are situated along the mid-dorsal and mid-ventral lines, and occupy the posterior fourth to two-fifths of the animal's length. There were from 38 to 55 pairs, on a corresponding number of segments. In length they are about equal to the diameter of the body, but they diminish in size towards the anterior, and less markedly towards their posterior limit; anteriorly, before fading away completely, they become mere tubercles. They are in constant movement, in some degree reminding the observer of cilia; the resemblance is frequently increased by the regular propagation of the beat along the line of the gills, in a postero-anterior direction, like the propagation of a ciliary wave; but there is this difference, that the movement of the individual gills is a swinging movement from side to side, *i.e.* in a direction at right angles to the direction of propagation of the wave, not, as in the case of ciliary movement, in the same direction as the wave. The structure of the gills will be described with that of the body-wall.

In addition to the oscillations of the gills themselves, the whole posterior part of the body of the worm is continually performing undulatory movements.

The *body-wall* (figs. 2-5) consists of the usual layers. The surface epithelium is high and columnar over the body generally, low over the gills (fig. 6). The subjacent circular muscular layer is thin, and extends unbroken throughout the body. The longitudinal muscular layer, on the other hand, is thick, but is characterised by inequalities of distribution; in the anterior part of the body (fig. 2) it is of the same thickness at all parts of the body-circumference, but in the gill region inequalities appear, while posteriorly (fig. 3) it is absent from parts of the body-wall. The position of the bands of fibres that persist varies: they may be lateral, one on each side; or one dorsal and one ventral; or there may be one, a ventro-lateral, band only. The position of the absent fibres is taken by an indefinite network with a few cells, the appearance being somewhat that of a scaffolding or meshwork from which the fibres have dropped out.

An inner circular layer of muscular fibres is well marked in the anterior part of the body (fig. 2). The muscular fibres of the septa are continuous with the fibres of this layer; and special bundles of fibres, passing vertically between the sacs of the dorsal and ventral setæ on the same side, may be considered as belonging to it (*cf.* also *Limnodrilus socialis*, post).

In the gill region the circular muscular layer of the body-wall is continued over the gills without splitting, while the longitudinal layer closes the base of the space within the gill, the fibres maintaining their straight course without being deflected. In the interior of the gill, within its muscular layer, are a number of branched cells whose processes anastomose (*a*, fig. 6); these may entirely fill the distal part of the gill-cavity. Proximally, near the base of the gill, there is always a space; cells and cell-processes may stretch across it, and other cells may form a definite, almost epithelial layer on the inner surface of the muscular coat (fig. 6). The two vessels of the gill run on opposite sides, within the muscular coat.

Beddard, who describes a septum shutting off the cavity of the gill from the general body-cavity, nevertheless speaks of the gill-cavity as "evidently belonging to the cœlom." I do not think this follows either from his description or mine; the gill-cavity appears to be a space between the muscular layers of the body-wall, which undergo a separation consequent on the circular layer alone being continued over the gill. Beddard also states that the movements of the branchiæ are caused by muscular fibres, elongated, fusiform, with central nucleus, or sometimes branched and star-shaped, which traverse the cavity of the branchia from side to side. These fibres are obviously the branched cells which I have described above; but I can find no reason to suppose that they are muscular, either in Beddard's description or my own preparations. On the one hand, the observed movements of the gills could not be accounted for by the contraction of such fibres; while, on the other hand, all the movements shown by the gills in my specimens could be caused by a contraction, on one or other side of the gill, or on both sides simultaneously, of the fibres derived from the circular muscular coat.

A fairly obvious feature in the constitution of the body-wall is the *lateral line.* It exists on each side within the circular muscular layer as an aggregation of cells, which in its situation and in its relation to the longitudinal muscular layer recalls the similar structure in the Nematodes. The circular muscular layer is continuous over the line of cells, but the longitudinal layer is completely divided by it on each side (figs. 2, 3, 4). The cells are of somewhat small size, their outlines indistinct, their nuclei ovoid or spindle-shaped. The line extends, midway between dorsal and ventral rows of setæ, from the third or fourth segment to within a few segments of the posterior end. It is easily followed in transverse sections; its nature can also be seen in vertical sections where the lateral body-wall is cut tangentially; the line of cells is seen to form a continuous track, of uniform width, in the substance of the longitudinal muscular layer. The line is continuous, however, only as far back as the anterior gill-region; behind this it is interrupted, and consists of a series of segmentally arranged groups of cells in the posterior part of each segment in front of the septum. Near the posterior end of the body the groups of cells, as seen in transverse sections, project further inwards and spread out somewhat in the body-cavity (fig. 4). The lateral line is also the situation from which numerous bundles of muscular fibres arise.*

The cœlom and its partitions.—The partitions which separate off the cavities in the gills, and the question of the cœlomic nature of these latter, have already been considered.

The septa are extremely thick and muscular in the anterior part of the body (fig. 2). The first septum is $\frac{3}{4}$; from here onwards to $\frac{9}{10}$ the septa have the above character; $\frac{10}{11}$ and all succeeding septa are thin; they contain, however, muscular fibres, both radial and circular.

Beddard states that "there appears always to be a partition which shuts off the upper part of the cœlom from the lower part" (he is speaking of the branchial region); the upper cavity he found "exclusively occupied by the intestine, the lower cavity by the nervous system and the principal blood-vessels;" in his figure the partition is shown as a thin peritoneal membrane, on which are a number of nuclei.

I do not find any partition of this nature in my specimens. There are, however, in the branchial region a number of well-defined, fairly thick bands, which pass across from one lateral line to the other. These do not form a continuous sheet, but have a

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* For the most recent contribution on the subject of the lateral line, *v.* H. Pointner, "Beiträge zur Kenntnis der Oligochætenfauna der Gewässer von Graz," *Zeit. f. wiss. Zool.*, Band xcviii., Heft 4, 1911.

segmental arrangement, being present for some distance in front of each septum (fig. 5). In this situation, moreover, the intestine and dorsal vessel are above, the nerve cord and ventral vessel below the band.

Other muscular strands are also to be seen (*cf.* fig. 5): thus fibres may be observed passing from the transverse bands in an oblique direction downwards to the body-wall. There are, in addition, a number of strands in the upper part of the body-cavity which pass between the intestine and the parietes; these appear to be each constituted by a single cell, with a large ovoid nucleus situated to one side of the strand.

In the most posterior part of the body the ventral portion of the cœlom may be completely filled by the blood-vessels, nerve cord, and a number of cells and fibres, so that there is here no free space below the level of the transverse bands (fig. 5).

Circulatory system.—The dorsal vessel is, as described by BEDDARD, not dorsal at all for the greater part of its course; it is situated ventrally, or rather ventro-laterally on the left side (figs. 3, 8), or it may be in places directly on the left of the intestine (fig. 5). Though not lying immediately on the intestinal wall, it has nevertheless a closer relation to the gut and to the chloragogen cells than has the ventral vessel, and the branches which unite it with the plexus on the intestine are much shorter than those which connect the plexus with the ventral vessel (fig. 8). In sections it is as a rule larger than the ventral vessel. It passes up the left side of the alimentary canal in the eleventh and tenth segments, and thenceforward is dorsal in position. In life it is contractile.

The *ventral vessel* (figs. 3, 5) is on the right of the dorsal in the posterior part of the body; it lies on or near the nerve cord; it is connected by numerous vessels with the intestinal plexus. Anteriorly it is formed by the union of the hearts. Its place is taken in front of the ninth segment by a trunk which is formed in segment v by the union of two vessels coming from the anterior end of the body, and presumably originating in the forking of the front end of the dorsal vessel; this 'anterior ventral' vessel receives the lateral loop vessels on each side, including the large loops in segment viii from the supra-intestinal; very soon thereafter it becomes enveloped in the chloragogen cells and disappears on the ventral surface of the alimentary canal.

There is a rich *intestinal plexus* in the gut-wall, which in segments x–xiii becomes almost a sinus; sections through this region frequently show a continuous blood-space all round the circumference of the alimentary tube. Besides the connections with dorsal and ventral vessels, the plexus is joined to the supra-intestinal by a series of wide communications.

Owing to the comparatively large size and consequent opacity of my specimens during life, it was not easy to trace out in the living worms all the details of the course of the vessels to the gills and body-wall. Fig. 7 represents what could be seen; and in addition I have worked out the point in sections (fig. 8). In the gill-region the dorsal vessel gives in each segment two branches, one dorsalwards, on the inner surface of the body-wall (*d.d.*), which gives a twig across the mid-dorsal line and then enters the dorsal gill; and one ventralwards (*v.d.*), with a similar course and distribution on the ventral side. The two branches may, in the region of the anterior gills, arise in common (fig. 7). The ventral vessel gives two branches: one goes to the right and bifurcates almost immediately into two divisions, which correspond to the two branches of the dorsal vessel,—one running dorsalwards on the inside of the body-wall to the dorsal gill (*d.br.v.*), the other taking a short course ventralwards to the ventral gill (*v.br.v.*). The second branch of the ventral vessel (*l.br.v.*), leaving the main trunk on the left side of the latter, arches over the nerve cord and goes to the left side of the body-wall; it gives a branch to the right below the nerve cord, which seems, according to sections, sometimes at least to meet and anastomose with the branch from the ventral vessel to the ventral gill; thus in these cases a ring is formed round the ventral nerve cord.

I am not satisfied that the arrangement above described is constant; in one series of sections the two vessels going to the dorsal gill were derived, one from the dorsal vessel in the usual way, described above, and the other from the branch from the ventral vessel to the left side of the body-wall (*i.e.* the dorsally directed branch of the vessel *l.br.v.* in fig. 8 went up into the gill).

In front of the gills the parietal vessels have the form of lateral loops, two per segment,—one on the anterior face of the septum, the other more anteriorly in the segment. There are also, as described by BEDDARD, a number of longitudinal vessels, some of which connect successive loops, while others, smaller, pass over several segments at least. The muscular layers of the body-wall are penetrated by numerous twigs, but no capillaries seem ever to enter into the surface epithelium.

The *supra-intestinal* vessel is hardly or not at all distinguishable in front of the sixth segment, and it is small as far back as segment viii; here two considerable loops, one on each side, put it in connection with the 'anterior ventral' vessel; these loops, though not as large as the hearts in the next segment, are still extremely conspicuous structures. In segment ix it gives rise to the first pair of hearts, and in the same segment a number of vessels radiate from it across the body-cavity to the parietes. In this part of its extent it lies directly beneath the dorsal vessel, and, like the latter, gets round to the left side in the posterior part of its course. It is largest in segments x and xi; it communicates by wide channels with the intestinal plexus, and is throughout in close relation with the gut and its chloragogen cells. It becomes smaller in segment xii and very soon disappears.

The *hearts* are two pairs, in segments ix and x. The first pair originate above from the supra-intestinal vessel, pass downwards close to the gut, then, taking a backward course, leave the intestine and perforate septum $\frac{9}{10}$ separately; continuing parallel for a short distance, they then unite in x to form the ventral vessel. The second pair appear to be more tortuous and of rather smaller calibre; they originate above from the dorsal vessel, which is here on the left side, so that the heart of the right side arches over the intestine; they pierce septum $\frac{10}{11}$ separately (this septum thus transmits three vessels ventral to the intestine) and unite with the ventral vessel in xi. Where the hearts join in the ventral vessel there are in both segments (x and xi) projections of cells into the lumen; these may, according to the evidence of sections, entirely block the cavity of the vessel.

Lastly, the *anterior loops* occur in segments ii–viii; they are non-contractile, and the posterior are larger than the anterior; in vii they are of about the same size as the dorsal or the ventral vessel, and in viii they are so large as to resemble the hearts. In ii–vii they run from the dorsal vessel to the anterior ventral, or to the branches which unite to form the latter; in viii, as already said, they run from the supra-intestinal to the anterior ventral. They give branches to the body-wall, which in vi, vii, and viii are of moderately large size. It may be added that the dorsal vessel also gives considerable branches to the body-wall in vi and vii, and the parietal vessels form a plexus in the prostomium and most anterior segments. Behind segment iv the parietal vessels have a longitudinal course, running parallel and fairly close together, so that about 20 such vessels are visible on examining the dorsal surface of the worm; there would thus be about 40 longitudinal vessels in all at any particular level, each of which runs through several segments without losing its individuality; this arrangement, as before noticed, ceases at the gill region.

The only other feature which I propose to select for special mention is the presence of remarkable *giant fibres* in the ventral nerve cord. They may be seen throughout the body on the dorsal side of the cord. They are of different sizes; the larger appear as tubes in transverse section, with a roughly circular or oval outline; a part of their lumen is always empty, and a part, to one side, is occupied by a substance which sometimes has the appearance of a fairly solid mass, sometimes that of a thin coagulum; the shape of this contained matter varies, being sometimes ovoid, sometimes quite irregular; at times it is connected here and there with the wall of the tube by a number of branching threadlike extensions; sometimes it occupies a considerable portion, sometimes very little of the lumen (figs. 3, 5, 6). Other fibres, also running longitudinally on the dorsal and dorso-lateral surface of the cord, are not tubular, and in their staining reactions somewhat resemble muscle fibres.

The number of these large fibres varies from place to place; there are in all, in any section, about five to ten; they are most often six or seven in number, of which one to three have the tubular appearance described above, the rest being larger or smaller solid fibres.

The actual size of the tubular fibres also varies. One is generally larger than the others,—in the posterior part of the body very much larger,—and this one is there constantly to the left of the middle line. These fibres are on the whole larger towards the hinder end of the animal; in the anterior segments they average about 20μ in diameter; as the gill region is approached they may be 40μ; while posteriorly one, but only one at any given level, may be as much as 71μ; these large fibres are, however, much constricted at the septa in this region, *e.g.* to about 15μ or even much less.

The fibres are thus very conspicuous in sections through the posterior part of the body, and especially so is the largest fibre of the group (fig. 3), not only because of its actual size, but because, the whole section being so much smaller, it occupies relatively a far larger space than is the case anteriorly; its diameter may be nearly as great as that of the whole nerve cord, and may actually be greater than that of the ventral vessel close to it.

I am inclined to think that these fibres, or at any rate the specially large one, were seen by Beddard and described by him as the dorsal vessel. As will be seen, his description of the dorsal vessel is altogether at variance with the condition found by me, while it corresponds exactly to that of the large giant fibre.

The dorsal vessel is described by Beddard as being below the partition dividing the cœlom into upper and lower parts; as having thicker walls, and much less blood in the lumen, in sections, than the ventral; the blood in the dorsal vessel is, he states, never so darkly stained by carmine as the blood in the ventral vessel, to explain which he supposes that possibly the muscular walls of the dorsal vessel are particularly impermeable to the staining fluid; when fully expanded the dorsal is stated to be of about the same calibre as the ventral vessel, but in certain parts its lumen was so contracted that the vessel could only with difficulty be recognised; the openings of the branchial vessels into the dorsal vessel were not seen, since at the point where these vessels should open it always happened that the dorsal vessel was very much contracted, while the end of the branchial vessel was much dilated (*i.e.* the dorsal vessel, according to Beddard's interpretation, would thus have a regularly moniliform shape, being contracted almost to obliteration once in each segment).

From my description, however, it appears that the dorsal vessel is above the incomplete muscular partition of the cœlom, and has no close relation to the ventral nerve cord; its lumen is in my specimens always full of blood, which has the same staining reactions as blood elsewhere (this, of course, is only what would be expected in sections stained on the slide); I found the dorsal to be often, if not usually, of greater calibre than the ventral vessel; the openings of the vessels into it were always well marked and patent, and there were no constrictions of importance along its course.

The specially large giant fibre, on the other hand, is below the cœlomic partition, and has the relation to the nerve cord described by Beddard for the dorsal vessel (on the left side just above the cord); the contents of the tube, which usually have the appearance of a coagulum, do in fact stain differently from the blood in the vessels; in diameter it is seldom (and only at the posterior end) as large as, or larger, than the ventral vessel; and at the septa it is regularly much constricted, so as to be, in the posterior portion of the animal, moniliform; while, of course, no vessels are to be seen opening into it.*

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* The appearance of giant fibres has led other observers also to consider them as tubes containing a coagulable substance, *e.g.* Semper, who also found that the coagulum reacted to stains quite differently from blood-plasma; in the crayfish the fibres have been held to be blood-vessels. Compare Ashworth (1), section ii., "Historical Account of the Giant Cells and Giant Fibres of Annelids."

I have only a few remarks to make on the other systems. The *alimentary canal* is a fairly uniform tube throughout, showing little differentiation into distinct regions. The pharyngeal epithelium is markedly ciliated; chloragogen cells begin in segment vi, and cease in the anterior gill region; the canal becomes somewhat wider in segment xi, from which point it may be spoken of as intestine; the anus is dorsal. The 'septal glands,' in segments iii, iv, and v, are collections of cells, not massed together in definite lobes, but surrounding the alimentary tube on all sides in the posterior part of each of the three segments; the septa are here bulged backwards, and the funnel-shaped space so formed is filled with the cells (fig. 2, *p*). The glands are thus, apparently, merely collections of peritoneal cells.

The *nephridia* are long, closely coiled tubes, with a pear-shaped reservoir near the external aperture; the reservoir is less marked in the posterior nephridia. They begin in segment xii, and cease from fifteen to thirty segments in front of the posterior end; the external apertures are in line with, and in front of, the ventral setal bundles, near the anterior margin of each segment.

The *cerebral ganglion* is deeply indented anteriorly, less so behind; the dorsal vessel, here divided, is closely applied to its under surface. The *ventral nerve cord* is relatively very large in the posterior part of the body (fig. 5), and may be equal in diameter to the intestine; it is even absolutely larger than in the (much thicker) anterior part of the body; thus in one specimen, when sectioned, the transverse diameter of the cord was 61μ anteriorly, 110μ where the gills commenced, and 82μ in the posterior gill region.

Unfortunately none of my specimens were sexually mature. Testes were present in x, and ovaries in xi, and in one specimen the male deferent apparatus was beginning to form, in the shape of a funnel on septum $\frac{10}{11}$, while a backward pouching of the same septum indicated the commencement of the vesicula seminalis; but there was nothing distinctive to be discovered.

Limnodrilus socialis, sp. nov.

The mode of occurrence of this worm has already been described. On a subsequent occasion I found it even more abundantly in the same locality; the small pools were beginning to dry up, and the water was everywhere very foul; the worms occurred in large tangled masses of sometimes several pounds in weight, their tails waving as before; a considerable proportion were sexually mature on both occasions (December and February). Again, on March 1st, there were still numbers of the worms in the mud of the nullah; a quantity of these were taken, and on examining them I was surprised to find that the large majority were headless, the whole of the anterior segments, including all the genital organs, having disappeared. Thus, in each of two batches of over fifty individuals, only four complete specimens were found. The worms nevertheless behaved as usual, waving their posterior ends, and contracting on being disturbed; when isolated in a dish they appeared to move and coil themselves up in the same way as perfect individuals (see below).

A possible explanation of this curious circumstance seems to be that by the expulsion of the genital products, which apparently takes place towards the end of February, the anterior segments of the body are so much damaged that they die and are thrown off; the worms, however, continue to live, though it may be doubted whether they are capable of regenerating the anterior end; probably they die after a time, and the whole generation thus perishes each year.

On touching any part of a mass of these worms they cease their waving movements; a feeble disturbance merely causes them to hold themselves rigid, while a more violent one causes a general contraction of all the individuals. Contraction also takes place if the mud near them be disturbed. It looks, at first sight, remarkably easy to scoop up a number of the worms; but as soon as the spoon touches the mud the waving tails vanish in a flash, and however quickly the scoop be made, probably few will be obtained. This, of course, is not the case with the large masses described above, which are so tightly intertwined that they cannot escape thus. The same waving movements and sudden contractions are seen in the worms kept in a vessel in the laboratory, where a slight jarring of the table is sufficient to arrest the movements. Isolated individuals usually coil themselves up into a spiral on being disturbed.

External features.—The usual colour is a pale reddish brown, deeper anteriorly than posteriorly; by reflected light under a low-power binocular microscope the posterior part of the body often has a patchy, opaquish yellow colour, which has the appearance of being due to a golden-bright granular deposit on the inner surface of the body-wall; it is probably in reality a deposit in the peritoneal cells. Some specimens from the foul pools mentioned above were black in their posterior half; and it may be mentioned, by way of comparison, that I have found *Clitellio arenarius*, usually of a red colour, completely black when inhabiting a part of the shore contaminated by sewage.

The *length* of the worms when extended may be as much as three inches; smaller specimens measure one and a half or two inches. Their greatest *breadth* is less than a millimetre. The number of *segments* is commonly about 110; there is a double annulation in the first few. The *prostomium* is bluntly conical. The *clitellum* includes the eleventh with more or less of the twelfth segment.

The *setæ* (fig. 9) of both dorsal and ventral bundles begin in segment ii, and are of the same form. They are moderately stout, have the usual double curve, and are bifid distally; the proximal prong of the fork is shorter and stouter than the distal (about three-quarters as long, and one and a third times as thick at the base); the nodulus is distal to the middle of the length of the shaft (proximal : distal : : 3 : 2, or thereabouts). The length of the setæ in the anterior part of the body is about 115μ, but posteriorly it is less, the average being about 80μ. The number of setæ per bundle is six, seven, or eight in the anterior part of the body, diminishing to three or four posteriorly.

In the first few segments the prongs of the fork may have a slightly different character, being longer and separated by a smaller angle than elsewhere. In the eleventh segment the ventral setæ are absent, their position being occupied by the male aperture.

The *body-wall* (figs. 10, 11) consists of the usual layers. In addition to the circular and longitudinal muscular layers, there is regularly present a well-marked muscular band, passing vertically through the body-cavity, between the dorsal and ventral setal sacs of the same side in each segment (fig. 10). The *peritoneal cells* lining the inner surface of the body-wall have a distinctive character (figs. 10, 11); they are fairly large, ovoid, and transparent; in sections they are very slightly coloured, the only part of the cell-body which takes up the stain being a quantity of contained granular matter; the circular or oval nucleus, with a well-marked nucleolus, is conspicuous; they resemble chloragogen cells, but are without the numerous yellow particles which characterise these latter. Similar but larger cells, pyriform in shape, attached by their stalk-like narrow ends, are also found on septa $\frac{6}{7}$ and $\frac{7}{8}$, and round the nephridia of segments vii and viii. There is a *lateral line* (fig. 10), similar to that described for *Branchiura sowerbyi* (see p. 289); the cells composing it extend peripherally outwards as far as the circular muscular coat, and divide the longitudinal layer along a line which runs midway between dorsal and ventral setal bundles; in this worm, however, the lateral line is well marked only in the anterior segments. No free *cœlomic corpuscles* were seen, except a few yellow granular cells, which were probably detached chloragogen cells.

Alimentary canal.—The pharynx extends backwards through the third segment; its tall columnar epithelium, as also that of the œsophagus, is ciliated. From the third to the seventh segment the ventral wall of the canal is raised into a prominent longitudinal ridge, due to the greater height of the epithelium along this tract (fig. 11); the lumen is thus crescentic. Chloragogen cells begin in segment v.

As appendages of the alimentary canal may be mentioned paired masses of cells in segments vi and vii. These are situated in the anterior part of the segment, ventrolaterally to the œsophagus; in transverse section they have a pyriform shape, with the small end below, near the ventral vessel, and the glands of the same pair may unite with each other round the vessel (fig. 11). Some of the cells contain yellow granules like those of the chloragogen cells, but their general character is very different from that of these latter, inasmuch as they are more compact, more irregular in size and shape, and stain more deeply in both cell-body and nucleus; moreover, though they are in contact with the chloragogen cells, they do not merge into them, and the masses have a distinct outline of their own. Similar but smaller aggregations were also found in segments v and viii.

The *circulatory system* (figs. 12, 13, 14) is of considerable interest. The *dorsal vessel* is ventral in position for the greater part of its course; it runs alongside and on the left of the ventral vessel; both are sinuous, the ventral vessel more markedly so; the convexities of their curves face away from each other. The dorsal vessel is somewhat laterally situated in segments xi and x; it becomes more ventral again in ix, only to leave the ventral surface altogether and reach the dorsal side of the œsophagus in viii. The vessel is surrounded by chloragogen cells, and is situated in close contact with the intestinal wall, as far forwards as ix; it then separates from the alimentary tube and becomes free in the body-cavity. It is contractile throughout its length.

BEDDARD (3) mentions a ventral position of the dorsal vessel as a rare peculiarity among the Oligochæta, which is found in the genera *Branchiura* and *Dero.* It is a curious coincidence that these two worms were found in association with the species under description, as related previously.

The *supra-intestinal vessel* can be traced in the living animal as well as in sections as far forwards as the anterior part of segment v. It is covered by chloragogen cells throughout its course; in the anterior part of its extent it appears in transverse sections as a fusiform space, a special channel of the gut plexus; it is large in segment vii; in segment viii it may, in the living specimen, be hardly visible (perhaps from accidental causes), or, on the other hand, it may be large and conspicuous; in sections it is here larger than either the dorsal or the ventral vessel.

In the anterior part of segment ix, situated transversely like a half ring on the dorsal side of the intestine, is a sinus-like blood-space, with the following connections (figs. 12, 13). Posteriorly it dissolves into a close network of small vessels in the intestinal wall. On the right side it is in open communication with a large vessel in the gut wall, which runs along the right side of the alimentary tube, gradually dying away, and becoming indistinguishable posteriorly at about segment xxi, while anteriorly it ceases as a distinct vessel in segment viii; this, again, though a perfectly distinct, and indeed a very conspicuous, vessel in the living animal, is covered by chloragogen cells, and appears in sections as a special channel of the intestinal plexus. Anteriorly the sinus in segment ix may in favourable cases in the living worm be seen to be connected with the supra-intestinal vessel, though the channel of communication through septum $\frac{8}{9}$ seems as a rule to be of inconsiderable width. The above description is confirmed by sections; the supra-intestinal can be traced as a well-marked vessel up to the septum, where all blood-channels are constricted; on the other side of the septum there is no longer a supra-intestinal vessel, but a sinus encircling the upper half of the gut, from which, on the right side, the vessel described above takes origin.

The *intestinal plexus,* which has already been referred to, extends throughout the length of the intestine, and reaches as far forwards as segment iv. For some distance behind the genital segments it is fed on the left side by a conspicuous series of branches, one in the anterior part of each segment, from the dorsal vessel; and on the right side by twigs from the channel described above as running along the right side of the intestine (fig. 14).

The *hearts* (figs. 12, 13) are a single pair of vessels, which arise from the supra-intestinal anteriorly in viii, pass obliquely downwards and backwards, pierce septum $\frac{8}{9}$ and gradually converge, to unite about the middle of segment ix. When full of blood their anterior ends are much swollen ; their contractions are alternate, pass downwards and backwards, and have no time-relation to the contractions of the dorsal vessel.

The genus *Limnodrilus* possesses in general two pairs of hearts ; the present species is therefore remarkable in having only one pair. There is, however, in the sexual animal a special *loop to the genital organs*, including the seminal vesicles and egg-sac. There is no trace of any such vessel in the non-sexual animal as a rule ; on one occasion, however, in a specimen in which no genital organs were discoverable, a loop was seen in segment ix ; this specimen was perhaps just about to develop sexual organs. The loops develop along with the organs they supply, and soon extend backwards from segment ix in complicated windings ; in the fully developed sexual animal they may extend as far as xvi,—in one case two segments behind the posterior limits of the genital sacs, here appearing to be applied to the wall of the intestine ; they end ventrally in segment x by joining the ventral vessel (fig. 12). The loops are contractile, and it is a fascinating occupation to watch the wave of contraction wandering along the complicated windings of the loop through segment after segment. It seems not impossible, therefore, to compare these genital loops with the second pair of hearts of other species of *Limnodrilus* ; they would be hearts developed only at sexual maturity, greatly increased in length, and modified for their special function. I have no actual note of their dorsal origin ; it is, however, presumably from the dorsal vessel, since the supra-intestinal does not exist behind segment viii.

The *ventral vessel* (fig. 12) is formed anteriorly at about the level of septum $\frac{4}{5}$ by the union of a pair of vessels, one on each side, coming from the front end of the animal. After receiving the lateral loops of segment vii it becomes smaller, and in the next part of its course it appears to be variable. In the living animal it was seen on one occasion to be continued as a fair-sized vessel to the junction of the hearts in ix, and so onwards after being thus reinforced. In three other cases it became very narrow ; but close observation at times when it was filled with blood showed that it was here also continued to join the angle between the hearts, or to one or other heart immediately in front of the junction. In other cases no connection could be made out, nor could any such channel be discovered in either of two series of transverse sections ; in these cases the vessel ended on the intestine in front of septum $\frac{8}{9}$, sometimes bending to the right, towards the anterior end of the channel in the right wall of the intestine (*v. sup.*) before disappearing.

The condition therefore resembles in some degree that described in *Bothrioneurum* and *Lophochæta* (*cf.* BEDDARD, 3, p. 70), where the ventral vessel of the anterior segments is continued backwards on the intestine as a 'subintestinal' vessel, while there is a fine channel of communication between this subintestinal vessel and the point of union of the hearts. The specimens in which the connection between anterior and posterior parts of the ventral vessel is altogether wanting show a condition similar to that described above for *Branchiura sowerbyi* ; and with this, again, may be compared *Tubifex costatus* (*Heterochæta costata*), Clap. (10), the only difference being that in this latter species the 'anterior ventral' is continued backwards for a short distance on the intestine, beyond the level of union of the hearts.

To return to the course of the ventral vessel in the species under description: the vessel formed in segment ix by the junction of the hearts extends to the posterior end of the body; it is more sinuous than the dorsal vessel; it is situated on the right of the nerve cord, the dorsal vessel being on the left. It is less intimately united to the intestine than the latter, not being covered by chloragogen cells; it is somewhat widely separated from the intestine in the genital segments.

The *lateral commissures* in front of the hearts form an elegant tracery of complicated loops. In the posterior part of the body the loops run on the anterior face of the septa, and give branches outwards to the body-wall, which form the *cutaneous plexus.* This extends through about the posterior half of the body; it consists of a number of fair-sized vessels which penetrate the muscular coats, and so come to lie between the cells of the surface epithelium. There are four chief capillary vessels on each side in each segment, at about equal distances from each other; the condition may therefore be compared with that in *L. hoffmeisteri*, as described by VEJDOVSKY (11, p. 116, and plate vii. figs. 16, 17); the special mode of branching there described is not, however, found in the present species; there is no collection of chloragogen cells round the origin of the cutaneous branches; and the cutaneous vessels in the form under description branch freely and anastomose. Though sometimes the secondary branches seem to come to a blind end, this is probably due to the pressure on the specimen, and I do not think they ever really end blindly.

Nephridia are present in segments vii and viii; there is then a hiatus as far as segment xiii. Thenceforwards, too, they are not present in every segment; three or more consecutive segments may possess nephridia, and then they may be absent from one or two; two or three more will have them, and so on; but there is no general rule as to their distribution. The funnel is small, with long cilia round its margin; these wave slowly and languidly; but a few long flame-like flagella, arising from within the funnel and beating down the tube, are much more active; these flame-like flagella are repeated several times in the course of the tube. The tube itself is long, loosely coiled, without a terminal vesicle; it ends on the surface immediately in front of and lateral to the setal sac. The peculiarity of the nephridia of segments vii and viii—that they are surrounded by large pear-shaped peritoneal cells—has already been mentioned.

The *cerebral ganglion* is deeply cleft in front, slightly so behind (fig. 15).

The *reproductive organs* were well developed in a considerable number, perhaps in the majority of specimens. The *testes* are in x, attached by a narrow base to the junction of septum $\frac{9}{10}$ with the ventral body-wall. The *funnel* is also in x, on the opposite septum; it has the usual characters. The *vas deferens* is in xi; it is long and much coiled, wider in its first than in the later part of its course (39μ as against 27μ later); its lumen is also relatively and absolutely greater, and its walls stain less deeply, in its first part. The cells of which its wall is composed have nuclei which are much elongated transversely to the axis of the tube; their length may be as much as one-third of the circumference. The vas deferens is continued into the *atrium*, which begins in the posterior part of xi, the septum ($\frac{11}{12}$) being here much bulged backwards. The atrium is of an elongated pyriform shape, its first part being the broader (90μ); the lumen is at first small, or even, in transverse sections, invisible; only the basal portions of the cells take the stain. The penial end of the atrium is narrower, the lumen is more distinct, the whole of the cells are deeply stained so as to obscure the nuclei. The *prostate* is a fairly large, somewhat spherical cellular mass, continuous with the wall of the atrium, to the first part of which it is attached, a little way beyond the end of the vas deferens. The atrium joins the *penis*, which lies in a canal directed forwards and downwards to the male aperture. This canal is narrow and cylindrical, wider near its external termination, contracting again, however, at the actual aperture, which is situated ventrally on xi, in the position of the missing setal sacs. The penis itself is surrounded by a chitinous *penis sheath* lying loosely within the canal. The sheath is tubular, circular in cross section, narrowing gradually along its course, but expanding again and curving forwards at its outer end; its length is about 520μ, its breadth 49μ above, at its narrowest part 28μ. The lower side of its expanded end terminates in a free margin; the upper side is curved strongly upwards and joins the wall of the penis canal (fig. 16); in the section there illustrated a horizontal cellular shelf projects backwards into the open end of the penis sheath. The sheath ends some distance above the external aperture of the penis canal. The *vesiculæ seminales* comprise a pair of sacs in ix, forward bulgings of septum $\frac{9}{10}$, and a long single sac extending back through xi and a number of succeeding segments, which is essentially a backward bulging of septum $\frac{10}{11}$.

The *ovaries* in segment xi correspond in position to the testes; they are large, extending upwards at the sides of the alimentary canal, and becoming dorsal to it. The *funnel* is situated ventrally on septum $\frac{11}{12}$; the *oviduct* is a minute passage leading to the exterior in the inter-segmental constriction between xi and xii. The *ovisac* extends backwards in the same way as the sperm-sac. The *spermathecæ* are in segment **x**; their external aperture is just in front of and in line with the setal sacs. At first the passage runs vertically; its lumen here is narrow, and its epithelial lining consists of deeply staining cubical or low columnar cells, with a cuticle on their free surface. The height of the epithelium soon becomes irregular, and the outline of the lumen in consequence wavy. All this first part, or duct, is invested by a strong muscular covering, in two layers, a longitudinal external and circular internal; its diameter is about 80μ. After bending about, the cavity widens very considerably; the lining consists of a rather irregular layer of low columnar cells, and the lumen is filled with a granular coagulum; the diameter of the ampulla is about 270μ. There were no spermatophores.

The diagnosis of the genus *Limnodrilus*, as given by MICHAELSEN (5), runs as follows:—"Ventrale und dorsale Bündel lediglich mit gleichartigen, gabel-spitzigen

Hakenborsten. Männliche poren am 11, Samentaschenporen am 10 segm. Supraintestinalgefäss und Subintestinalgefäss vorhanden; Transversalgefässe des 8 und 7 Segm. herzartig; integumentaler Blutgefässplexus meist vorhanden, aber spärlich. Nephridien mit Endblase. Hoden im 10 Segm.; Samenleiter lang, in das proximale Ende der Atrien einmündend; Atrien mit einer grossen Prostata; Penis mit Chitinscheide. Samentaschen im 10 Segm. Spermatophoren in den Samentaschen."

The present, therefore, differs from other species of the genus in the absence of a subintestinal vessel; in the presence of only one pair of hearts; in the absence of a terminal dilatation of the nephridial canal; and apparently in the ventral position of the dorsal vessel. But having regard to the rest of the anatomy, especially the characters of the setæ, of the genital organs, including the chitinous penis-sheath, and the cutaneous blood-plexus, there can be little doubt that it should be included in the genus.

Of the species within the genus, it resembles most closely *L. hoffmeisteri*, Clap., with which it appears to be very similar in its general appearance, size, number of segments, number of setæ per bundle, characters of brain and pharynx. None of these, however, are particularly distinctive; more striking are the investment of the anterior nephridia with bladder-like (blasenförmigen) cells, and the number of cutaneous twigs per segment. The general proportions of the penis-sheath are much the same; but the curve of the tube and the character of its mouth differ considerably (*cf.* VEJDOVSKY, 11, pl. xi. fig. 4). The mode of origin of the cutaneous capillaries, the fact that they do not end blindly in the present species, and that the dorsal and ventral vessels are, as usual, on opposite sides of the alimentary tube in *L. hoffmeisteri* (*cf.* VEJDOVSKY, *op. cit.*, pl. viii. figs. 16, 17), on the same side in this species, as well as, presumably, the points given above wherein this species differs from all others of the genus, also serve to distinguish them.

I propose the following diagnosis:—Colour pale reddish brown; length 40–75 mm.; segments about 110, double annulation in the first few; prostomium bluntly conical; clitellum xi–$\frac{1}{2}$ xii. Setæ 6–8 per bundle anteriorly, 3–4 posteriorly. A single pair of hearts in viii; dorsal vessel is ventral in position, to left of ventral vessel, from posterior end as far as genital segments; no subintestinal vessel. Nephridia in vii and viii invested with large pyriform peritoneal cells; no nephridia in ix–xii; not present in every segment from xiii onwards. Cerebral ganglion deeply cleft in front, slightly so behind. Chitinous penis-sheath 10–11 times as long as its widest part is broad, curved forwards at its lower end, where its anterior lip is strongly reflexed upwards.

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EXPLANATION OF FIGURES.

(Figs. 2, 3, 4, 5, 6, 10, 11, 16 drawn by camera lucida.)

Fig. 1. Single- and double-pointed setæ of *Branchiura sowerbyi*. × 450.

Fig. 2. Section through anterior part of *Branchiura sowerbyi*; septum $\frac{4}{5}$, which is bulged backwards, is cut through in the upper part of the figure. Blood-vessels shaded. × 154.

circ. m., circular muscular coat; *ep.*, surface epithelium; *in. circ. m.*, inner circular muscular coat; *l. l.*, lateral line cells; *long. m.*, longitudinal muscular coat; *m. set.*, dorso-ventral muscular bundle between setal sacs of same side; *œs.*, œsophagus; *p.*, peritoneal cells ("septal gland"); *s.*, ventral setæ of segment iv; *sept.*, septum $\frac{4}{5}$, consisting of decussating muscular fibres; *v. n. c.*, ventral nerve cord, with giant fibre dorsally.

Fig. 3. Section through gill region of the same; the anterior face of the section is towards the observer, *i.e.* left and right are reversed. The longitudinal muscular layer is here broken up, leaving visible a fibrillar groundwork with a few nuclei. × 250.

c., a group of cells connected with the ventral vessel, prominent in this particular section; *chl.*, chloragogen cells; *d. v.*, dorsal vessel, showing a connection with the enteric plexus; *g. f.*, giant fibre, to the left of which, in the figure, are seen a row of similar but smaller fibres; *int.*, intestine; *plex.*, part of intestinal blood-plexus; *v. v.*, ventral vessel. Other references as above.

Fig. 4. Cells of the lateral line in the posterior part of the same, in transverse section. The lateral line is here discontinuous; where present the cells project some distance inwards and spread out. × 560.

cut., cuticle; *int. ep.*, intestinal epithelium; *int. m.*, intestinal muscular coat; *per.*, peritoneal cells round intestine. Other references as above.

Fig. 5. Transverse section of the same near the extreme posterior end, showing the transverse muscular partition, the absence of a definite body-cavity in the ventral part of the section, and the relatively large size of the ventral nerve cord. × 250.

m., bands of muscle fibres, in various directions; *transv.*, transverse band (the cœlomic partition); *x.*, groundwork of fibrillæ and nuclei. Other references as before.

Fig. 6. Section along a ventral gill, to show epithelial covering, continuation of circular muscular layer of body on the gill, gill cavity, and cells contained within it. × 250.

a., branching cells within gill cavity; *b. v.*, blood-vessel; *cav.*, gill cavity; *m.*, muscular strands coming down from the transverse partition. Other references as before.

Fig. 7. *Branchiura sowerbyi*; blood-vessels to the gills; from a sketch from life, from the right side; the dorsal vessel is therefore behind the intestine as seen by the observer. Of the two cutaneous branches shown, the one on the right is coming towards the observer and is superficial, the one on the left is on the deep surface.

cut., cutaneous branch; *d. g.*, dorsal gill; *d. v.*, dorsal vessel; *int.*, intestine; *v. g.*, ventral gill; *v. v.*, ventral vessel.

Fig. 8. Transverse section through gill region of *Branchiura sowerbyi*; diagrammatic, constructed from sections to show the course of a number of vascular branches, which are not on the same level. The dorsal vessel *d. v.* gives off a dorsally directed branch *d. d.* to the dorsal gill, and a ventrally directed branch *v. d.* to the ventral gill. The ventral vessel *v. v.* gives off a branch on the right side which bifurcates into a dorsal, *d. br. v.*, and a ventral division, *v. br. v.*, going to the dorsal and ventral gills respectively. The ventral vessel also gives off a branch on the left side, *l. br. v.*

d. g., dorsal gill; *ep.*, surface epithelium; *int.*, intestine; *i. p.*, intestinal plexus; *l. m.*, longitudinal muscular layer (the circular layer is not separately represented); *v. g.*, ventral gill; *v. n. c.*, ventral nerve cord.

The section is seen from its anterior face; right and left are therefore reversed.

Fig. 9. Seta of *Limnodrilus socialis.* × 750.

Fig. 10. Part of transverse section through the fourth segment of *Limnodrilus socialis*, showing the lateral portion of the body-wall. × 250.

circ. m., circular muscular layer; *cut.*, cuticle; *ep.*, surface epithelium; *l. l.*, lateral line cells; *long. m.*, longitudinal muscular layer; *m. set.*, muscular bundle between setal sacs of the same side; *per.*, peritoneal cells; *s.*, setæ.

Fig. 11. Transverse section through sixth segment of the same. × 115.

chl., chloragogen cells; *d. v.*, dorsal vessel; *gl.*, gland-like masses of cells; *œs.*, œsophagus with ventral ridge projecting into lumen; *s. i. v.*, supra-intestinal vessel; *v. n. c.*, ventral nerve cord; *v. v.*, ventral vessel. Other references as above.

Fig. 12. Portion of vascular system of the same, from the right side; from a sketch from the living. The anterior and posterior parts of the ventral vessel are continuous by means of a fine channel; the transverse sinus is seen in ix, and a part of the contractile loop to the genital organs.

Fig. 13. Portion of vascular system of the same from above, showing the relations of dorsal and supra-intestinal vessels, the hearts, the transverse sinus and its associated plexus; from a sketch from the living.

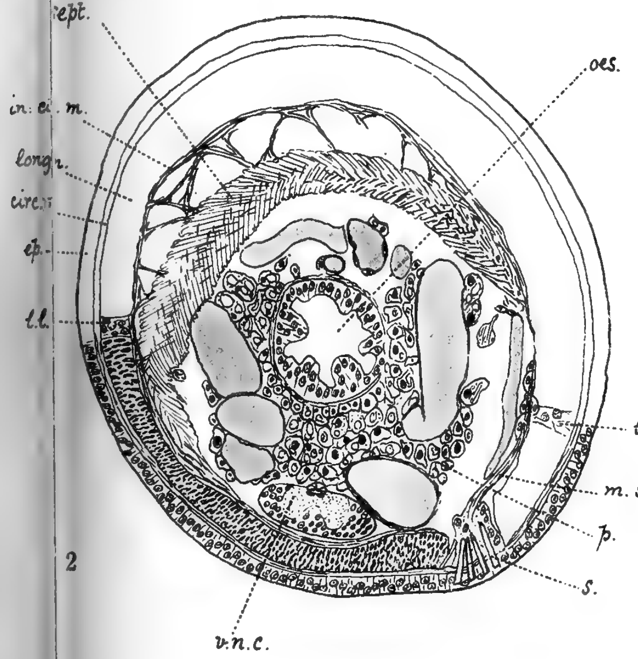
Fig. 14. Blood-vessels on the left side of the intestine of the same; from a sketch from the living; the anterior end is towards the left. The dorsal vessel is shown below the intestine.

Fig. 15. Outline of cerebral ganglion of the same.

Fig. 16. Longitudinal section through lower part of penis tube and sheath of the same, to show the shape of the lower end of the chitinous sheath and its relations. × 250.

circ. m., circular muscular layer; *ep.*, surface epithelium; *long. m.*, longitudinal muscular layer; *per.*, peritoneal cells; *s.*, penis sheath; *t.*, penis tube; *v. def.*, vas deferens; *x.*, shelf-like projection into lower end of penis sheath.

STEPHENSON: BRANCHIURA SOWERBYI, BEDDARD.—PLATE I.



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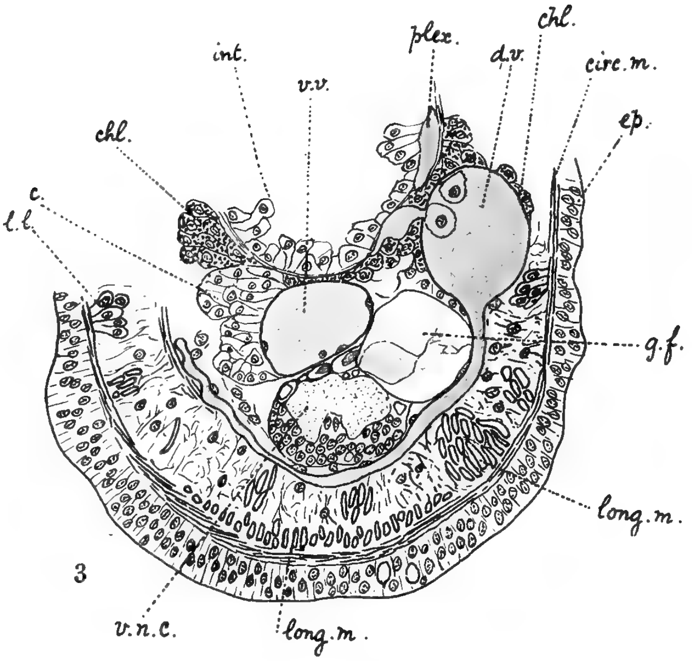

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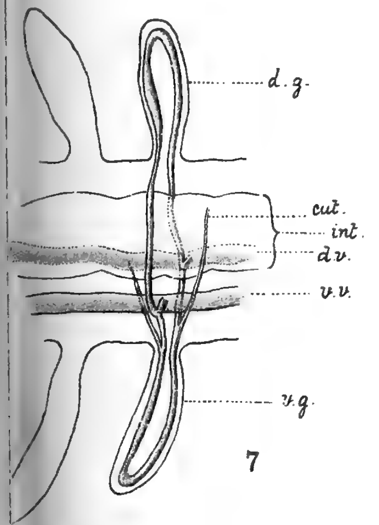

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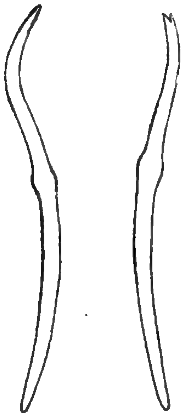

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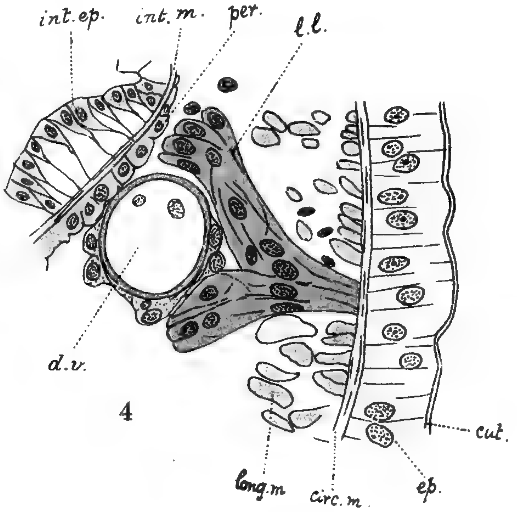

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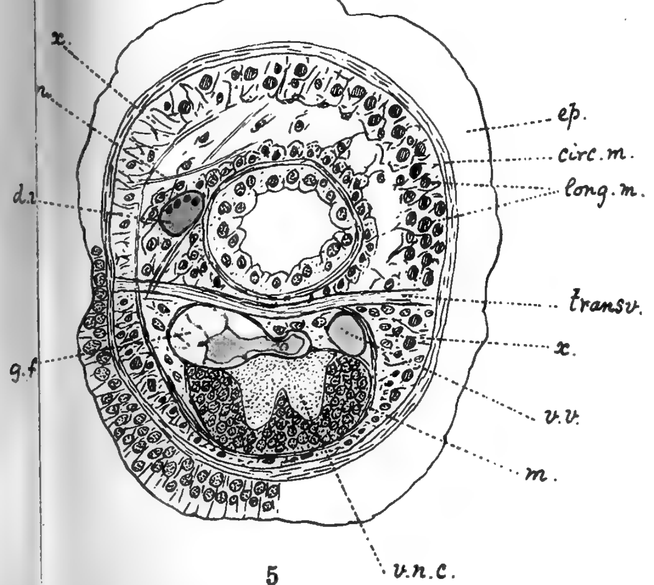

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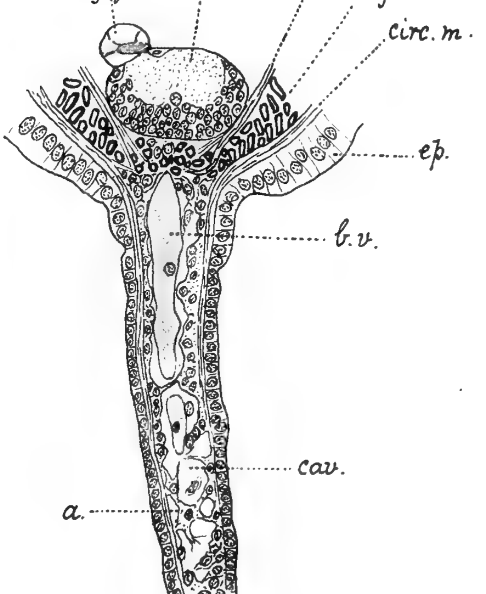

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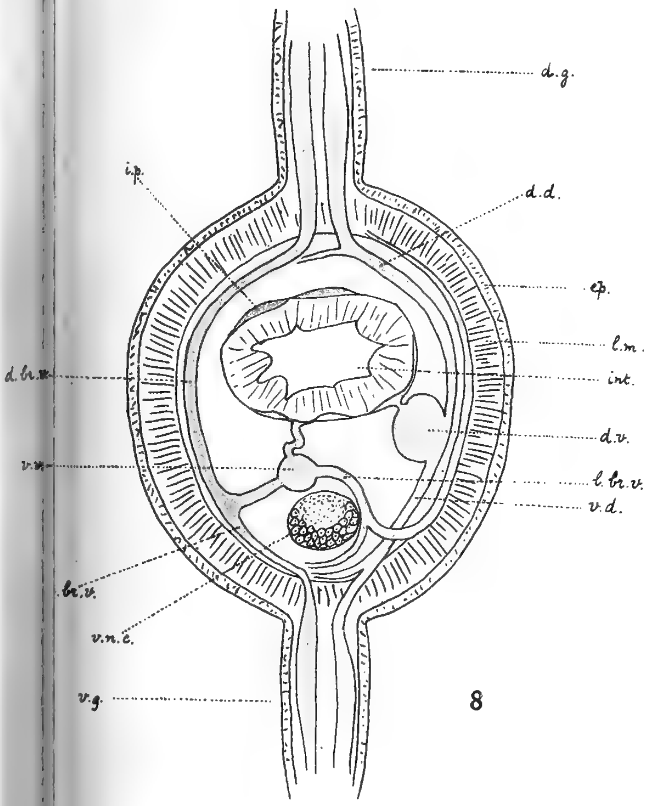
McFarlane & Erskine, Edinr.

BRITISH MUSEUM NATURAL HISTORY

STEPHENSON: BRANCHIURA SOWERBYI, BEDDARD.—PLATE II.



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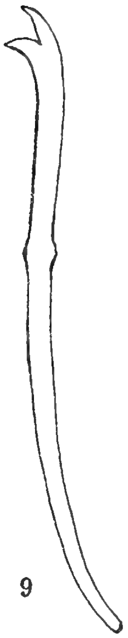

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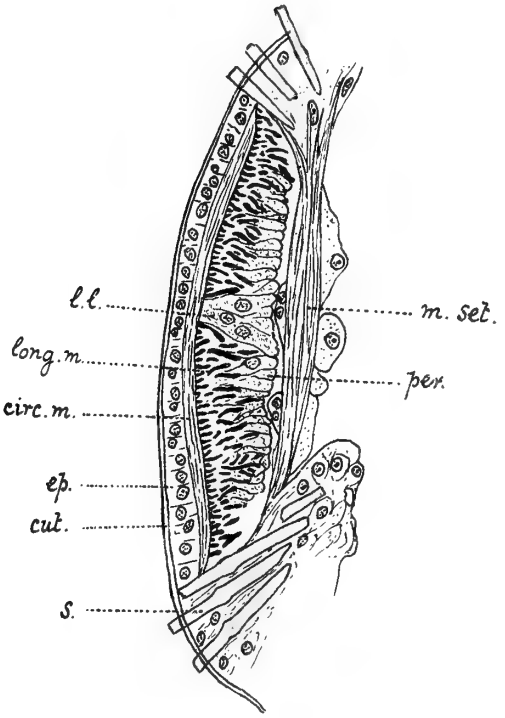

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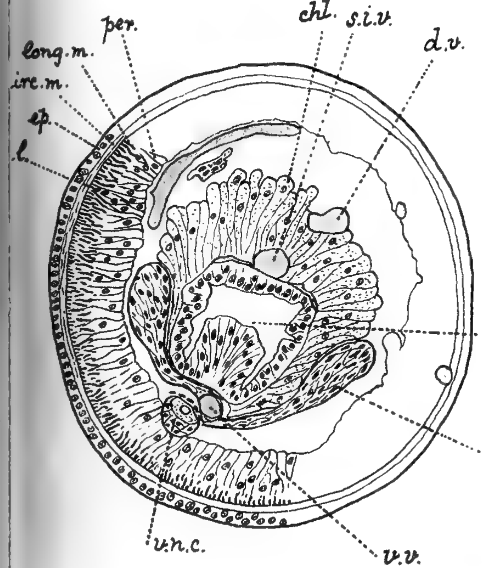

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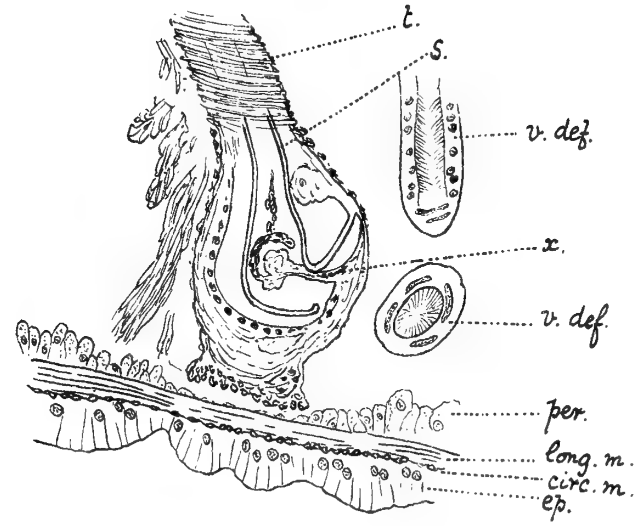

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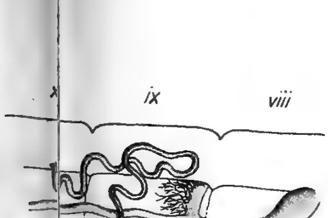

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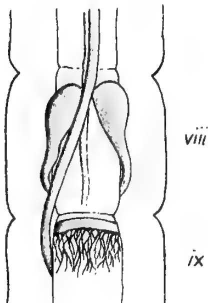

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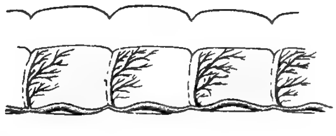

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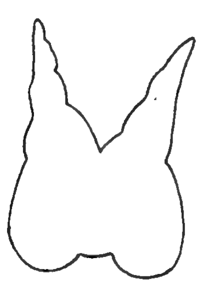

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McFarlane & Erskine, Edinr.

XVI.—The Tunicata of the Scottish National Antarctic Expedition, 1902-1904.

By **W. A. Herdman**, D.Sc., F.R.S., Professor of Zoology in the University of Liverpool. (With One Plate.)

(MS. received January 8, 1912. Read February 19, 1912. Issued separately July 3, 1912.)

So far as regards number of individuals, and their size, this is one of the largest collections of Ascidians brought back in recent years from Antarctic seas. It contains almost exactly the same number of species of ASCIDIACEA (*Ascidiæ Simplices* + *Ascidiæ Compositæ*) as the *Discovery* collection—viz. fifteen or sixteen—but whereas in the latter collection nearly all the species were represented by single specimens, in the *Scotia* collection most species can show long series of individuals—in all there are about two hundred specimens, as against the thirty-three brought home by the *Discovery*.

The sixteen species in the present collection represent almost as many genera, and half a dozen families. The systematic arrangement is as follows:—

ASCIDIACEA.

Family MOLGULIDÆ.

Paramolgula gregaria (Lesson).
Paramolgula horrida (Herdman).

Family CYNTHIIDÆ.

Boltenia legumen, Lesson.
Fungulus antarcticus, n. sp.
Halocynthia setosa, Sluiter.

Family STYELIDÆ.

Styela lactea, Herdman.
Styela paessleri, Michaelsen.
Synstyela incrustans, Herdman.
Polyzoa opuntia, Lesson.
Goodsiria placenta, Herdman.

Family ASCIDIIDÆ.

Ascidia charcoti, Sluiter.

Family DISTOMIDÆ.

Colella pedunculata (Q. and G.).
Holozoa cylindrica, Lesson.

Family POLYCLINIDÆ.

Polyclinum complanatum, Herdman.
Amaroucium distomoides, Herdman.
Amaroucium sp.

It is interesting to notice how greatly some of these recent collections from the far South differ from one another in the species represented. The following table—which gives only the sixteen species in the *Scotia* collection—shows that only one form (*Halocynthia setosa*) from that collection was also taken by the *Discovery*, whereas ten species were taken by the *Challenger*, eight by the Hamburg Magellanic and South Georgia Expedition, and five by the French Antarctic Expedition under Charcot. This can be explained to some extent, at least, by the precise localities visited: the *Scotia*, the *Challenger*, and the Hamburg collections were largely made in the Magellan and Falklands neighbourhood, while the other three collections were mainly from farther south.

"SCOTIA" SPECIES.	"DISCOVERY."	"CHALLENGER."	CHARCOT.	"SOUTHERN CROSS."	MAGELLAN AND SOUTH GEORGIA.
Paramolgula horrida, .		×			×
,, *gregaria*, .		×			×
Boltenia legumen, . .		×			×
Fungulus antarcticus, .	("Scotia" only)				
Halocynthia setosa, . .	×		×		
Styela lactea, . . .		×	×	×	
,, *paessleri*, . .					×
Synstyela incrustans .		×			×
Polyzoa opuntia, . .		×			×
Goodsiria placenta, . .		×			
Ascidia charcoti, . .			×		
Colella pedunculata, .		×	×		×
Holozoa cylindrica, . .		×	×	×	×
Polyclinum complanatum, *Amaroucium distomoides*, *Amaroucium* sp., . .	In collection of Australian Museum, Sydney.				

Although only one of the *Scotia* Tunicata requires to be described as new to science, several of the species are of considerable interest, and most of them add something to our knowledge either in the characters and variation of the species or in distribution. The one new species (*Fungulus antarcticus*) is a very remarkable form belonging to the deep-sea genus *Fungulus*, known only from a single species obtained during the *Challenger* Expedition between the Cape of Good Hope and Kerguelen Island.

This collection shows again what I remarked upon more than twenty years ago in the case of the *Challenger* collection, that the Ascidian fauna of the far South is characterised by the abundance and the large size of the individuals of a comparatively few species. *Halocynthia setosa* and *Holozoa cylindrica* are the two largest species, the one simple and the other compound, and both are represented by a large number of specimens. I have, however, written on this matter, and also on the number of Antarctic as compared with Arctic species, so recently in my report* upon the *Discovery* collection that these matters need not be discussed further here.

Family MOLGULIDÆ.

Paramolgula gregaria (Lesson). (Plate, fig. 9.)

Cynthia gregaria, Lesson, *Cent. Zool.*, p. 157.
Molgula gregaria, Herdman, *Challenger* Report on Tunicata, Part I., p. 73.

Locality.—Station 118, on hulks, Stanley Harbour, Falkland Islands, January 16, 1903.

There are over forty specimens of this species in the collection, ranging in size from 2 × 1·5 cm. up to 6·5 × 5 cm. The majority are about 4 cm. in diameter. They have

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* *National Antarctic Expedition: Natural History*, vol. v., "Tunicata," 1910.

the characteristic smooth test and translucent grey tint, and they also agree closely in internal details with the *Challenger* specimens from shallow water off the Falkland Islands.

MICHAELSEN has suggested that this species and *Paramolgula gigantea* (Cunningham) are the same. No doubt they are related forms; both belong to the restricted genus *Paramolgula*, having only broad, ribbon-like longitudinal bars but no true folds in the branchial sac (a fact I overlooked in drawing up my "Revised Classification of the Tunicata" in 1891, as MICHAELSEN has pointed out), but I do not consider them as identical. In addition to differences in the external appearance—the shape and the condition of the test—the branchial sacs are not alike in detail, and the dorsal tubercles differ widely. I give here a figure of the dorsal tubercle (Plate, fig. 9) of *P. gregaria* from the *Scotia* collection for comparison with that of *P. gigantea* figured in the *Challenger* Report.

LESSON figures his species with five lobes round each aperture, but that is no doubt an error. The branchial aperture has six and the atrial four lobes.

Paramolgula horrida (Herdman) (?). (Plate, figs. 10 and 11.)

Locality.—Station 118, on hulks, Stanley Harbour, Falkland Islands.

I have very little doubt that this single large specimen (measuring 7·5 cm. in length and 5·5 cm. in breadth) belongs to the same species as the specimen from "off the Falkland Islands, 5–12 fathoms," which I described in the *Challenger* Report as *Molgula horrida.* They both fall within the more modern genus *Paramolgula*, separated off from *Molgula* by TRAUSTEDT because of the absence of true folds in the branchial sac. As the *Challenger* description was drawn from a single specimen, and as this *Scotia* specimen differs a little in detail, it may be well, in the interests of a fuller knowledge of the species, to add a few of the characteristics of the individual before me.

The shape is irregularly ovate, and flattened, and the colour is a very dark brown. The other external characters can be seen from the figure (Plate, fig. 10). The Test is leathery and rough on the surface. It is thin but tough, and dark but smooth and glistening on the inner surface. The Mantle is dark brown and opaque. It is thick, but soft and not muscular, or at least the muscles do not form obvious bands.

The Branchial Sac has on each side seven wide longitudinal vessels which look like narrow folds. Between the distant wider transverse vessels, narrower intermediate ones branch in all directions in a dendritic manner, so as to form rounded and oval and variously shaped meshes in which the stigmata lie. The stigmata are also rather irregular in arrangement, being in some parts in spirals and in other places side by side in rows (see fig. 11).

The Tentacles are of different sizes, there being eight larger much branched, with some smaller ones between.

The Dorsal Tubercle has its long axis antero-posterior and its opening at the side. The horns form two close spirals, both coiled inwards. Whether *P. patagonica* of MICHAELSEN is also the same species as *P. horrida* is very doubtful. I am inclined to regard it as distinct.

Family CYNTHIIDÆ.

Boltenia legumen, Lesson.

Locality.—Station 118, on hulks, Stanley Harbour, Falkland Islands, about twenty specimens; and eight specimens from 6 fathoms, Port Stanley, February 2, 1904.

There are over two dozen specimens of this species in the collection, and they range in size from 1·5 to 7 cm. in greatest length of body—about the same range as in the case of those in the *Challenger* collection. All of these specimens of *B. legumen* belong to the "forma typica" of MICHAELSEN's system * of subdivision of this species, and agree in character with the *Challenger* specimens from the same locality. In some cases the little bristles on the surface of the test are more abundant and more prominent than in others, but there are all gradations between. This is evidently a very common Ascidian in shallow water at the Falklands.

Fungulus antarcticus, n. sp. (Plate, figs. 15 to 18.)

A single specimen which clearly belongs to the rare and interesting genus *Fungulus* was obtained at Station 301 from a depth of 2485 fathoms, on March 13, 1903, at lat. 64° 48′ S., long. 44° 26′ W.; temp. 31°·02. The genus was established in 1882 for another solitary individual found in the Southern Ocean during the *Challenger* Expedition, at Station 147, between the Cape of Good Hope and Kerguelen Island, lat. 46° 46′ S., long. 45° 31′ E.; depth, 1600 fathoms, on a bottom of Globigerina ooze. The two localities are thus nearly 3000 miles apart, but agree in that both are in the far south and in very deep water.

The *Scotia* specimen, although closely related to the *Challenger Fungulus cinereus*, Herdman, cannot be placed in the same species. The general appearance and anatomy, and especially the remarkable structure of the branchial sac, are the same; but the relation of the peduncle to the apertures and the details of structure are different in the two forms. The description of *F. antarcticus* is as follows:—

The body is club-shaped (fig. 15), like a rounded knob about 1·5 cm. in diameter on the summit of a short, stout peduncle, which is also about 1·5 cm. in length and from 4 to 6 mm. in thickness. The peduncle is continuous with the ventral edge of the body, while the dorsal edge projects markedly. The surface is smooth and the

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* "Die Holosomen Ascidien des magalhaenisch-südgeorgischen Gebietes," *Zoologica*, Bd. xii., Heft 31, Stuttgart, 1900, p. 109.

colour pale yellowish grey. The branchial aperture is a little way along the ventral edge of the anterior end, and appears to be bilabiate or elliptical rather than lobed. The atrial aperture is in the middle of the dorsal surface, and is a square or four-lobed opening. In *F. cinereus*, the branchial aperture was described as triangular, and the atrial as bilabiate, but the figure of the former in the *Challenger* Report is not very different from the figure now given (fig. 16) from the *Scotia* specimen.

The Test is thin and membranous, but tough. Under the microscope it is seen to be finely roughened all over the outer surface. In minute structure the test agrees with that of *F. cinereus* as described in the *Challenger* Report. The Mantle is very thin and inconspicuous, but muscular. It is penetrated by numerous, very fine, closely placed muscle bundles which, in the tubular extension of the mantle which occupies the hollow peduncle, run longitudinally parallel to one another.

The Branchial Sac is remarkably delicate, and is, in fact, merely a very loose wide-meshed net with folds at intervals where the longitudinally-running vessels are crowded together (fig. 17). The transverse vessels are of two sizes, occurring alternately. The looseness of the branchial sac and the minute undulations in practically all the muscle bundles of the mantle give the impression that when alive and filled with sea-water the animal had the power of expanding to a considerably larger size than it now shows. Possibly the test when alive was of a gelatinous consistency and capable of being dilated.

There are no spicules in the vessels of the branchial sac. The endostyle is narrow but conspicuous; there are no spicules in its wall. The branchial tentacles are few and only slightly branched. The alimentary canal is relatively small, and is confined to the posterior end of the left side close to the top of the peduncle (fig. 18). The stomach wall has a number of close-set longitudinal folds.

The gonads are one on each side, rather long and irregular, with the narrower end pointing to the atrial aperture (fig. 18).

This new species differs from *Fungulus cinereus*, Herdman, in the shape and proportions of the body (see figures) and in the much paler colour of the test; in the details of position and shape of the branchial and atrial apertures; in having the transverse vessels of the branchial sac distinctly of two sizes; in having a well-marked stomach with longitudinal folds; and in the length and shape of the gonads.

Halocynthia setosa, Sluiter.

This very striking and characteristic species was obtained by the *Scotia* in considerable quantity at the South Orkneys. It was originally described by SLUITER * from two specimens obtained by the French Antarctic Expedition under Dr JEAN CHARCOT at "Ile Booth Wandel, 40 mètres"; but as the figures in the report on the Charcot Expedition did not seem to me to be characteristic, I gave a supplementary description, with figures,

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* *Bull. Mus. Hist. Nat. Paris*, 1905, No. 6, p. 472; and *Expéd. Antarct. Franç. (Charcot)*, "Tuniciers," p. 40.

of the species in my report upon the Tunicata of the *Discovery* Expedition.[*] The *Discovery* obtained in all five specimens from the east end of the Barrier and the neighbourhood of the winter quarters in McMurdo Bay, in 10–20 fathoms.

The more abundant material obtained by the *Scotia* gives us still further information in regard to the characteristics and variation of the species. Some of the *Scotia* specimens, measuring up to 11 × 7 × 5 cm., are the largest yet obtained; and some of them show a short peduncle at the place of attachment, a feature not previously observed. The characteristic spines on the test reach in some of these larger specimens to a length of 21 mm. and a breadth of about 1 mm. at the base. In some of these specimens the musculature of the mantle is remarkably strong, and consists externally of circular siphonal sphincters, beyond which is an oval sphincter, of numerous fibres, enclosing both siphons, while more internally radial muscles formed of exceedingly stout and strong fibres run outwards from the base of the siphons. Connective tissue permeated by fine fibres covers and unites all these various muscle bundles.

Of the six folds on each side of the branchial sac, the largest is the one next to the dorsal lamina on each side, and the smallest is generally the third counting from the dorsal to the ventral edge. The transverse vessels are of four different sizes, and the stigmata are from nine to twelve in a mesh. One dorsal tubercle examined measured 4·8 mm. from side to side and 3·2 mm. antero-posteriorly.

The nerve ganglion is extraordinarily narrow and elongated, and may reach 9·5 mm. in length, with two nerves diverging from each end which can be traced with the eye round the sphincters of both siphons. The subneural gland is in the form of a thin layer over the ganglion.

A strong band of muscle fibres lies under the dorsal lamina and extends from the mantle into the wall of the branchial sac near the posterior end of the nerve ganglion.

Two of the specimens had Amphipods in the branchial sac. The specimens were obtained as follows:—

I. Station 325,[†] 9–10 fathoms, Scotia Bay, South Orkneys, July 1903.
    (1) 9 × 6 × 6 cm. (on a short peduncle).
    (2) 9·5 × 6·5 × 3 cm. (very short peduncle).
    (3) 8 × 5·5 × 4 cm.
II. Station 325, 9–10 fathoms, June 1903; temp. 29° F.
    (1) 4 × 4·5 × 2·5 cm. (test only).
    (2) 8 × 5·5 × 4 cm. (with a smaller one attached).
III. Station 325, 9–10 fathoms, August 1903; temp. 29° F.
    (1) 6 × 5 × 4·5 cm. (also four empty tests).
IV. Station 325, 9–10 fathoms, May 1903; temp. about 28° F.
    (1) 7·4 × 5 × 5 cm.
    (2) 6 × 4 × 4 cm. (also four empty tests).

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[*] *Report National Antarctic Exped.: Nat. Hist.*, vol. v., "Tunicata," London, 1910.

[†] The whole of Scotia Bay is termed Station 325; consequently, depths vary.

V. Station 325, 9–15 fathoms, April 1903; temp. 28° to 29° F.

About a dozen specimens ranging from 11 × 7 × 5 cm. down to 5·5 × 5 × 3·2 cm. (one empty test).

VI. Station 325, 9–15 fathoms, December 26, 1903; temp. 31°·4 F.

(1) 4½ × 3 × 3 cm.

Family Styelidæ.

Styela lactea, Herdman. (Plate, figs. 1–8.)

Styela lactea, Herdman, *Challenger* Report on Tunicata, Part I., p. 156.
Styela flexibilis, Sluiter, *Charcot Exped.*, "Tuniciers," p. 36.
(?) *Cynthia verrucosa*, Lesson, *Cent. Zool.*, p. 151.

Localities.—(1) Station 118, on hulks, Stanley Harbour, Falkland Islands.

(2) Scotia Bay, South Orkneys, Station 325, February 2, 1904.

(3) Attached to *Holozoa cylindrica*, thrown up on beach, Scotia Bay, January 17, 1904.

(4) Station 118, shore pools, Port Stanley, January 1903. (Two elongated specimens.)

The specimens from the Falkland Islands are about twenty in number, ranging from little globular spiky balls (see figs. 3, 4) of 1 cm. in diameter to irregular barrel-shaped masses (fig. 1) of 8 cm. in length and 5 to 6 cm. in breadth. The specimens from Scotia Bay attached to the compound Ascidian *Holozoa cylindrica*, Lesson (= *Distaplia ignota*, Herdman), are small and globular, bristling with short pointed spikes, and of a pure white colour (fig. 2); while the remaining specimen from Scotia Bay (February 2) is much larger, roughly cylindrical in shape, less spiny, and of a duller colour (fig. 1). Still, all transitions in shape and appearance can be found between the extreme forms, so there can be no doubt that all belong to the one species, *S. lactea*, found by the *Challenger* Expedition at Kerguelen Island, and by the *Southern Cross* Antarctic Expedition at Cape Adare.

The largest *Scotia* specimens correspond closely with Sluiter's *S. flexibilis*, found during the Charcot Expedition at "Ile Booth Wandel." That species agrees in internal characters with *S. lactea* so closely that I have no doubt that the two are the same, and that *S. flexibilis* must be regarded as a synonym of *S. lactea*. It is, I think, possible also that the *Cynthia verrucosa* of Lesson, found attached to Fucus on the shores of Malonines Islands, Antarctic, which is figured as having five lobes round each aperture, is really this same species. If so, the number of lobes shown by Lesson is, of course, erroneous.

The following additional characters, taken from the larger *Scotia* specimens, may be useful to compare with the descriptions of other specimens:—

Size 7 × 4 × 3·5 cm. Barrel-shaped, attached by flat area at posterior end about 3·5 cm. in diameter. Colour pale creamy white with a pinkish tinge in places. Test thin, leathery, raised at intervals to form little pointed tubercles, the larger of which are echinated (fig. 5). Mantle muscular, with regular circular and longitudinal bands. Branchial Sac with four large folds on each side. There are six to nine bars on a fold, and four in the interspace. Dorsal lamina a broad plain membrane. There are about thirty very long simple tentacles and some intermediate smaller ones. The dorsal tubercle has both horns coiled inwards to form short spirals (fig. 8). There are two or three long gonads on each side, and many endocarps. Fig. 7 shows the arrangement of the alimentary canal.

In the smaller, more globular specimens the conical spiny tubercles on the test are relatively more numerous and more closely and regularly placed (see figs. 2, 3, 4, and 6). The *Challenger* specimen figured, from Kerguelen, was intermediate in size to the larger and the smaller *Scotia* examples, and was smoother in character of test.

Styela paessleri, Michaelsen. (Plate, figs. 12 to 14.)

This species was described by MICHAELSEN in 1900 from specimens obtained in the Straits of Magellan. The *Scotia* specimens from the Falkland Islands seem to be rather larger on the whole, but agree in essential characters.

The following description, from the *Scotia* material, may be useful:—There are about twenty specimens, varying in size from 1 cm. to 3 cm. in length by 1·5 cm. in average breadth, obtained from Station 118, at the Falklands, depth 6 fathoms; and a couple from Port Stanley, February 2, 1904, 6 fathoms.

The colour varies from a creamy white to a yellowish brown, and the surface of the test is in most places closely wrinkled. The branchial sac has four folds on each side, the largest being those adjacent to the dorsal lamina, with ten bars each, while the others have usually six bars. Fig. 12 gives the plan of both sides of the branchial sac as seen in section, with the number of bars and of rows of stigmata shown by the figures. The folds have from five to ten bars, and there are from two to five (usually four) bars in the spaces between. These numbers agree fairly well with those given by MICHAELSEN. The transverse vessels are of three sizes arranged with regularity: 1—3—2—3—1, and having a narrow horizontal membrane in addition crossing the meshes (fig. 13). Most of the meshes are square, with five to seven stigmata in each. The extreme dorsal and ventral meshes are more elongated transversely, and contain a greater number of stigmata.

The dorsal tubercle is of curious form (fig. 14), a simple crescent with the horns anterior and having a globular excrescence in the concavity. The dorsal lamina is a plain membrane. The tentacles are crowded and number about a hundred. They are of two sizes, roughly fifty of each. MICHAELSEN records only sixty tentacles, but as the specimens he examined were smaller than ours, the difference need not be regarded as important.

Although some of the above characters do not agree precisely with those given by MICHAELSEN, still the differences are not, I think, greater than what may reasonably be ascribed to individual variation within the limits of a species. The dorsal tubercle is perhaps the feature that shows most divergence, but MICHAELSEN himself remarks in the original description that it is probable that other specimens might show a different form of tubercle.

Polyzoa opuntia, Lesson, subspecies *coccinea*, Cunningham.

Goodsiria coccinea, Cunningham, *Trans. Linn. Soc. Lond.*, xxvii.

Several specimens of this common species were obtained at the Falklands:—

(1) Station 349, shore pools, Cape Pembroke, January 1903 to January 1904. One large, lobed colony and a couple of small ones. This is part of collection made on behalf of *Scotia* by Mr PEARSON, Cape Pembroke lighthouse-keeper, during twelve months.
(2) Station 118, rock cod trap, Stanley Harbour, 3¼ fathoms, January 1903. One elongated colony, about 26 cm. in length.

Goodsiria (*Gynandrocarpa*) *placenta*, Herdman.

Several specimens that seem to agree closely with this South African species were obtained at the Falklands, as follows:—

(1) Station 118, Stanley Harbour, January 7, 1903. One small colony.
(2) Station 118, rock cod trap, Stanley Harbour, 3¼ fathoms, January 1903. Part of a large colony which probably measured 10 or 12 cm. across.
(3) Station 118, Port Stanley, 6 fathoms, February 1904. One colony measuring about 10 by 5 cm.

Synstyela incrustans, Herdman.

(?) *Allæocarpa zschaui* (Michaelsen).

Locality.—Station 118, on hulks, Stanley Harbour, Falkland Islands.

There are about a dozen colonies of this species, ranging in size from 1 or 2 cm. up to 5 or 6 cm. in diameter. Most of them were adhering in masses along with the larger specimens of *Paramolgula gregaria*.

In detailed characters these specimens agree well with the *Challenger* specimens of *Synstyela incrustans* obtained in the Straits of Magellan, but they also agree with MICHAELSEN's description of *Allæocarpa zschaui* from South Georgia; and when mature, the Ascidiozooids show the male unisexual polycarps on the left, and the female on the right-hand side of the mantle, which is a character of MICHAELSEN's proposed generic division *Allæocarpa*. As, however, he names my species *Synstyela incrustans* as the type form of *Allæocarpa*, and as he apparently does not in his system retain *Synstyela* as a genus, but substitutes the name *Allæocarpa* for it, I must point out that *Synstyela*, Giard, has the prior claim and must be retained as the name of the genus, even when, as happens to be the case, our knowledge of the internal characters has been increased and the definition added to since the genus was originally created. Consequently I must regard MICHAELSEN'S *Allæocarpa zschaui* as a *Synstyela*, and furthermore I find myself unable to distinguish it as a species from *S. incrustans* of the *Challenger* Report. In MICHAELSEN'S "Revision der compositen Styeliden oder Polyzoinen,"* where both species are described, in his table on p. 73 he distinguishes them by the proportions of the oviduct and the number of internal longitudinal bars in the branchial sac, as follows:—

S. zschaui having the oviduct broader than long, and having sixteen to seventeen bars on each side; and

S. incrustans having the oviduct longer than broad, and having twelve to fourteen bars on each side of the sac.

Now, in the first place, with a soft, easily deformed structure like the oviduct it is almost impossible to be sure of the true proportions; and secondly, I find them varying considerably in my specimens; so that I cannot say they agree more in this character with the one species than with the other. Then as to the number of longitudinal bars, on dissecting out and mounting a branchial sac from a *Scotia* specimen I find the number of bars to be fifteen on each side. According to MICHAELSEN, if it had sixteen the species would be *zschaui*, and if it had fourteen it would be *incrustans*. Under these circumstances, and as I find the specimens before me agree equally well with the descriptions of these two species, I think there can be little doubt but that *A. zschaui*, Michaelsen, is a synonym of *Synstyela incrustans*, Herdman.

Diandrocarpa monocarpa (Sluiter) is certainly not the same species as *Synstyela incrustans*, although it is probably a *Synstyela*. The number of longitudinal bars in the branchial sac is very much smaller than in the present species.

Family ASCIDIIDÆ.

Ascidia charcoti, Sluiter.

Locality.—Station 325, in shore pool, Scotia Bay, South Orkneys, February 2, 1904.

The single large *Ascidia* in the collection clearly belongs to SLUITER'S *A. charcoti*, a species found by the Charcot Expedition to be abundant at "Ile Booth Wandel." The *Scotia* specimen measures 8·5 × 5·5 × 2 cm., and was attached by a small area in the middle of the left side. The branchial aperture has only seven lobes, a curious little detail in which it agrees with SLUITER'S description. The atrial has the usual six lobes characteristic of the genus. The test reaches a thickness of 2 to 3 mm., but has not the red colour mentioned by SLUITER; and the mantle is unusually thick and spongy

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* *Mitteilungen aus dem Naturhistor. Museum*, xxi., Hamburg, 1904.

for an *Ascidia*. The branchial sac is also thick, and both mantle and branchial sac are of a distinctly pinkish colour which may be the remains of the orange-red that SLUITER records. There are twelve moderate-sized tentacles, and the horse-shoe shaped dorsal tubercle is very large, reaching up to the base of the tentacles. It seems larger than in SLUITER's specimens, in which, however, the dorsal tubercle is recorded as being rather variable.

SLUITER states that no teeth are present on the dorsal lamina; but I find that in the *Scotia* specimen the dorsal lamina has marked denticulations along its free edge, amounting in one part to short tentacular languets. But still I have no doubt that my specimen belongs to SLUITER's species, and that the dorsal lamina must be regarded as somewhat variable in character. The viscera on the left side of the body are unusually large and opaque.

Family DISTOMIDÆ.

Colella pedunculata (Quoy and Gaimard).

? *Sycozoa sigillinoides*, Lesson.
? *Colella tenuicaulis*, Herdman.
? *Colella umbellata*, Michaelsen.

One colony having a stalk bifurcated near the top and bearing two "heads" was found at Station 346 on Burdwood Bank, 56 fathoms, on December 1, 1903, and presents to some extent characters recalling all the species named above. In the branching of the peduncle it is like MICHAELSEN's *C. umbellata* from the Falklands; in the general appearance of the "head," however, it is more like QUOY and GAIMARD's *C. pedunculata*, found by the *Challenger* at the Straits of Magellan, the Falkland Islands, Kerguelen, etc. The long slender stalk recalls the Australian *C. tenuicaulis*; and it is possible that LESSON's *Sycozoa sigillinoides* may be identical with one or more of these other named forms. Both the "heads" are, unfortunately, in the single colony in a very ragged condition—possibly dead when collected—so that the more minute characters of the Ascidiozooids cannot be determined.

Holozoa cylindrica, Lesson. (Plate, fig 2.)

———(?) *ignotus*, Herdman, *Challenger* Report, ii., 1886, p. 251.
Julinia australis, Calman, *Quart. J. Micr. Sci.*, 1894, p. 1.
Distaplia ignota, Herdman, *Report on "Southern Cross" Tunicata*, Brit. Mus., 1902, p. 197.
Holozoa cylindrica, Less.—Hartmeyer, in Bronn's *Tier-Reichs*, "Tunicata," 1909.

This large and apparently abundant Antarctic species was obtained by the *Scotia* Expedition at the following localities:—

I. Station 346, Burdwood Bank, 56 fathoms, December 1, 1903. Seventeen fragments from 10 to 30 cm. in length by 2 to 4 cm. in diameter. All in bad condition, soft and partly macerated, with many other animals, Hydroids, Polyzoa, etc., entangled in the irregular, ragged surface.

II. Station 325, Scotia Bay, April 1903. One specimen, 30 × 4 × 3 cm., bad condition.

III. Station 325, Scotia Bay, South Orkneys, December 6, 1903; temp. 29·8°; floating on surface. 80 cm. × 2 (tapering to 1) cm.

IV. Station 325, Scotia Bay, South Orkneys, December 26, 1903; temp. 30·7°.
  (1) 85 (incomplete) × 1·5 (tapering to 1) cm.
  (2) 75 cm. (incomplete) and two fragments.

V. Station 326A, Brown's Bay, South Orkneys, November 1903. Two specimens: (1) 55 × 2 to 3 cm; (2) 40 × 2 cm.

VI. Scotia Bay, South Orkneys, January 17, 1904; temp. 32·5°; thrown up on beach. One colony, 20 × 5 cm., with several *Styela lactea* attached; in bad condition; most of Ascidiozooids lost.

VII. Scotia Bay, South Orkneys, January 3, 1904; temp. 31·5°; thrown up on beach. Two very long specimens: (1) over 100 × 2 cm.; (2) over 150 × 2 cm.

VIII. Scotia Bay, South Orkneys, November 25, 1903; surface. Three small colonies, 20 to 30 × 1 to 1·5 cm.

IX. Scotia Bay, March 25, 1903. One small colony, 10 × 2 cm.; bad condition; most of Ascidiozooids gone.

Most of these specimens are, unfortunately, in very bad condition, and were probably dead or decomposing when collected. The *Challenger* specimens were in such a rotten condition that it was impossible to determine even the genus. But from the rather better material brought home by the *Southern Cross* Expedition I was able to determine that the *Challenger* specimens—evidently the same species—belonged to the genus *Distaplia.* What CALMAN described as *Julinia australis* in 1894 is again the same.

SLUITER, in his report on the Charcot Tunicata, thinks that "*Julinia*" may be recognised as an independent genus because of the elongated form of the colony; but *Distaplia clavata* (Sars), from Arctic seas, although it does not attain to such a length, has the same elongated form—and therefore it cannot be said that a *Distaplia* with this habit of growth is unknown.

The colony found floating on the surface in Scotia Bay, December 26, and measuring about 85 cm. in length, is the best preserved specimen in the collection, and I think the best preserved that I have seen in any collection brought back from the Antarctic. The colony, although soft, does not seem to be rotten. The Ascidiozooids are distinct and large and closely placed throughout its length. Their exposed ends measure about 2 mm. across, and are of an opaque pale yellow colour, in contrast to the translucent grey of the test in which they are embedded. Throughout the greater part of the colony the Ascidiozooids appear to be in long meandering lines, but here and there one comes upon a circular, elliptical, or more irregular group (fig. 2), reminding one of the arrangement in a *Botrylloides.* Both ends of the colony are incomplete, and at the upper end the Ascidiozooids appear to be dropping out of the test.

Some of the Ascidiozooids in this colony are the best preserved I have seen in all the various samples of this species that have passed through my hands, and their anatomical and histological characters agree in detail with the excellent account of "*Julinia*" given by CALMAN. In fact, I can agree with CALMAN in every respect save that of bestowing a new name on the genus. It is evident from his remarks that he recognised the close affinity to *Distaplia*, and the only mistake he made was in not referring the species to that genus.

I agree, however, with HARTMEYER* that it is practically certain that this form had a distinctive generic name applied to it at a still earlier date. The "*Holozoa cylindrica*" of LESSON (*Voyage* "*Coquille*," Zool., ii. p. 439; 1830) agrees in all the points that are mentioned in the brief description with our form. It is said to have a "holothuriform" body, cylindrical, with rounded ends, free and floating (which is apparently the condition in which our form is usually picked up), of mucous appearance, with a whitish fibrous centre composed of tubes coming from the ends of the animals (= Ascidiozooids). It was found "30 leagues from Terre-des-Etats," at the southern extremity of America. I notice that MICHAELSEN (*Hamburger magalhaensische Sammelreise*, "Tunicaten," 1907, p. 40) has also suggested with a (?) that LESSON's *Holozoa cylindrica* is the same as "*Julinia*" (or *Distaplia*) *ignota.*

Family POLYCLINIDÆ.

Polyclinum complanatum, Herdman (?).

The species was described† from a specimen obtained at Port Jackson, Australia. The *Scotia* material was taken at Station 483, at the entrance to Saldanha Bay, on May 21, 1904, from a depth of 25 fathoms. It consists of four fragments, cut probably from the same colony, the largest of which measures about 6 cm. by 2. The colony was apparently flattened, and had much the same shape and colour as the Australian one. The Ascidiozooids also have the same type of structure. The post-abdomen is rather longer than in the Australian specimens, but that is a matter that varies with the reproductive condition. The specimens are, however, so fragmentary, and there is so little that is distinctive, that I cannot be certain as to the identity of the species; but there is nothing in the microscopic details to negative the view that the Falkland Islands specimens belong to this Australian species.

Amaroucium distomoides, Herdman (?).

I refer one large colony and a few small fragments in the *Scotia* collection to this Australian species.‡ The original specimen came from Port Jackson; the *Scotia*

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* In the new edition of the "Tunicata" of BRONN'S *Tier-Reichs.*

† See HERDMAN, *Descriptive Catalogue of the Tunicata of the Australian Museum, Sydney, N.S.W.*, 1899, p. 81. On the plate (Pcl. I. figs. 9–12) it is referred to as "*Polyclinum depressum.*"

‡ See HERDMAN, *ibid.*, p. 75.

material is from Port William, Station 349, Falkland Islands, February 6 to 8, 1903, 6 fathoms. The large colony measures about 14 cm. by 3 cm., and is attached along the length of a Laminaria-like Alga. The test is dark greyish brown, and the small yellow Ascidiozooids show all over the surface as closely placed dots or streaks of a lighter colour. In further details this specimen agrees well with the description of the Australian one. One zooid was, however, noticed with an eight-lobed branchial aperture. The stomach has longitudinal folds. The stigmata are large. The dark colour of the test is due to dense crowding with small test-cells. The *Scotia* colony was evidently taken at the reproductive season, as it contains abundance of embryos in various stages of development up to the tailed larval stage ready to be set free.

Amaroucium sp. (?).

Some small colonies, a few millimetres to about 1 centimetre across, which were found attached to groups of *Styela paessleri* and other Ascidians from the Falkland Islands, belong to the genus *Amaroucium*, but may be only young colonies of some larger form such as *A. distomoides*, or *A. pallidulum* obtained by the *Challenger* Expedition at Port William.

It may be remarked in regard to the three last species of Compound Ascidians that they require re-examination in the living state. Many of the Compound Ascidians are scarcely determinable from the contracted and bleached specimens in preserved collections. It may well be that one or other of the above Polyclinids had in the living state a bright colour or some other characteristic appearance that is now wholly lost.

THALIACEA.

(MS. received March 13, 1912.)

Family Salpidæ.

The very large collections of Thaliacea, which were obtained at the South Orkneys and other Antarctic localities (some from under the ice), were found on examination to belong entirely to the genus *Salpa* and to represent two species only; and in fact all the specimens, except a single one, are different conditions and sizes of the common and widely distributed species, *Salpa runcinata-fusiformis.*

Salpa runcinata-fusiformis, Chamisso-Cuvier.

Station 432, surface, March 30, 1904; temp. 31·8°. Nearly one hundred specimens, from 3 cm. to 6 cm. in length, all of the aggregated form, and many of the larger ones showing echinated ridges on the test. Most of them showed embryos projecting into the peri-branchial cavity, one in each.

Station 427, from coarse tow-net, March 26, 1904. About one hundred specimens, from 3 cm. to 5 cm. in length. In other respects they resemble those from the last locality, except that the nuclear mass has more of a canary-yellow tint in these, and was a pinker colour in the others.

Station 325, trap-hole, surface, June 4, 1903, Scotia Bay, South Orkneys. A dozen specimens, all rather large, up to 6 cm., and having some red pigment on the nucleus.

Station 416, taken by trawl lowered to 2370 fathoms, but probably captured at surface, March 17, 1904, lat. 71° 22′ S., long. 18° 15′ W. About forty specimens, much smaller, up to 4 cm. in length at most, all with a pale yellow-coloured nucleus.

Station 422, vertical net, surface to 800 fathoms, March 23, 1904; temp. 31·1°; lat. 68° 32′ S., long. 12° 49′ W. This jar contains a large matted mass of Salpæ, Medusæ, Macrurous Crustacea, and small fish, also a large species of Sagitta. It looks as if it had at one time become dry. The Salpæ seem to be all of the aggregated form of this species, and are of medium size.

Station 391, "Tunicate," water-bottle on sounding wire (depth of sounding, 2630 fathoms), February 27, 1904. A single, very large specimen of the solitary form, fully 8 cm. in length, but rather damaged, with a chain measuring at least 4 cm.

Surface otter trawl, February 24, 1904. One specimen, aggregated form.

Station 325, "Doliolum," trap-hole, surface, June 1903, Scotia Bay, South Orkneys. About twenty specimens of the chain form.

"Doliola?," while sounding, March 22, 1904. Three specimens.

Station 325, surface, June 1903, temp. 28·9°, Scotia Bay, South Orkneys. About ten specimens.

Station 325, surface, June 1903, temp. 29°, Scotia Bay, South Orkneys. Three specimens.

Station 430, vertical net, March 28, 1904, temp. 31·0° F. About fifty specimens, badly preserved, along with some Medusæ.

Station 432A, surface, March 30, 1904, temp. 31·8°. Half a dozen specimens.

Station 325, surface, June 1903, temp. 29°, Scotia Bay, South Orkneys. One damaged specimen.

Station 409, "Tunicate," vertical net, fathoms 0–100, March 5, 1904, temp. 30°. One damaged specimen.

Station 391, evening, while sounding, February 27, 1904. One damaged specimen.

Salpa scutigera-confederata, Cuv.-Forsk.

Station 535, on Gulf weed, surface, June 27, 1904, "Doliolum." One badly preserved specimen, which had probably been dried at one period, solitary form of the species.

ADDENDUM.

As this paper was going to press I received from Dr Bruce a couple of tubes containing the following:—

Polyzoa pictonis, subspecies *patagonica*, Michn. One poor specimen from shore, Port Stanley, Falklands, January 1903. Station 118.

Lissamaroucium magnum, Sluiter. One colony about 3·5 cm. in diameter, trawled from Station 346, 56 fathoms, December 1, 1903, Burdwood Bank.

Amaroucium sp. (?). One colony about 3 cm. in diameter from same haul as the last species. Station 346.

EXPLANATION OF THE PLATE.

Fig. 1. *Styela lactea*, Herdman. Large barrel-shaped specimen. Nat. size.

Fig. 2. Part of large colony of *Holozoa cylindrica*, Lesson, with three small specimens of *Styela lactea* attached. Nat. size.

Fig. 3. Globular specimen of *Styela lactea*, showing the positions of the branchial and atrial apertures. Nat. size.

Fig. 4. Anterior end of similar specimen, showing the branchial aperture. Nat. size.

Fig. 5. One of the echinated spines of *Styela lactea*. Enlarged.

Fig. 6. Small, globular and very spiny specimen of *Styela lactea*. Nat. size.

Fig. 7. Alimentary canal of *Styela lactea*. Slightly enlarged.

Fig. 8. Dorsal tubercle and tentacles of *Styela lactea*. × 40.

Fig. 9. Dorsal tubercle of *Paramolgula gregaria*, Lesson. Enlarged.

Fig. 10. *Paramolgula horrida*, Herdman, right side. Nat. size.

Fig. 11. Part of branchial sac of *P. horrida*. × 40.

Fig. 12. Diagrammatic plan of both sides of branchial sac of *Styela paessleri*, Michaelsen, supposed to be cut through the endostyle and spread out; I. to IV., branchial folds. The number of bars on the folds and in the interspaces is shown.

Fig. 13. Small part of branchial sac of *Styela paessleri*. × 40.

Fig. 14. Dorsal tubercle of *Styela paessleri*. × 40.

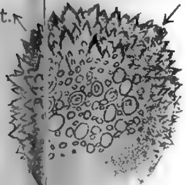
Fig. 15. *Fungulus antarcticus*, n.sp., from the left side. Nat. size.

Fig. 16. Branchial aperture of the same. Enlarged.

Fig. 17. Part of branchial sac of same species, from the inside. × 40.

Fig. 18. Dissection of *Fungulus antarcticus*, to show alimentary canal and gonads. A little enlarged.

HERDMAN: "SCOTIA" TUNICATA.



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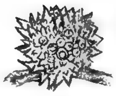

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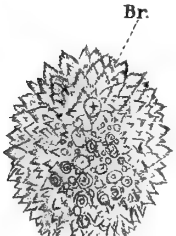

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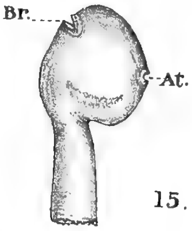

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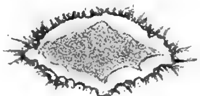

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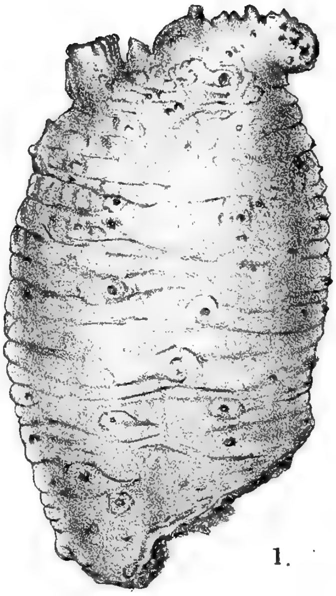

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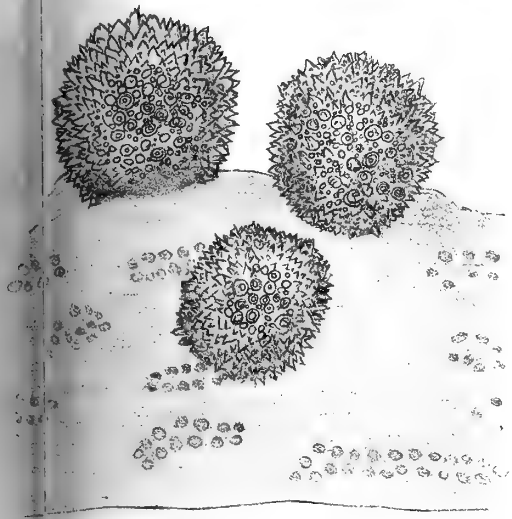

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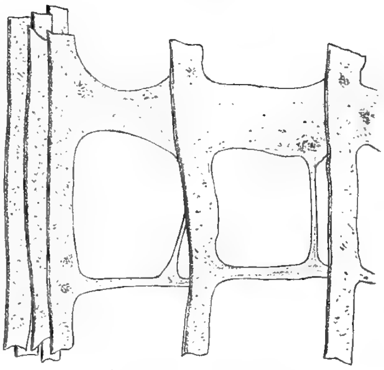

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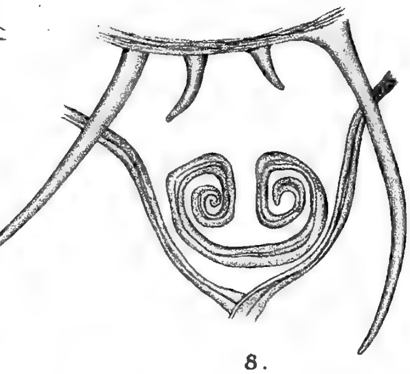

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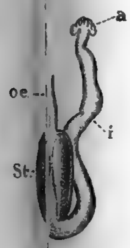

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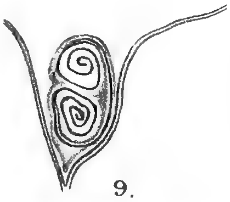

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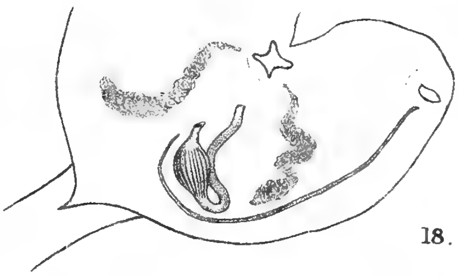

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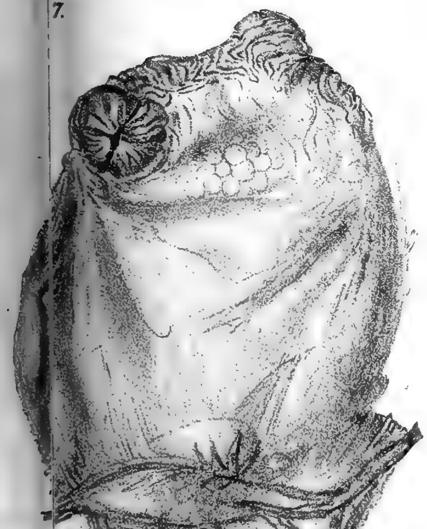

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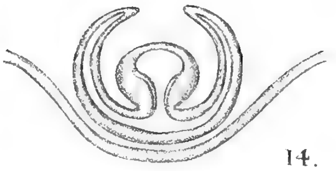

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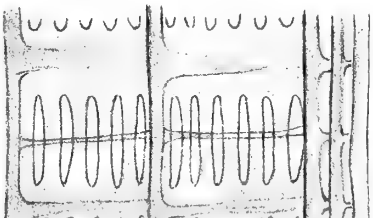

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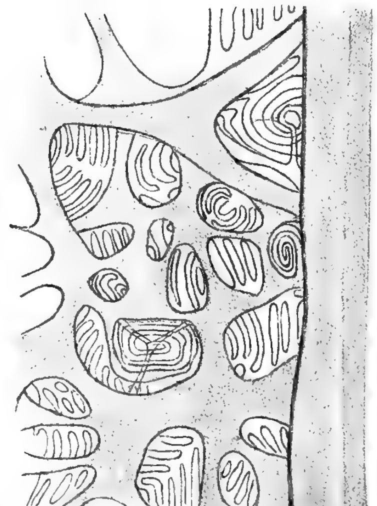

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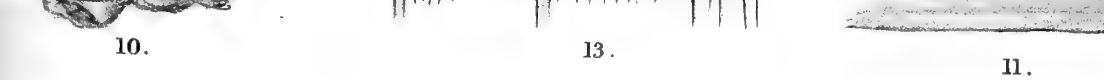

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M'Farlane & Erskine, Lith., Edin.

XVII.—Scottish National Antarctic Expedition: Observations on the Anatomy of the Weddell Seal (Leptonychotes Weddelli). By David Hepburn, M.D., C.M., Professor of Anatomy, University College, Cardiff (University of Wales). Part III.

(MS. received March 28, 1912. Read June 3, 1912. Issued separately July 18, 1912.)

THE RESPIRATORY SYSTEM, AND THE MECHANISM OF RESPIRATION.

In the specimen under consideration there were fifteen pairs of ribs, of which nine pairs were vertebro-sternal. The costal cartilage associated with each of these was long and very flexible. The articulation of the first pair of costal cartilages with the sternum was effected by means of a short but strong band of fibrous tissue, which permitted considerable freedom of movement and did not form a junction of the more or less rigid character seen in man.

The chondro-sternal joints of the second, third, and fourth costal arches were of the diarthrodial variety, each joint being divided into two separate cavities by an interarticular ligament. The fifth, sixth, seventh, eighth, and ninth chondro-sternal joints presented diarthrodial joints without interarticular ligaments.

The sternum was long, narrow, somewhat like a four-sided rod, and divided into segments (suggestive of vertebral centra) by amphiarthrodial joints which were placed opposite the chondro-sternal joints from the second to the ninth. A suprasternal tapering cartilage extended towards the head for a distance of two inches, while the ensiform cartilage extended backwards to a similar distance and ended in a broad semilunar expansion.

The intercostal muscles were well developed, being thick and fleshy, presenting little or no fibrous intersection. They were arranged so as to present an external and an internal muscle in each intercostal space, and the direction of their fibres was similar to that seen in man; but the fibres of the external muscle were continued between the costal cartilages close up to the margin of the sternum without the intervention of an intercostal membrane.

The triangularis sterni muscle arose from the deep surface of the sternum on its own side of the mesial plane. It consisted of a number of slips, which were wide enough to give the appearance of a complete sheet of muscle. These were attached to the sternum from the level of the third costal cartilage backwards to the level of the ninth. The fibres ran forward and outwards to be inserted into the deep surfaces of the costal cartilages from the second to the ninth inclusive, and into fibrous bands which passed from one cartilage to the other. The general line of insertion into the costal cartilages was near to the series of costo-chondral joints, each of which, except that of the first rib, formed a diarthrodial joint. On the ninth costal cartilage this muscle interdigitated with the attachment of the diaphragm. This large, well-developed muscle was supplied by a series of twigs derived from the intercostal nerves in relation to which it was attached.

The sterno-mastoid muscle extended from the anterior end of the sternum and from the side of its pointed suprasternal cartilage to the mastoid process. There being no clavicle, this muscle appeared narrow.

The sterno-hyoid and sterno-thyroid muscles arose from the sternum under cover of the previous muscle. They formed a thin continuous sheet which probably included the omo-hyoid muscle along its lateral border in the vicinity of the hyoid bone. The entire sheet was innervated from the hypoglossal nerve, and the insertion of fibres into the thyroid cartilage and into the hyoid bone suggested the character of its constituent parts. A thin band of muscle fibres occupying their usual position formed the thyro-hyoid muscle.

There were two well-defined scalene muscles, both of which were situated on the dorsal side of the subclavian vessels and cervical nerves, and may therefore be regarded as the representatives of the scalenus medius and scalenus posticus muscles.

The musculus scalenus medius was inserted into the costal cartilage of the first rib close to the costo-chondral articulation.

The musculus scalenus posticus was inserted into the lateral aspects of the third, fourth, fifth, and sixth costal cartilages close to the costo-chondral articulations. At each insertion the pointed attachment interdigitated with similar attachments of the musculus obliquus externus abdominis, whose digitations extended to the cartilage of the first rib.

Regarding the skull and the cervical column as providing the more fixed or rigid attachment for the scalene and sterno-mastoid muscles, it is fairly evident that these muscles may act as elevators of the ribs and sternum by drawing them towards the head.

The diaphragm was well defined in all its parts, but its dorso-lateral portions were very thin, and in the absence of a central tendon of the trefoil type it presented appearances deserving detailed description, more especially in regard to the important position occupied by this muscle in the mechanism of respiration. Its strongest part was the mesial or vertebro-sternal element, which presented two well-marked, pointed crura attached to the lumbar vertebræ. From this origin the muscular fibres passed in a ventral direction on either side of the abdominal aorta until they reached the ventral aspect of this vessel, where to a small extent their fibres intermingled; but for the most part the fibres of the right crus were on the ventral side of those of the left crus.

This distinction between the fibres of the two crura was maintained as they continued towards the œsophagus, along the lateral aspects of which they passed, thereby forming the œsophageal opening, which was practically in the mesial plane. A short distance on the ventral side of the œsophageal opening the muscular fibres were inserted into a circular tendinous ring placed slightly to the right of the mesial plane, and through this ring the inferior vena cava passed. From the ventral face of this tendinous ring strong muscular bands extended to the deep face of the broad ensiform cartilage.

From each side of the dorsal segment of the fibrous ring surrounding the inferior vena cava there extended a narrow tendinous septum in the dorso-lateral direction. Neither of these septa reached the ribs, although the one on the right side was more strongly marked than that on the left side. Into the dorsal faces of these septa there were inserted muscular fibres derived from the lateral aspects of their respective crura, as well as a small, feeble muscular slip from the ventral surface of the second last rib (the 14th) near its head.

From the ventral aspects of the tendinous septa under consideration, a sheet of muscular fibres passed outwards to be attached by slips or digitations into the ribs close to their junction with cartilages from the 8th to the 13th inclusive. The digitation belonging to the 13th rib was attached just in front of the angle of the rib. This ventro-lateral part of the diaphragm was very thin. Areolar tissue occupied the intervals between digitations attached to the 13th and 14th ribs, and also between the 14th rib and the lateral margin of the crus. The association of the diaphragm with the 15th rib was so feeble as to be doubtful. Probably these weak places may be regarded as corresponding to arcuate ligaments, although in the human sense these structures were undefined. At any rate, these arched ligaments had no other representation, neither could the slight intermingling of crural fibres on the ventral aspect of the aorta be regarded as other than a very feeble median arched ligament. Altogether the dorso-lateral development of the diaphragm was extremely feeble. Those muscular fibres attached to the 8th rib were in close contact with the mesial part of the diaphragm between the sternum and the fibrous ring enclosing the inferior vena cava.

From what has been described it will be evident that there was no central tendon of the trefoil pattern, but in its place a vena caval ring, from which there extended two dorsal-lateral septa, of which the right was the stronger marked. The shortness of the left septum permitted a greater mingling of the fibres belonging to the left crus with those forming the rest of the left half of the diaphragm.

The general arrangements within the chest cavity do not call for special discussion. The two pleural sacs and the mediastinal interval followed the customary disposition. It may, however, be noted that the mediastinal layers of pleural membrane were in close apposition from the second segment of the sternum backwards to the hinder end of the sternum, and that consequently the ventral or anterior section of the mediastinum was a mere chink, in its sternal relations.

The lungs were extremely dark in colour, brown almost to black. They were quite soft, but yielded no feeling of crepitation on pressure, so that they suggested a complete absence of air.

When they were removed each was placed in water, and they sank as if solid. A small portion cut from the lung also sank in water, so that this tissue had entirely lost its buoyancy. It is not quite easy to account for such a complete absence of air from the substance of the lung. The animal is known to have lived for some days, because it was killed by poisoning with hydrocyanic acid after an attempt had been made to rear it by artificial feeding. The carcase was preserved by injecting an arsenical solution. Neither of these processes would account for the absence of air from the lung tissue. We must therefore assume that either the natural elasticity of the lung tissue has produced the condition noted, so that the expiratory apparatus of the animal is able to produce a practical deflation of the lungs, which is doubtful; or that, partly owing to the length of time they have been preserved and partly owing to the preservative solutions, the air has practically all passed into solution and disappeared.

A portion of the lung was prepared for microscopic examination, and, notwithstanding the number of years that have elapsed since the animal was embalmed, the different tissues were easily recognisable, but to staining agents such as hæmatoxylin and eosin they reacted very slowly and not very satisfactorily.

The hyaline cartilage of the bronchioles was cellular, and very similar to the cartilage in the ear of the mouse.

The lobules of the lung were very clearly defined by interlobular tissue, which was continuous with the sub-pleural tissue, and throughout this tissue there was a well-marked amount of elastic fibres.

All the air spaces were shrunken, *i.e.* collapsed, almost to the point of obliteration, but they were free from exudation. The capillary blood-vessels in the walls of the air spaces were crowded with blood corpuscles, which may have been the result of the preservative injection.

There is some reason, therefore, for considering that the normal elasticity of the lung in this seal was much greater than that of man, and that, consequently, the air would be much more effectively expelled from the lungs of the seal during expiratory movements.

Attention may be drawn to certain of the body muscles whose attachments and disposition were such as to add to their expiratory value. The panniculus carnosus muscle was a thin sheet enveloping the trunk from the hinder end of the abdomen to the face, and on the face and head forming a cowl modified for facial or expression muscles in relation to the various apertures in that region. The fore limbs were in effect pushed through this axial sheet. The disposition of its fibres showed dorso-lateral and ventro-lateral directions, separated from each other by a lateral aponeurosis, and attached by aponeurotic fibres to the dorsal and ventral mesial lines such as may be seen in the porpoise, but less distinct. The direction of the muscle fibres in the dorso-lateral section was obliquely from before (cephalic) backwards (caudal), whereas in the ventro-lateral section their direction was obliquely from behind forwards. The general effect of the contraction of this sheet would be to expel the air from the very elastic and flexible thorax, as well as to compress the abdomen.

The musculus obliquus abdominis externus showed no attachment to the ilium. By one end it was attached through digitations to the entire series of costal arches from the first to the fifteenth. Its fibres were directed obliquely backwards towards the ventral mesial line, and, having given place to a thin aponeurotic sheet, many of these fibres interlaced with those from the opposite side to form the linea alba.

The hinder part of the muscle, however, did not form any attachment to the ilium, but as a muscular arch, equivalent to the ligament of Poupart, they were attached to the ventral aspect of the body of the pubis. Near to the pubis a slit in the muscle sheet served the purpose of an external inguinal ring, in which the spermatic cord was situated. A muscle so attached could clearly act as a very powerful expiratory muscle provided the glottis were open.

The musculus obliquus abdominis internus was attached dorsally to the lumbar aponeurosis and to the crest of the ilium, while ventrally it was inserted into the hinder borders of the last four ribs and also through its aponeurosis into the linea alba. The greater proportion of its aponeurotic fibres passed ventrally to the rectus abdominis muscle along with those of the external oblique, but a few of them blended feebly with the aponeurosis of the transversalis abdominis muscle. This muscle (transversalis) presented lumbar and iliac attachments as well as a series of digitations on the hinder seven or eight ribs. Its mesial attachment to the linea alba was by an aponeurotic sheet placed on the deep side of the rectus abdominis muscle. The hinder or inguinal margins of these two last muscles were very closely, almost inseparably, blended together, and both were much thinner than the external oblique muscle.

The rectus abdominis muscle occupied an abdominal sheath whose composition has already been indicated. It was attached posteriorly to the body of the pubis, and extended anteriorly to the first costal cartilage, to which, as well as to all the other sternal cartilages, it was attached by tendinous slips. Here again we can see that this muscle, acting from a rigid attachment to the pubis, may act as a powerful expiratory muscle in association with an open glottis.

The lungs, beyond what has already been said, do not call for detailed description. Each presented a great oblique fissure, and thereby an apical and a basal lobe. In addition the right lung possessed a transverse fissure, and therefore a middle or ventral lobe. Furthermore, the right lung had an azygos lobe on its mediastinal aspect in relation to the margin between diaphragm and pericardium.

On several occasions I have had the opportunity of making a detailed examination of the respiratory mechanism of mammals whose habitat is either partly or entirely marine, and on each occasion I have been impressed by the remarkable flexibility of their thoracic wall, with the associated peculiarities in the attachments of certain of the muscles. Attention has already been drawn to some of these peculiarities in the descriptions given above, and it is almost impossible to avoid the conclusion that respiration necessitates a more flexible chest-wall in the case of mammals surrounded by water than in those which are surrounded by air, apart from the fact that the normal attitude of the latter may be horizontal, as in the case of quadrupeds, or vertical, *i.e.* erect, as in the case of man.

On the other hand, this flexibility of the chest becomes not only a drawback, but may be an actual source of danger when the marine mammal comes on shore either by intention or as the result of accident. Thus it is well known that a cetacean dies when it runs aground, not necessarily by starvation, but because it is suffocated, since the flexibility of its chest-wall renders respiratory movements impossible under the superincumbent weight of its body.

The leader of the Scottish National Antarctic Expedition made very careful observations on the attitude of seals when they left the water and resorted to the ice, and he noted that they do not assume positions which would hamper their chest movements. Thus they recline on the side when asleep so as to leave the movements of one side of the chest unimpeded, while at other times their common attitude is to lie prone with the chest raised off the ground by the short fore limbs. Considerations of this kind lead to the conclusion that respiration, but more especially the act of inspiration, can be seriously impeded or even rendered impossible by the weight of the animal's own body. That free inspiratory movement of the chest-wall in man may be hampered by the weight of his body may be readily observed in the case of an operatic singer who, by the exigencies of his performance, is called upon to sing in the supine position; for although in this position he can fill his lungs sufficiently for ordinary respiration, yet he cannot inspire deep enough for effective vocalisation. Clearly, therefore, the respiratory mechanism is affected by the attitude of the individual as well as by the surrounding medium, air or water, in which the animal performs the necessary respiratory movements.

There can be no doubt that, whatever the natural attitude of the mammal may be, or whatever its habitat, the ordinary movements of inspiration and expiration are carried out with the minimum expenditure of effort consistent with the amount of air required for each respiratory act. On the other hand, special circumstances may call for additional or extraordinary efforts both as regards inspiration and expiration. The discussion of respiratory movements is usually left, and by many observers considered properly left, to the physiologist; but as these movements are entirely dependent upon a definite mechanism in which the muscular arrangements play an important part, they cannot fairly be excluded from the province of the anatomist, and it is from the standpoint of structure that I propose to offer some observations which seem warranted by the conditions I have seen in the seal under consideration, as well as in the porpoise.

It may be well in the first instance to deal with the lungs themselves; and, as the condition in which I found them has already been stated, it will only be necessary to add that, except for the presence of the azygos lobe on the right side, they corresponded with the human lungs so far as the number and arrangement of fissures and lobes was concerned. There is no reason to suppose that during the act of inspiration they would inflate in a manner different from the lungs of man. Now, among the many interesting, elaborate, and ingenious attempts to explain the respiratory act, none is more suggestive than that of KEITH,* who approaches the discussion of the subject more as an anatomist than as a physiologist.

It is not my intention to follow Professor KEITH in detail and offer a criticism of the conclusions arrived at by him. At the same time, some of his statements appear to me to overlook certain of the anatomical facts. Perhaps the most important fundamental statement made by KEITH is in reference to the lungs when he says "the upper lobe is normally expanded by one mechanism, the lower by another," and as a consequence he insists that "the great fissure, which divides the upper from the lower lobe, is functional in its significance." Supposing this view to be correct, it would follow that since there is a third lobe in the right lung of man and a fourth or azygos lobe in the right lung of a quadruped, with the fissures required for their delimitation, the mechanism for expanding the right lung must differ from that required for the left lung. Further, as regards the apical or upper lobe, KEITH maintains that because of the impressions of certain ribs upon the lateral and anterior aspects of the upper lobe, but not upon "the dorsal surface of the upper lobe," there is "a constant relationship between ribs and spaces" for that part of the lobe which presents impressions, but a "downward and upward" movement of the dorsal unmarked part, in which it follows the movement of the lower lobe, because "the lower lobe and the dorsal part of the upper lobe are chiefly expanded by a diaphragmatic mechanism." The argument for a functional significance for the great oblique fissure seems to me unnecessary if the substance of the apical lobe is to expand in two different ways simultaneously, for, at least as far as the dorsal part is concerned, the presence of the fissure does not seem to confer any advantage.

I am not disposed to maintain that the fissures of the lungs have no significance, although to my mind it is rather structural than functional. Even "the obliteration of the pleural cavity by adhesions has so little apparent effect on the respiratory movements that their presence cannot be detected during life," any more than the obliteration of the lobulated character of the kidneys interferes with their functions. After all, the outstanding requirement is that the lungs shall expand to the capacity corresponding to the immediate muscular effort that is being performed, and naturally, therefore, the capacity undergoes constant variation. With this end in view, I cannot but think it is best to consider the muscular mechanism of inspiration *as a whole*, and the muscular mechanism of expiration *as a whole*, since it is their co-ordinated and not their individual action that we depend upon. Probably, in quiet ordinary breathing, no animal, any more than the human individual, employs the full scope of its inspiratory mechanism, and hence in man it has become customary to employ such terms as "thoracic" and "abdominal" to indicate the character of the inspiratory effort which is most noticeable in the female and in the male respectively. At the same time, there is no record of this distinction in the inspiratory act among the sexes of the lower animals, nor between the human sexes during infancy and early adolescence. It

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* "The Mechanism of Respiration in Man," by ARTHUR KEITH, pp. 182-207, in *Further Advances in Physiology*, edited by LEONARD HILL, published by Edward Arnold, London, 1909.

appears to me, therefore, that the double mechanism which KEITH supports for the expansion of the apical and basal lobes of the lung is more apparent than real, and that the so-called *types* of breathing in man are rather the result of the erect attitude whereby, from the natural configuration and diameters of the diaphragmatic section of the thoracic cavity in the two sexes, it is with less muscular effort that the male expands the lower part of his chest and the female expands the upper part of her chest in order that each may obtain the amount of air necessary for ordinary quiet breathing. When additional efforts call for more air, or when, as in the supine position, the easy movement of the chest is impeded, then there is an immediate departure from the characteristic method; but I do not think that we must postulate a double inspiratory mechanism.

The key to the whole mechanism of inspiration is undoubtedly the part performed by the contraction of the diaphragm. We cannot, therefore, overestimate the importance of its attachments and structure; nor must we forget that, like any other muscle, its action is the result of the contraction of its fibres, whereby its attached ends are brought more or less near to each other. The most favourable method of examining the diaphragm is to consider the adult structure from the point of view of its development.

The first part of the diaphragm to appear in the embryo, and the part which may be considered the most powerful in the adult, is its mesial or vertebro-sternal portion, whose vertebral ends or crura arise from the lumbar vertebræ and constitute its axial or fixed end. These muscular fibres having adapted themselves to the positions of the abdominal aorta and the œsophagus, by a certain amount of intermingling of the fibres from opposite sides of the mesial plane, become inserted into the central tendon, whose shape varies from the trefoil tendon of man to the vena caval ring with its lateral septa as seen in the Weddell seal. From the ventral aspect of these tendinous structures a second set of muscular fibres extends to the deep surface of the lower or hinder end of the sternum. The mesial part of the diaphragm is therefore in reality a digastric muscle pursuing an arched course from the vertebral column to the sternum. The arched character of its course is more pronounced in its dorsal segment, while in its ventral or sternal segment the arched character is lost, being replaced by a straight or flat course. This change in the curve of the two segments is due partly to the disposition of the abdominal viscera and partly because the vertebral attachments are some distance farther tailwards than a point which would correspond with the hinder end of the sternum.

By its contraction two results may follow:—(1) the lower (hinder) end of the sternum is either drawn closer to the vertebral column or else prevented from being projected ventrally (forwards) by other influences; (2) the arched dorsal segment between the vertebral column and the central tendon becomes more or less flattened, and in consequence the adjacent abdominal viscera are pushed towards the ventral abdominal wall. At the same time its restraining or bracing action upon the hinder end of the sternum becomes correlated to the restraining action of the first costal arches upon the manubrium sterni, whereby the manubrium sterni is maintained at a relatively fixed distance from the vertebral column. By reason of the somewhat rigid character of the first costal cartilages in man, as well as from the fact that they are frequently encased in an ossified shell, the restraining nature of the connection between the first pair of ribs and the sternum is very well marked; but even in the Weddell seal, where a short and powerful fibrous ligament takes the place of the first costal cartilage, the manubrium is very firmly retained in its relation to the backbone.

The next part to be added to the diaphragm developmentally constitutes its ventro-lateral segments. In the adult these are composed of muscular fibres which arise from the ventral and lateral aspects of the central tendon. From this position they extend in a fan-shaped manner to be inserted into the deep surfaces of the costal arches by digitations which correspond very closely in number with those ribs that do not reach the sternum directly through their costal cartilages—that is to say, the false or vertebro-abdominal series of ribs.

This thin sheet of muscle becomes more and more arched as its slips sink lower on the series of ribs. When therefore it contracts, each digitation will either draw its own particular rib nearer to the central tendon or else maintain the ventral end of its rib at a more or less definite distance from the central tendon.

In this way the ventral ends of the false ribs are provided with temporary or intermittent fixed points, fixation by the contraction of the diaphragm being substituted for fixation by the sternum, as is the case with vertebro-sternal ribs. In fact, the series of ribs could with effect be classified as vertebro-sternal and vertebro-diaphragmatic.

The flattening of the arched surfaces of the diaphragm must increase the available thoracic space, but under ordinary conditions the addition so provided cannot of itself be very great, and only becomes important as the central feature of a larger movement.

Developmentally, the last part to be added to the diaphragm is also its weakest part both in man and in the Weddell seal. This is the dorso-lateral segment, which consists of muscular fibres forming a delicate sheet extending between the dorso-lateral aspects of the central tendon and the ligamenta arcuata externa and interna, and through these with the vertebral column on the one hand and the last rib on the other. The arched course of these fibres in man must enable them to aid the flattening of the dorsal parts of the diaphragm and thereby again assist in pushing the abdominal contents in a ventral direction, but in the seal they are so feebly developed that the effect of their contraction must be practically negligible. I do not doubt that contraction of the diaphragm may produce some depression of the central tendon, more especially at its dorsal side, but I doubt whether the depression of the central tendon can take place on its sternal side or be so pronounced as a whole as to give the "piston action" described by some observers. My reasons for holding this view may be shortly summarised. The pericardial bag rests by its base upon the diaphragm, and, when a central tendon of the trefoil pattern is present, the fibrous bag and the central tendon are intimately united to each other, but the ventral surface of the pericardium is attached to the manubrium sterni by a sterno-pericardial ligament which is described by MACALISTER* as strong and rounded. A similar ligament of weaker character attaches the pericardium to the ensiform cartilage. These ligaments, especially the former, would resist the traction of the pericardium in the abdominal direction, and so resist the depression of the central tendon. Again, the normal liver presents indented grooves corresponding to, and resulting from apposition with, the ribs which cover it, and these grooves indicate a fairly constant relation between the liver and the ribs, since they could not be formed by any plunging or piston action communicated to the liver from the diaphragm. If, on the other hand, the flattening of the dorsal portion of the diaphragm pushed the liver ventrally towards the ribs, and at the same time the contraction of the ventro-lateral portions of the diaphragm drew the lower ribs towards the liver or even maintained them in a position to resist the liver, then the liver markings would be at once accounted for. Further, STARLING† states that during ordinary respiration the central tendon of the diaphragm is practically motionless, but that as soon as respiration becomes laboured there is an actual downward movement of the diaphragm, and that during laboured inspiration the breathing is mainly thoracic in both sexes, "and the abdomen recedes with each inspiration." Apparently, therefore, according to this observer, it is fair to conclude that a laboured inspiration, by calling for more powerful action of the diaphragm, results not only in greater flattening and depression of the dorsal segment of the arched diaphragm, but also in the lower ribs being drawn closer to its central tendon than during ordinary breathing, which is just what an examination of the muscular attachments would lead one to expect. I therefore arrive at the general conclusion that the diaphragm is the keystone in the inspiratory mechanism, and that its chief action consists in resisting the ventral (forward) movement of the hinder (lower) end of the sternum and of those ribs which are not directly articulated to the sternum. As a result of this controlling action the whole series of ribs may participate uniformly in a general lifting or elevating movement which characterises their position at the end of inspiration as contrasted with their sunken or depressed position at the end of expiration. Such an elevation of the ribs does not call for any rotation of their shafts, and indeed, from the nature of their capitular and tubercular articulations with the vertebral column, rotation of the shaft would be impossible. But the chondro-sternal as well as the articulations just mentioned are from the nature of their ligaments adapted to the movements of elevation and depression of the rib as a whole, and even a small amount of such movement at the vertebral end of a rib would tend to be magnified by the length and obliquity of its shaft. In fact, the capsules of the costo-transverse articulations are sufficiently long to permit of the gliding action necessarily associated with such elevation and depression.

In the seal there are two muscles whose attachments are only readily comprehensible when considered as part of the mechanism for depressing the ribs after they have

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* MACALISTER, *Text-book of Human Anatomy*, 1889.

† E. H. STARLING in Schäfer's *Text-book of Physiology*, vol. ii. pp. 276 and 280.

been elevated. These are the musculus obliquus externus abdominis and the musculus rectus abdominis. Both of these muscles are attached to the pubis, *i.e.* to the unyielding or rigid pelvis, and between them they provide slips or digitations of insertion into nearly all of the ribs, even extending to the first. Further, the musculus obliquus abdominis externus has no attachment to the ilium—in other words, both of these powerful muscles were pubo-costal in their attachments. With a distended chest and a glottis firmly closed so as to render the chest wall fairly rigid, these muscles by their contraction could clearly compress the abdominal contents; but in association with an open glottis, of necessity they must pull their rib attachments towards the pubis—in other words, they must act as depressors of the ribs and thus as powerful expiratory muscles. Such a depressor action compels one to presume and to accept an elevated position of the ribs during inspiration.

There is nothing in the mechanism which seems to require one mode of action for inspiration by the vertebro-sternal ribs and another mode of action by the vertebro-abdominal ribs. Of course, the first costal arch, from the nature of its sternal articulation, is, even in the seal, capable of less elevation than those ribs whose shafts and costal cartilages are longer and whose sternal articulations permit greater freedom of movement; but, in order to secure a uniform method of elevation throughout the series of ribs, it is necessary to provide some more rigid line or *point d'appui* for the start of the movement, and the combination of the first costal arch with the manubrium sterni, together with their powerful scalene and sterno-mastoid muscles, provides such a line. Moreover, in man the clavicle is added to this line by the sterno-mastoid and trapezius muscles as well as by such ligaments as the costo-clavicular and the sterno-clavicular. Again, it will be found that those ribs which elevate most readily are just those whose *heads* are provided with an interarticular ligament passing between the head and the intervertebral disc. Such a powerful structure would be unnecessary unless there were a tendency for the head of the rib to be drawn away from the vertebral column as the dorso-ventral and transverse thoracic diameters increased owing to the elevation of the ribs in full inspiration. There is no ordinary form of inspiration which requires a larger amount of air under regulated control than the inspiratory movement performed by the trained singer, and one of the approved methods of obtaining this result aims at the expansion of the large dorsal surface of the lungs by cultivating the upward movement of the ribs in relation to the dorsal surface of the chest, as being not only easier than, but preferable to, a forced action of the diaphragm. An examination of the mechanism of respiration leads me to the conclusion that, in all forms of respiration, this mechanism acts in the same way, but not, in all its parts, to the same extent, for any particular respiratory act; that ordinary and laboured respiration differ in degree rather than in kind; that the degree of respiration depends upon the amount of air required for any particular form of exertion; that the difference between the respiration of the quadruped and the respiration of man results from differences in their attitude (horizontal and erect), whereby each cultivates that form of chest movement which requires the minimum of muscular effort. The differences between the adult human male and female types of breathing are adaptations due to the avoidance of severe muscular effort so long as a smaller effort will serve the purpose, and in my opinion they result from the normal differences in the lower or diaphragmatic diameters of the thoracic cavity in the two sexes. To a large extent these differences may be accounted for by the width of the female false pelvis as compared with that of the male. Since the abdomen proper (*i.e.* excluding the true pelvis) contains no organs which are not common to both sexes, it follows that a wide false pelvis, by providing increased accommodation in the lower abdominal regions, is naturally associated with a reduction in the dimensions of the upper or diaphragmatic end of the abdomen. These conditions make elevation of the sternal ribs more necessary in the female than in the male, whose larger diaphragmatic thorax permits of ordinary breathing without the pronounced or visible elevation of his sternal ribs, although their movement may become visible whenever the supply of air required calls for an extension of the elevating movement.

In either sex, a change from the erect attitude to the horizontal (*e.g.* to the supine) position is usually followed by the introduction of more or less of the respiratory features of the opposite sex, owing to the temporary interference with the amount of rib movement in common use when the ribs are unobstructed.

XVIII.—The Marine Mollusca of the Scottish National Antarctic Expedition. By James Cosmo Melvill, M.A., D.Sc., F.L.S., and Robert Standen, Assistant Keeper, Manchester Museum. *Communicated* by Dr W. S. Bruce. (With One Plate.)

(MS. received April 24, 1912. Read June 3, 1912. Issued separately August 26, 1912.)

PART II.

Being a Supplementary Catalogue.

Since we had the pleasure of working out the Mollusca obtained by the Scottish National Antarctic Expedition, Dr W. S. Bruce has kindly transmitted to our care some additional material, overlooked in the first instance, and taken (*a*) from deposits from jars in which Sponges were placed; (*b*) from Algæ and other growths, principally coming from Scotia Bay; and (*c*) from a new species of *Cephalodiscus*.

Of these the last, when macerated out and closely examined, produced the most prolific and interesting results; but, notwithstanding this fact, the condition of many of the specimens extracted leaves much to be desired, so fragmentary and useless for scientific purposes was a very large proportion found to be. A certain few, however, are happily in better condition and recognisable, and, of these, we find several to have been described by Dr Hermann Strebel of Hamburg in 1908, the year subsequent to our first paper upon the subject being published.

Others remain, of which over twenty do not appear to be represented in the collections to which we could obtain access, nor mentioned in any of the treatises yet published on the Antarctic fauna. We are therefore emboldened to consider them new to science in the accompanying supplementary catalogue.

We include afresh in the list of species obtained by this expedition those already catalogued in our first paper, thus rendering it as complete as possible, and signalise with an asterisk (*) those which are amongst the addenda now chronicled.

We would thank Mr Edgar Smith, I.S.O., for having examined some of the material, and likewise would express our indebtedness to the Rev. Lewis J. Shackleford, Messrs B. R. Lucas and J. Wilfrid Jackson, F.G.S., for having aided us in the difficult task of extracting such small and fragile objects from the mass in which they were too often almost hopelessly embedded. Mr T. Iredale has also kindly drawn up the description of a new species of *Chætopleura* for this paper.

We would only add that we have extended the Bibliographical Catalogue of the Antarctic Molluscan Fauna from 1907 to 1912 at the end of this enumeration.

REVISED LIST OF SPECIES CONTAINED IN THE "SCOTIA" COLLECTIONS.

A. REGIO ANTARCTICA—INCLUDING GOUGH ISLAND.

Class GASTEROPODA.

Order AMPHINEURA.

Sub-order POLYPLACOPHORA.

Callochiton illuminatus (Reeve).
Tonicia atrata (Sowb.).
* *Plaxiphora setigera* (King).
* *Chætopleura brucei*, Iredale, sp. n.
* *Hemiarthrum setulosum*, Carpenter.
* *Lepidopleurus pagenstecheri*, Pfeffer.

Order PROSOBRANCHIATA.

Sub-order DIOTOCARDIA.

(*a*) Docoglossa.

Family *Acmæidæ*.

Acmæa ceciliana, Orbigny.

Family *Patellidæ*.

Patella ænea, Martyn, var. *deaurata*, Gmelin.
,, *fuegiensis*, Reeve.
,, *polaris*, Hombron and Jacquinot.

(*b*) Rhipidoglossa.

Section **Zygobranchiata.**

Family *Fissurellidæ*.

Fissurella oriens, Sowb.
,, *picta*, Gmel.
Tugalia antarctica, M. and St.
* *Puncturella noachina* (L.)

Family *Pleurotomariidæ*.

* *Scissurella eucharista*, sp. n.
* ,, *euglypta*, Pelseneer.
* ,, *supraplicata*, Smith
* ,, *timora*, sp. n.

Section **Azygobranchiata.**

Family *Cyclostrematidæ.*

* *Cyclostrema calypso*, sp. n.
* ,, *coatsianum*, sp. n.
* ,, *gaudens*, sp. n.
* ,, *meridionale*, sp. n.

Family *Trochidæ.*

* *Calliostoma modestulum*, Strebel.
Photinula expansa (Sowb.).
,, *tæniata*, Wood.
,, *violacea*, King.
Valvatella antarctica (E. Lamy).

Sub-order MONOTOCARDIA.

Section (*a*) **Ptenoglossa.**

Family *Ianthinidæ.*

Ianthina exigua, Lamarck.

Family *Scalidæ.*

* *Scala magellanica*, Phil.

Section (*b*) **Tænioglossa.**

Family *Naticidæ.*

* *Natica impervia*, Phil.
,, (*Lunatia*), sp. juv.

Family *Trichotropidæ.*

* *Trichotropis antarctica*, sp. n.

Family *Capulidæ.*

* *Calyptræa chinensis*, L.
,, *costellata*, Phil.
,, *dilatata*, Lamk.

Family *Littorinidæ.*

Littorina (*Lævilitorina*) *caliginosa* (Gould).
,, ,, *coriacea*, M. and St.
,, (*Pellilitorina*) *pellita*, v. Marts.
,, ,, *setosa*, Smith.
* *Lacuna abyssicola*, sp. n.

Lacuna divaricata, Fabricius.
,, *notorcadensis*, M. and St.
* ,, *wandelensis*, E. Lamy.

Family *Rissoidæ.*

Rissoa adarensis, Smith.
,, (*Cingula*) *cingillus* (Mont.).
* ,, *deserta*, Smith.
,, *edgariana*, M. and St.
* ,, (*Onoba*) *filostria*, sp. n.
,, *fraudulenta*, Smith.
* ,, (*Onoba*) *fuegoensis*, Strebel.
,, *parva* (Da Costa).
* ,, (*Onoba*) *paucilirata*, sp. n.
,, ,, *scotiana*, M. and St.
* ,, ,, *sulcata*, Strebel.
* ,, (*Ceratia*) *turqueti*, E. Lamy.
,, (*Manzonia*) *zetlandica* (Mont.).
Eatoniella kerguelenensis, Smith.

Family *Litiopidæ.*

Litiopa melanostoma, Rang.

Family *Cerithiidæ.*

Cerithium georgianum, Pfeffer.
,, *pullum*, Phil.
* *Bittium brucei*, sp. n.
* ,, *burdwoodianum*, sp. n.
* *Cerithiopsis macroura*, sp. n.
,, *malvinarum* (Strebel, MS.), M. and St.

Family *Turritellidæ.*

* *Turritella algida*, sp. n.
* *Mathilda rhigomaches*, sp. n.

Family *Tritoniidæ.*

Gyrineum vexillum (Sowb.).

Section (*c*) **Gymnoglossa.**

Family *Eulimidæ.*

* *Eulima antarctica*, Strebel.

Family *Pyramidellidæ.*

* *Turbonilla smithii*, Pfeffer.
* ,, *xenophyes*, sp. n.

Section (*d*) **Rachiglossa.**

Family *Muricidæ.*

Trophon brucei, Strebel.
,, *cinguliferus*, Pfeffer.
,, *crispus* (Couthouy).
* ,, *falklandicus*, Strebel.
,, *geversianus* (Pallas).
,, *hoylei*, Strebel.
,, *liratus* (Couthouy).
,, *minutus* (Strebel, MS.), M. and St.
,, *philippianus*, Dunker.
* *Antistreptus magellanicus*, Dall.

Family *Nassidæ.*

Nassa (*Ilyanassa*) *Vallentini*, M. and St.

Family *Buccinidæ.*

Chrysodomus (*Sipho*) *archibenthalis*, M. and St.
,, ,, *crassicostatus*, M. and St.
Neobuccinum eatoni, Smith.
Euthria fuscata (Brug.).
,, *magellanica* (Phil.).
,, *michaelseni*, Strebel.
* ,, *rosea*, Hombron and Jacquinot.

Family *Volutidæ.*

Voluta (*Cymbiola*) *ancilla*, Solander.
Guivillea alabastrina, Watson.
* *Mitra* (*Volutomitra*) *porcellana*, sp. n.

Section (*e*) **Toxoglossa.**

Family *Conidæ.*

Columbarium benthocallis, M. and St.
Mangilia costata (Donovan).
* *Bela anderssoni*, Strebel.
* ,, *fulvicans*, Strebel.
* ? *Thesbia*, sp.
* *Savatieria concinna*, sp. n.

Family *Cancellariidæ.*

Admete magellanica, Strebel.
* ,, *limneæformis*, Smith.
* *Paradmete typica*, Strebel.

Order OPISTHOBRANCHIATA.

Sub-order TECTIBRANCHIATA.

Section **Bulloidea.**

Family *Tornatinidæ.*

* *Retusa antarctica*, sp. n.
,, *truncatula* (Brug.).

Section **Siphonarioidea.**

Family *Siphonariidæ.*

Siphonaria redimiculum, Reeve.

Order PULMONATA.

Sub-order BASOMMATOPHORA.

Family *Auriculidæ.*

Marinula nigra, Phil.

Class SCAPHOPODA.

Dentalium eupatrides, M. and St.
,, *megathyris*, Jousseaume.

Class PELECYPODA.

Order PROTOBRANCHIATA.

Family *Nuculidæ.*

Nucula minuscula, Pfeffer.
* ,, *pisum*, Sowb.
Yoldia eightsii (Couth.).
* ,, *profundorum*, sp. n.

Order FILIBRANCHIATA.

Sub-order ANOMIACEA.

Family *Anomiidæ.*

Anomia ephippium, Linn.

Sub-order ARCACEA.

Family *Arcidæ.*

Arca (*Bathyarca*) *strebeli*, M. and St.
Lissarca notorcadensis, M. and St.
,, *rubrofusca*, Smith.
Limopsis longipilosa, Pelseneer.

Sub-order MYTILACEA.

Family *Mytilidæ.*

Mytilus edulis, Linn.
,, *magellanicus*, Chemnitz.
,, *ovalis*, Lamarck.
Philobrya meridionalis (Smith).
,, *quadrata* (Pfeffer).
* ,, *sublævis*, Pelseneer.
,, *wandelensis*, E. Lamy.
* *Crenella decussata* (Mont.).
Modiolarca mesembrina, M. and St.

Order PSEUDOLAMELLIBRANCHIATA.

Family *Pectenidæ.*

Pecten colbecki, Smith.
,, *multicolor*, M. and St.
,, ? *patagonicus*, King.
,, *pteriola*, M. and St.
Amussium 18-*liratum*, M. and St.

Family *Limidæ.*

Lima goughensis, M. and St.
,, (*Limatula*) *pygmæa*, Philippi.

Order EULAMELLIBRANCHIATA.

Sub-order SUBMYTILACEA.

Family *Carditidæ.*

* *Cardita congelascens*, sp. n.
* ,, *pallida*, Smith, var. *12–costata* nov.

Family *Astartidæ.*

* *Astarte magellanica*, Smith.

Family *Lucinidæ.*

* *Diplodonta lamellata*, Smith.
Cryptodon falklandicus, Smith.
Cyamium antarcticum, Philippi.
* ,, *denticulatum*, Smith.
,, *falklandicum*, M. and St.

Family *Erycinidæ.*

Lasæa consanguinea (Smith).
Kellyia cycladiformis, Desh.

Kellyia lamyi, M. and St. = *australis*, Lamy non Desh.
* ,, *magellanicus*, Smith.
* *Davisia cobbi*, Cooper and Preston.
Scacchia plenilunium, M. and St.

Sub-order TELLINACEA.

Family *Tellinidæ*.

Tellina (*Mæra*) *pusilla* (Philippi).

Sub-order VENERACEA.

Family *Veneridæ*.

Chione philomela (Smith).
Tapes (*Amygdala*) *exalbida* (Chem.).

Sub-order MYACEA.

Family *Glycimeridæ*.

Saxicava arctica (L.), var. *antarctica*, Philippi.

Sub-order ANATINACEA.

Family *Lyonsiidæ*.

Lyonsia cuneata (Gray).

Family *Anatinidæ*.

Anatina elliptica, King and Broderip.

Order SEPTIBRANCHIATA.

Family *Cuspidariidæ*.

Cuspidaria brucei, M. and St.

At Dr BRUCE's request, we also include in the list of Mollusca obtained by the expedition certain species from St Vincent, Cape de Verde Islands, Pyramid Point, Ascension Island, and Funchal, Madeira. None of these call for special remark, beyond the fact that several, *e.g.* *Arca bouvieri*, are endemic species, and that, so far as we can ascertain, *Calliostoma montagui* and *Pisania maculosa* have not been hitherto recorded from Cape de Verde.

A. FROM ST VINCENT, CAPE DE VERDE ISLANDS.

Chætopleura fulva (Wood).
Patella plumbea, Lamarck.
Fissurella græca (Linné).
Haliotis lamellosa, Lamarck.
Monodonta articulata, Lamarck.
,, *punctulata*, Lamarck.

Monodonta turbinata (Born.).
,, *tamsi* (Dunker).
Calliostoma montagui (W. Wood).
,, *zizyphinus* (Linné).
Phasianella pulla, Linné, var.
Pachypoma (*Bolma*) *rugosa* (Linné).
Natica intricata, Donovan.
Calyptræa sinensis, Linné.
,, (*Infundibulum*) *radians*, Lamarck.
Littorina punctata, Gmelin.
,, *striata*, King.
Cerithium musicum, Sowerby.
,, *vulgatum*, Brug.
Planaxis lineatus, Cost.
Cypræa spurca, Linné.
Trivia arctica, Solander, var. *europæa*, Mont.
Cassis testiculus, Linné.
Obeliscus terebellum, Müll.
Murex rosarium, Chem.
Ocinebra corallina, Scacchi.
Purpura hæmastoma, Linné.
,, *neritoidea*, Linné.
Collumbella rustica, Linné.
,, ,, var. *azorica*, Drouet.
Nassa cornicula, Olivier.
,, *reticulata*, Linné.
,, *cuvieri*, Payr.
Pisania maculosa, Lamarck.
Leucozonia triserialis, Lamarck.
Conus genuanus, Linné.
,, *guinaicus*, Brug.
,, *mediterraneus*, Brug.
Tethys punctata, Cuvier.
Haminea navicula, Da Costa.
Siphonaria venosa, Reeve.
Arca bouvieri, Fischer.
Barbatia afra, Gmelin.
Pectunculus formosus, Reeve.
,, *concentricus*, Dunker.
Mytilus puniceus, Lamarck.
Pinna rudis, Linné.

Lithodomus aristatus, Dillwyn.
Spondylus gæderopus, Linné.
Cardita senegalensis, Reeve.
,, *ajar*, Brug.
Lucina pecten, Lamarck.
Chama senegalensis, Reeve.
Venus gallina, Linné.
Chione nodosa, Dunker.
,, *verrucosa*, Linné.
Cardium edule, Linné.

B. From Ascension Island. Pyramid Point, 40 fathoms.

Nerita ascensionis, Gmelin.
Pecten miniaceus, Reeve.
Chama, sp.

C. From Funchal, Madeira. Shore.

Patella cærulea, Linné.

Class GASTEROPODA.

Order Amphineura.

Sub-order POLYPLACOPHORA.

Chiton (*Plaxiphora*) *setiger*, King

Chiton setiger, King, *Zool. Journ.*, v. p. 338 (1831).
,, ,, Sowerby, *Conch. Illustr.*, p. 17.
,, ,, *Zool. Beechey's Voyage*, pl. xl. fig. 7.
,, ,, Reeve, *Conch. Icon.*, t. ix. fig. 48*a*; t. xiv. fig. 48*c*.
,, ,, Gould, *U.S. Explor. Exped.: Moll.*, p. 330, fig. 425.
Plaxiphora Carmichaelis, Gray, *P.Z.S. Lond.* (1846), p. 68.
,, ,, Haddon, *Challenger Rep.*, p. 32.
,, ,, H. and A. Adams, *Gen. Rec. Moll.*, i. p. 481, and iii., t. 55, fig. 3.
Chætopleura Savatieri, Rochebrune, *Bull. Soc. Phil. Paris* (1880–81), p. 119; *Miss. Sci. du Cap Horn.*
,, *frigida*, Rochebrune, *l.c.*, p. 137, t. 91, figs. 5*a*, 5*b*.

Hab.—Gough Island, April 22, 1904. Station 461.
Scotia Bay, South Orkneys, rarely. Station 325.

Chætopleura brucei, Iredale, sp. n. (Plate, figs. 24, 24*a–d.*)

Shell of medium size, ovate, depressed, girdle fleshy, densely covered with hairs, the longer being very prominent on a bed of shorter ones, appearing to be grouped and longest near the sutures. Valves broad, with a well-marked keel, though not very high, the posterior valve having the mucro about the anterior third.

Shell smooth, the lateral areas being indicated by a very faintly raised ridge.

Down the median keel of the five centre valves is a row of pustules which do not reach to the mucro, and two parallel rows can be seen on either side, these rows showing on the anterior portion of the posterior valve; but on the first median valve this arrangement is not so apparent.

Scattered radiating rows of similar pustules are seen on the anterior valve, where faint ridges are indicated; similar sculpture is seen on the posterior part of the end valve. On the pleural areas of the median valves scattered pustules are also present, whilst the lateral areas have them also few and scattered. Otherwise the only feature is the concentric growth-ridges, which are well marked on each ridge, indicating regular growth in still water.

The internal features are, as noted by PILSBRY for *C. peruviana*, Lamk. (*Man. Conch.*, xiv. p. 29, 1892), the anterior valve with 9, central valves 1, and posterior valve 9 slits.

Hab.—Scotia Bay, South Orkneys. Station 325. One fine specimen only. Agrees closely with *C. peruviana*, Lamk., and seems to be the first record for the genus from east of South America. (T. IREDALE.)

Lepidopleurus pagenstecheri, Pfeffer.

Leptochiton pagenstecheri, Pfeffer, *Jahrb. hamburg. wissenschaftlichen Anstalten*, iii Jahrgang, p. 107, t. iii. fig. 3 (1886).

Hab.—Scotia Bay, 9–10 fathoms. Station 325.

THIELE considers this *Chiton* conspecific with *L. kerguelensis*, Haddon, from Kerguelen Island, but IREDALE does not accept this conclusion, though admitting the close alliance of the two species.

Hemiarthrum setulosum, Carpenter.

Hemiarthrum setulosum, Carpenter, MS., p. 13.—Dall, *Bull. U.S. Nat. Mus.* ii., (1876), p. 44. —Haddon, "*Challenger*" *Polyplacophora*, p. 14, t. i. fig. 4; t. ii. fig. 4*a*, 1.—Martens and Pfeffer, *Jahrb. des hamburg. wissenschaftlichen Anstalten*, iii. p. 108, t. iii. fig. 4 (1886).

Hab.—Station 325, Scotia Bay, 9–10 fathoms, on Fuci and other Algæ.

Very small and juvenile specimens, probably referable to the above. IREDALE also doubts the identity of the South Georgian *Hemiarthrum* with that described by DALL from Kerguelen Land, but more material is wanted for comparison.

Order PROSOBRANCHIATA.

Sub-order DIOTOCARDIA.

Section **Zygobranchiata.**

Family *Fissurellidæ.*

§ Emarginulidæ.

Puncturella noachina (L.).

Patella noachina, Linnæus, *Mantissa*, p. 551.
Puncturella noachina, Lowe, *Zool. Journ.*, iii. p. 78 (1827).
Cemoria princeps, Mighels, *Proc. Boston Soc. Nat. Hist.* (1841), p. 49.
Rimula galeata, Gould, *U.S. Explor. Exped.*, p. 369, t. xxxi. figs. 476, 477.

Hab.—Trawl, Burdwood Bank, Station 346, south of the Falkland Islands, lat. 54° 25′ S., long. 57° 32′ W., December 1, 1903.

Bleached but perfect specimens of a British and North European species, also known to extend to the Falkland Islands and Straits of Magellan. It is likewise recorded by Dr HERMANN STREBEL,* from Berkeley Sound, lat. 51° 53′ S., long. 58° W.

We include under the name *noachina* (L.) various forms, *e.g. conica*, D'Orb., *falklandiana*, A. Ad., *cognata*, Gould, and *galeata*, Gould. It is most probable that the gatherings from Burdwood Bank would come under the name mentioned second, *falklandiana.*

Family *Pleurotomariidæ.*

Scissurella eucharista, sp. n. (Plate, figs. 1, 1*a*).

S. testa perminuta, globulosa, delicatissima, alba, naticoide, paullum elevata, anfractibus 4, quorum apicalis feré immersus, penultimo inflato, tumescente, ultimo epidermide evanida pallidé straminea contecta, infra suturam leniter planato, deinde bicarinato, quarum inter fines scissura extensa, angusta, cætera superficie delicate sub lente spiraliter tenuissime striata usque ad basim supra carinam radiatim leniter plicata, umbilico feré clauso, apertura rotunda, labro rotundo, tenuissimo.

Alt. 1, diam. ·75 mm.

Hab.—Burdwood Bank, 56 fathoms, trawled. Station 346.

A perfect example of one of the smallest shells possible, and yet full of character. We have compared it with the majority of the genus, and find it stands out conspicuously in general roundness of outline, the double carination, within which, towards the aperture, is situate the narrow extended slit, not causing, as is usual, an angular appearance. Indeed, in form it is almost naticoid. Below the carinæ, the surface to the base is transversely very finely striate, the umbilicus appears partly covered, the outer lip is round and extremely thin. Somewhat of the same form as *Sc. conica*, D'Orb., also from Southern waters; but in our species the slit is situate much nearer the suture, that of *conica* being almost median. (εὐχάριστος, elegant, agreeable.)

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* *Schwed. Sudpolar Exped.* (1908), p. 79.

Scissurella euglypta, Pels.

Scissurella euglypta, P. Pelseneer, *Voy. du S.Y. "Belgica": Zoologie*, p. 17, pl. iv. figs. 43–45 (1903).

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

Only one imperfect specimen, but recognisable.

Scissurella supraplicata, Sm.

Scissurella supraplicata, E. A. Smith, *Ann. and Mag. N.H.*, xvi. p. 72 (1875).
" " " *Phil. Trans. Roy. Soc. London*, vol. clxviii. p. 176, pl. ix. figs. 5, 5*a* (1879).

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

Several examples, mostly imperfect, of this pretty species, striking on account of its very marked plication above the double keel.

Scissurella timora, sp. n. (Plate, figs. 2, 2*a*).

Sc. testa minuta, tenuissima, alba, epidermide straminea omnino contecta, depresso-effusa, anfractibus 4; apicalibus parvis, ultimo lato, supra ad peripheriam planato, radiatim lineis obliquis tenuibus prædito, scissura angusta, profunda, infra ad basim concentricé trilirato, apertura ovata, intus alba, labro pertenui, columella paullum incrassata, feré recta.

Alt. 1, diam. 1·75 mm.

Hab.—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms, on *Macrocystis pyrifera* and other large Fuci.

A depressed, obliquely effuse little species, of which but few examples occurred, all in live condition, covered with straw-coloured epidermis. The upper part of the body whorl is not so conspicuously radiate as in many species; the slit is narrow, deep, its edges being carinate. (τιμωρός, honoured.)

Section **Azygobranchiata.**

Family *Cyclostrematidæ.*

Cyclostrema calypso, sp. n. (Plate, fig. 3).

C. testa perminuta, angusté sed profundé umbilicata, conica, alba, delicatula, anfractibus ad 5, inclusis apicalibus duobus lævibus, cæteris arcté longitudinaliter liratis, et spiraliter decussatim striatulis, numero lirarum ultimi anfractûs ad quadraginta, anfractibus omnibus ventricosis, ad suturas multum impressis, apertura rotunda, peristomate continuo.

Alt. 1, diam. 1·15 mm.

Hab.—Trawl, Burdwood Bank, lat. 54° 25′ S., long. 57° 32′ W., at 56 fathoms. Station 346.

Exceedingly minute, resembling *C. decussatum*, Pelseneer,* in many ways, but differing in (*a*) size, and (*b*) in fine and close longitudinal liration. To *C. conicum*, Watson, collected during the Challenger Expedition (Station 24), it likewise is akin; but in this species, more than double the dimensions to begin with, the lamellæ are much stronger proportionately, and fewer in number than in either *C. decussatum* or *C. calypso.*

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* P. Pelseneer, *Voy. du S.Y. "Belgica,"* p. 19, pl. v. fig. 48 (1903).

Cyclostrema coatsianum, sp. n. (Plate, figs. 4, 4*a*).

C. testa parva, alba, solidula, profundé umbilicata, elegantissimé sculpta, anfractibus 4, quorum duo apicales nitidi, albi, læves, duobus cæteris longitudinaliter æquicostatis, costis lævibus, incrassatis, subflexuosis, penultimo suprá planato, ultimo spiraliter quadricarinato, carina obtusa infrá suturas, binis ad peripheriam, præditis, simul ac ad basim, interstitiis omnibus subquadratis et fenestratis, regione umbilicari profunda, verticali, apertura rotunda, peristomate crassiusculo, continuo.

Alt. 1, diam. 2·25 mm.

Hab.—Trawl, Burdwood Bank, lat. 54° 25′ S., long. 57° 32′ W., 56 fathoms. Station 346.

A very small, solid, white, boldly but elegantly sculptured *Cyclostrema*, the nearest ally being *C. micans*, A. Ad., from the eastern tropics, known in Indian seas as *Liotia pulchella*,* Dunker. This species is somewhat larger, and the pattern of sculpture is different. We name this species in honour of Mr JAMES COATS, of Ferguslie House, Paisley, through whose generosity the Scottish National Antarctic Expedition was equipped with funds, and whose regretted death, by a strange coincidence, occurred just after this description had been drawn up, on March 22, 1912.

Cyclostrema gaudens, sp. n. (Plate, figs. 5, 5*a*, 5*b*).

C. testa minutissima, profundé umbilicata, depresso-discoidali, suprá planiuscula, alba, anfractibus ad 3½, quorum apex ipse depressus, perlævis, ultimo ad peripheriam obtusé carinato, undique longitudinaliter arcte lirato, liris circá viginti-duabus, apud basim circá umbilicum obscuré spiraliter carinato, apertura rotunda, peristomate tenui, feré continuo, operculo corneo, multispirali, nucleo centrali.

Alt. ·75, diam. 1 mm.

Hab.—Station 346, trawl, 56 fathoms, Burdwood Bank.

Slightly allied to the preceding, but much differing in sculpture, especially in the suppression of the prominent peripheral keeling of the body whorl. Judging from the figure, there is an affinity to *C. alveolatum*, Jouss.,† described from an unknown locality, the dimensions being only slightly less; the interstices, however, between the flexuous costæ do not appear, in our species, to be spirally striate, as is the case with JOUSSEAUME's species.

Cyclostrema meridionale, sp. n. (Plate, figs. 6, 6*a*, 22, 22*a*).

C. testa minutissima, depresso-trochoide, delicata, tenui, pallidé albo-cinerea, epidermide fugitiva straminea omnino contecta, profundé umbilicata, anfractibus 4, quorum duo apicales tumescentes, albi, perlæves, cæteris duobus—penultimo uni-, ultimo anfractu spiraliter bicarinato, apertura rotunda, peristomate continuo, paullulum incrassato, apud basim circá umbilicum crenello-carinato, operculo multispirali, corneo, nucleo feré centrali.

Alt. ·75, diam. ·50 mm.

Hab.—Gregariously, on various Algæ (*Fucus* and *Macrocystis*), Station 325, Scotia Bay, South Orkneys, 9–10 fathoms.

This well-defined but very minute species is evidently the same as that recorded from the same islands by Dr E. LAMY,‡ and considered a non-adult form of an unknown

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* A. ADAMS, *P.Z.S.* (1850), p. 44; DUNKER, *Mal. Blatt.*, vol. vi. p. 225 (1860).

† GUERIN, *Mag.*, p. 392, pl. xix. fig. 4 (1872).

‡ *Moll. Reg. Arct. Norv.*, p. 135, pl. xxi. fig. 1 (1908); *Bull. Mus. Nat. d'Hist. Naturelle* (1906), Paris, p. 123, (1910) p. 323.

species of *Margarita*. To us, and several other malacologists who have examined it with care, it not only appears almost full-grown, but with some confidence is now proposed to be included in the genus *Cyclostrema*, at all events provisionally; for this genus is somewhat multifarious already in its component parts, and much needs the services of a special monographer.

The nuclear whorls are, it is true, slightly nepionic, and shapelessly turgid, but the penultimate and body whorls are very well sculptured and defined, being acutely spirally bicarinate. Around the umbilicus, likewise, a third keel, crenulate, and not so acute, revolves. A pale straw-coloured epidermis covers the whole surface uniformly. The operculum, for microscopic aid in the examination of which we are much indebted to Messrs E. A. SMITH and ROBSON of the British Museum (Natural History), is dark red-brown, with nucleus not quite central, and multispiral. This we take the opportunity also to figure (fig. 22*a*).

Calliostoma modestulum, Strebel.

Calliostoma modestulum, H. Strebel, *Schwed. Sudpolar Exped.*, p. 70, Taf. i. fig. 13 *a*, *b* (1908).

Hab.—Station 346, Burdwood Bank, 56 fathoms, from Sponge.

Two very young specimens, trochoïd in form, with the upper whorls elegantly spirally lirate, we assign to the above name with a little doubt. The original type came from the West Falklands, lat. 52° 29′ S., long. 60° 36′ W., dredged at 197 metres (STREBEL).

With this occurred *Photinula expansa*, Sowb., and one broken example of a beautifully nacreous shell, which, judging from the figure,* may be *Calliostoma möbiusi*, Strebel. Our specimen is more trochoïd than photinuloid, though it possesses some characters of the latter, and is lightly spirally grooved, these being most conspicuous at the periphery of the body whorl. Dimensions: alt. 10, diam. 12 mm. It likewise may be compared with *Photinula Crawshayi*,† Sm., from Christmas Island, but the whorls are not ventricose. It is unfortunately somewhat broken; the operculum is present, being horny and multispiral.

Sub-order MONOTOCARDIA.

(*a*) **Ptenoglossa.**

Family *Scalidæ*.

Scala magellanica, Phil.

Scalaria magellanica, Philippi, *Archiv für Naturg.*, vol. i. p. 65 (1845).

Hab.—Station 346, Burdwood Bank, 56 fathoms, in Sponge.

Only very imperfect specimens, either very young or broken fragments; enough, however, to identify the species.

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* STREBEL, *Moll. der Magalhaen. Prov.*, ii. p. 133, Taf. v. fig. 22.

† SMITH, *Proc. Malac. Soc. Lond.*, vi. p. 335, fig. 2.

(*b*) Tænioglossa.

Family *Naticidæ*.

Natica impervia, Phil.

Natica impervia, Philippi, *Archiv für Naturg.*, vol. i. p. 65 (1845).

Hab.—Station 346, from Sponge at 56 fathoms.

Only very dead and featureless specimens.

Family *Trichotropidæ*.

Trichotropis antarctica, sp. n. (Plate, fig. 7).

T. testa parva, imperforata, fragili, breviter fusiformi, sordidé alba, anfractibus 6, quorum apicales tres detriti, sublæves, cæteris tenuiter et arcté decussatis, interstitiis quadratulis, ultimo cæteros exsuperante, apertura ovata, labro multum expanso, inflato, margine columellari paullum excavato.

Alt. 5·75, diam. (oris) 3·50 mm.

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

A very interesting form, and we deem it worthy of description, albeit the only specimen is imperfect, and the outer lip infested with growth of a Bryozoon. It seems adult, and is comparable with no other member of the genus known to us. It is much smaller in all its parts than *T. inornata*, Hutton, from New Zealand. There is no sign of umbilication, and the epidermis is not present, being completely worn off.

Calyptræa chinensis, L.

Patella sinensis, Linnæus, *Syst. Nat.*, ed. xii., p. 1257 (1769).
C. sinensis, F. and H., ii. p. 463, pl. lx. figs. 3–5, and (animal), pl. B.B. figs. 8–13.

Hab.—Burdwood Bank, south of the Falkland Islands. Station 346.

Indistinguishable from the shell of northern climes, including Great Britain.

Family *Littorinidæ*.

Littorina (*Lævilitorina*) *caliginosa* (Gould).

Hab.—An additional locality is Cape Pembroke, Falkland Islands, shore, February 2, 1904. Station 349.

Littorina (*Pellilitorina*) *pellita*, v. Mts.

Hab.—Additional locality for this species is Station 346, 56 fathoms, December 1, 1903. Lat. 54° 25′ S., long. 57° 32′ W. Obtained from new species of *Cephalodiscus*, occasionally.

Two more examples of *Lacuna notorcadensis*, M. and St., also occurred from the same locality as the type.

Lacuna abyssicola, sp. n. (Plate, figs. 8, 8*a*, 8*b*).

L. testa parva, profundé umbilicata, albo-calcarea, epidermide brunnea contecta, fragili, vix solida, anfractibus 5, quorum apex ipse miré immersus, duobus his proximis cum penultimis tumidulis, ultimo paullum effuso, lævi, omnibus infrá suturas canaliculatis et acute spiraliter carinatis, apud basim, circá umbilicum, crassi-carinato carinis binis, sulco interstitiali prædito, apertura rotunda, labro tenui, margine columellari laté reflexo.

Alt. 2, lat. 2·15 mm.

Hab.—Deposit No. 38, dredged March 18, 1904. Lat. 71° 22′ S., long. 16° 34′ W., 1410 fathoms. Station 417.

One specimen only, but adult and fairly perfect, save for a slight fracture of the outer lip. It appears nearly akin to *L. nautiliformis*, Jeffreys, or *L. cincta* of the same author, from the Atlantic, collected on the *Porcupine* Expedition, especially as regards the sculpture round the umbilical region, the thickened double carination with interstitial sulcus. Another feature of interest is the curiously immersed nucleus, and the strong canaliculation round the upper portion of each whorl, followed by an acute spiral keel. The substance of the shell is chalky white, covered with a dark-brown epidermis. The specific name proposed is given in consideration of the extreme depth at which it was dredged.

Lacuna wandelensis, E. Lamy.

Lacuna wandelensis, E. Lamy, *Expéd. Antarct. Française commandée par le Dr Jean Charcot: Moll.*, p. 5, pl. i. figs. 5, 6, 7 (Paris, 1906).

Hab.—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms, on *Macrocystis* and other large Fuci.

A very few examples, and all in non-adult condition, belong almost certainly to this species.

Family *Rissoidæ*.

Rissoa deserta, Sm.

Rissoa deserta, E. A. Smith, *Nat. Antarct. Exped.: Nat. Hist.*, vol. ii. p. 9, pl. ii. fig. 1 (1907).

Hab.—South Orkney Islands, Scotia Bay, 9–10 fathoms. Station 325.

The specimens are dead, but seem to agree in form with the above species.

Rissoa (*Onoba*) *filostria*, sp. n. (Plate, fig. 9).

R. testa parva, paullum inflata, solidula, parum rimata, anfractibus $4\frac{1}{2}$, quorum apicales duo læves, tumiduli, cæteris ventricosis, apud suturas impressis, arctissimé spiraliter tenuiliratis, apertura ovata, alba, labro paullum effuso, haud multum incrassato, feré continuo.

Long. 2, lat. 1·50 mm.

Hab.—South Orkney Islands, Scotia Bay, 9–10 fathoms. Station 325.

Allied to several *Onobæ*, mostly described of recent years from deep-sea explorations, such as *R. transenna*,[*] Wats., from Prince Edward Island, and *R. aëdonis*[†] of the same author, from Nightingale Island. *R. gelida*, E. A. Sm.,[‡] is, perhaps, the nearest ally; this is also an Antarctic species, and differs in the possession of an extra whorl, and being longer proportionately to its breadth, also in a lesser degree of ventricosity of whorl. Only two or three examples.

Rissoa (*Onoba*) *fuegoensis* (Strebel).

Rissoa (*? Cingula*) *fuegoensis*, H. Strebel, *Schwed. Sudpolar Exped.*, p. 56, Taf. vi. fig. 90 *a*, *b* (1908).

Hab.—Burdwood Bank, Station 346, 56 fathoms.

A straw-coloured, closely spirally lirate *Rissoa*, which we should consider as appertaining to the section *Onoba* in preference to *Cingula*.

Rissoa (*Onoba*) *paucilirata*, sp. n. (Plate, fig. 10).

R. testa ovata, angusté rimata, alba, epidermide tenuiter evanida straminea, interdum iridescente, contecta, anfractibus ad 5, ventricosulis, apud suturas multum impressis, quorum duo apicales nitidi, albi, læves, cæteris duobus fortiter spiraliter pauciliratis, liris penultimi duâbus, ultimi anfractûs septem vel octo, præditis, apertura ovato-rotunda, peristomate tenui, margine columellari ferè recto.

Alt. 2·25, diam. 1·25 mm.

Hab.—Burdwood Bank, Station 346, 56 fathoms.

Conspicuous for its strong, spiral, carinated liræ, which are fewer in number than those possessed by its allies; these spiral ridges seem much the same in the Aleutian species *R. Aurivillii*, Dall, § or *R. brachia*, Watson, ‖ from Culebra Island, West Indies. This last, indeed, seems a very near ally, though quite distinct.

Rissoa (*Onoba*) *sulcata* (Strebel).

Rissoa (*Cingula*) *sulcata*, H. Strebel, *Schwed. Sudpolar Exped.*, p. 56, Taf. vi. fig. 86 *a*, *b*, *c* (1908).

Hab.—With the last species named, at 56 fathoms. Station 346. One specimen.

The spiral sulci are interesting. In form it resembles *R. paucilirata*, but the essential characters are quite diverse. Colour inclined to reddish-fuscous.

Rissoa (*Ceratia*) *turqueti*, E. Lamy.

Rissoa (*Ceratia*) *turqueti*, E. Lamy, *Expéd. Antarct. Française Charcot*, p. 6, pl. i. fig. 8 (1906).

Hab.—With the preceding. One fine specimen in live condition, sub-pellucid, with faint relics of thin stramineous epidermis. Station 346.

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[*] *Rep. Challenger Exped.*, xv. p. 620, pl. xlvi. fig. 10.

[†] *Ibid.*, p. 600, pl. xlv. fig. 5.

[‡] Smith, *Nat. Ant. Exped.: N.H.*, vol. ii. p. 9, pl. ii. fig. 5.

§ *Proc. U.S. Nat. Mus.*, p. 309, pl. iv. fig. 8 (1886).

‖ *Rep. Challenger Exped.*, xv. p. 599, pl. xlv. fig. 8.

Eatoniella kerguelenensis, Sm., forma *major*, Strebel.

Eatoniella kerguelenensis, Smith, forma *major*, Hermann Strebel, *Schwed. Sudpolar Exped.*, p. 57, Taf. iv. fig. 56 *a–c* (1908).

Hab.—Station 325, Scotia Bay, South Orkneys, 9–10 fathoms.

This larger form of a mollusc already reported by us, in our former paper, as occurring, in its typical condition, at Scotia Bay, South Orkneys, has likewise been discovered in some quantity in Bay A, of greater size and solidity, often encrusted with bryozoic and other growths. Colour very deep plumbeous.

Family *Cerithiidæ*.

Cerithium pullum, Phil. (= *cælatum*, Couthouy).

Hab.—An additional locality is now given for this species, to that mentioned on p. 135 of our former paper, viz. Burdwood Bank, lat. 54° 25′ S., long. 57° 32′ W., in sponge. Station 346.

We do not repeat the synonymy, which will be found at the page just quoted.

Bittium brucei, sp. n. (Plate, fig. 11).

B. testa minuta, solidula, cylindrica, castaneo-brunnea, anfractibus ad 8, apicalibus . . . . (?), cæteris apud suturas impressis, supernis bino, ultimo trino odine granulato regulariter prædito, apud basim excavato, planato, apertura ovata, labro simplice, margine columellari crassiusculo.

Long. 2·75, lat. 1 mm.

Hab.—Dredge, Station 81, lat. 18° 24′ S., long. 37° 58 W., 36 fathoms.

A minute Cerithioid mollusc, which seems as if it should belong to the sub-genus *Joculator*, Hedley,[*] proposed for *Cerithiopsis ridicula*, Watson, and certain allies. At the same time it is so like *Bittium minimum*, T. Woods, well figured from a Tasmanian specimen by C. HEDLEY,[†] that it had better be included in that genus.

Bittium burdwoodianum, sp. n. (Plate, fig. 12).

C. testa fusiformi, brunneo-rufescente, parva, anfractibus ad 10, quorum apicales tres rufescentes, parum nitidi, læves, vel simpliciter longitudinaliter costulati, cæteris ad suturas multum impressis, trino ordine gemmarum, ultimo quatuor ordinibus similibus, regulariter spiraliter præditis, apertura ovata, labro paullum effuso, columella flexuosa.

Alt. 4, diam. 1 mm.

Hab.—From interior of *Liothyrina.* Station 346, Burdwood Bank, at 56 fathoms, December 1, 1903.

A little species, of simple character, inclined to a reddish hue, particularly as regards the apex and central portion of the various whorls, which are thrice spirally girt with regular rows of close grains, gemmulate and rounded. This might be considered a *Cerithium* by some authors. It is akin to *B. bisculptum*,[‡] Strebel, the apical whorls seemingly almost identical, and we consider these two species should stand in the same genus.

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[*] *Proc. Linn. Soc. N.S. Wales* (1909), p. 442.

[†] *Ibid.* (1909), p. 722, fig. 20.

[‡] *Schwed. Sudpolar Exped.*, p. 49, Taf. vi. fig. 92 *a–b* (1908).

Cerithiopsis macroura, sp. n. (Plate, fig. 13).

C. testa elongato-fusiformi, parva, angusta, nitida, albo straminea, anfractibus ad 10, quorum apicales duo vel tres nitidi, vitrei, perlæves, bulbosi, cæteris paullum ventricosis, apud suturas impressis, undique longitudinaliter arcte costulatis, costulis anfractuum superiorum pro maxima parte lævissimis, quatuor ultimis anfractibus spiraliter rugoso-liratis, liris ad juncturas costularum granulosis, apertura ovata, labro tenui, columella paullum producta, flexuosa, brevirostri.

Alt. 3·55, diam. 1 mm.

Hab.—Station 346, Burdwood Bank, 56 fathoms.

A small species, but distinguished, as the specific name chosen would show, by its very attenuate, fusiform whorls, the last three or four swollen, caudate, shining, smoothly costulate, not spirally crossed with granose liræ, as are the lower whorls; the columella is only slightly rostrate, the outer lip thin, the colour whitish straw. But few examples occurred. (μάκρος οὔρα, long-tailed.)

Cerithiopsis malvinarum, M. and St.

Cerithiopsis malvinarum (Strebel, MS.), Melvill and Standen, *Trans. Roy. Soc. Edin.*, xlvi. pt. i., p. 135, pl. figs. 6, 6*a*. (1907).

" " Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 49, Taf. i. fig. 10 *a–c* (1908).

Hab.—Shore, Hearnden Water, Falkland Islands. Station 349.

As mentioned in our first paper, we issued a description of this species in 1907, using, at Dr H. Strebel's request, the name he had given it in manuscript. The following year it was redescribed by him as "sp. nov.," and we are of opinion that he had not at that time seen our paper. The same remarks would apply also to *Trophon minutus*, M. and S.

Family *Turritellidæ*.

Turritella algida, sp. n. (Plate, fig. 14).

T. testa parva, attenuato-fusiformi, alba vel pallidé straminea, solidula, anfractibus ad 9–10, ad suturas multum impressis, quorum apex ipse bulbosus, albus, lævis, vitreus, huic proximus anfractus simili modo tumidus, lævis, cæteris ad medium unicarinatis, carinis acutis, prominulis, antepenultimo et penultimo lira alia minore infra medium præditis, ultimo inter carinam majorem et basim trilirato, apertura ovata, labro tenui.

Long. 6, lat. 2 mm.

Hab.—Trawl, Burdwood Bank, south of the Falklands, at 56 fathoms. Station 346.

Very small, but apparently quite adult. Conspicuous for a distinct and prominent median keel, the three last whorls also being provided with a minor spiral lira below, and the body whorl, between the strong median keel and the base, possessing three such spiral lirations.

Mathilda rhigomaches, sp. n. (Plate, fig. 15).

M. testa minuta, imperforata, fusiformi, delicata, pallidé fuscescente, anfractibus 6½, quorum apicales 2¼ heterostrophi, albi, læves, bulbosi, cæteris apud suturas impressis, pulchré spiraliter carinatis, carinulis tribus anfractuum superiorum, ultimo quatuor, arctissimé lirulis longitudinalibus decoratis, interstitiis quadratis, apertura rotunda, labro tenui, margine columellari paullum excavato.

Long. 2, lat. 1 mm.

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

In sculpture this little species resembles a *Lovenella*, especially *L. austrina*, Hedley,* from the opposite shores of Antarctica. It is only about a quarter of the size, however, of this shell, while the apex is heterostrophe, the peristome continuous. FISCHER (*Man. de Conch.*, p. 172, 1887) gives a list of Magellanic Mollusca, and includes a "*Mathilda magellanica.*" This is evidently a "nomen nudum." No description can be found, and the name rests on no authority. The remarks of M. DE BOURY † will probably, in connection with this, be found of interest. (*ῥιγομάχης*, contending with cold.)

(*c*) **Gymnoglossa.**

Family *Eulimidæ.*

Eulima antarctica, Strebel.

Eulima antarctica, H. Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 65, Taf. vi. fig. 91 *a–c* (1908).

Hab.—Trawl, Burdwood Bank, south of the Falkland Islands, 56 fathoms. Station 346.

One specimen, live, but hardly full-grown.

Family *Pyramidellidæ.*

Turbonilla smithii, Pfeffer.

Turbonilla smithii, G. Pfeffer, MS. in H. Strebel, *Mollusk. der Magalhaen. Prov.*, p. 659, Taf. xxiii. fig. 42 *a–d* (1905).

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

One example, immature, but with sufficient characters to pronounce fairly certainly.

Turbonilla xenophyes, sp. n. (Plate, figs. 16, 16*a*).

T. testa aciculato-fusiformi, delicata, subpellucida, albo-lactea vel pallidé straminea, paullum nitente, anfractibus 9, quorum apicales bulbosi, tumidi, leniter heterostrophi, cæteris ventricosulis, ad suturas impressis, sub lente delicatissimé longitudinaliter liratis, in speciminibus quibusdam feré vel omnino lævibus, apertura ovata, peristomate tenui, columella simplice.

Long. 2·75, lat. ·75 mm.

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* *Report Brit. Antarct. Exped.*, 1907–9 (Shackleton), vol. ii., part i. p. 5 (pl. i. fig. 7) (1911).

† *Journ. de Conch.*, vol. xxxi. p. 118 (1883).

Hab.—Trawl, Burdwood Bank, south of the Falkland Islands, 56 fathoms. Station 346.

A curious species, and one of which we are not quite sure of the proper position generically. It seems, however, to agree with *Turbonilla* in more than one feature. It is very delicate, resembling a terrestrial *Opeas* or others of the family Stenogyridæ, both in substance and form. Several examples occurred, the live specimens retaining a subpellucid appearance and dull straw-colour. (ξενοφύης, strange of form.)

(*d*) **Rachiglossa.**

Family *Muricidæ.*

Trophon falklandicus, Strebel.

Trophon falklandicus, H. Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 39, Taf. i. fig. 8 *a–c* (1908).

Hab.—Burdwood Bank, at 56 fathoms. Station 346.

Very young specimens are probably referable to this species. Another, judging alone from the plate (Strebel, *Zool. Jahrbuch*, Band xxi., Taf. vii. fig. 56, 1904), might belong to *T. Paessleri*, Streb. We cannot, however, help feeling that too many species have been created in such a variable assemblage as this section of the genus *Trophon* presents.

Trophon minutus, M. and St.

Trophon minutus (Strebel, MS.), Melvill and Standen, *Trans. Roy. Soc. Edin.*, xlvi., pt. i., p. 137, pl. figs. 7, 7*a* (1907).

„ „ Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 44, Taf. iv. fig. 47 *a*, *b* (1908).

Hab.—An additional locality to that mentioned in our former paper is Scotia Bay, South Orkneys, at 9–10 fathoms. Station 325.

Three or four more examples occurred, but the species is evidently rare. For the nomenclature of this species, and its authorship, see remarks under *Cerithiopsis malvinarum.*

Trophon philippianus, Dkr.

Hab.—Also from Burdwood Bank, at 56 fathoms, all the specimens being in very young condition, and found in Sponge. Station 346.

Antistreptus magellanicus, Dall.

Antistreptus magellanicus, W. H. Dall, *Proc. U.S. Nat. Mus.*, xxiv. p. 532 (1902).

„ „ Dall, *Bull. Mus. Comp. Zool. Harvard*, vol. xliii. p. 315, pl. xv. fig. 14 (1905).

Glypteuthria contraria, H. Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 29, pl. i. figs. 4 *a–c* (1908).

Hab.—Burdwood Bank, Station 346, at 56 fathoms.

Two examples of this small, but curious, sinistral species.

Family *Buccinidæ.*

Chrysodomus (*Sipho*) *crassicostatus*, M. and St.

Chrysodomus (*Sipho*) *crassicostatus*, Melvill and Standen, *Trans. Roy. Soc. Edin.*, vol. xlvi. part i., p. 138, pl. figs. 10, 10*a* (1907).

Sipho (? *Mohnia*) *astrolabiensis*, H. Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 31, Taf. iii. fig. 37 *a–d* (1908).

One specimen of *Sipho astrolabiensis* occurred in lat. 63° 9′ S., long. 58° 17′ W., at Astrolabe Island.

From the figure, there can be no doubt of its identity with our *S. crassicostatus*, described the year previously (1907). More examples came to hand from the locality already given by us, viz. Scotia Bay, South Orkneys, at 9–10 fathoms, Station 325; and we have now seen it likewise from Burdwood Bank, at 56 fathoms, Station 346.

Euthria rosea, Homb. and Jacq.

Euthria rosea, Hombron et Jacquinot, *Voyage au Pôle Sud*, v. p. 107, tab. xxv. figs. 4, 5.

" " Strebel, *Mollusk. der Magalhaen. Prov.*, p. 616, Taf. xxi. figs. 1–4 (1905).

Hab.—Burdwood Bank, from Sponge, at 56 fathoms. Station 346.

Family *Mitridæ.*

Mitra (*Volutomitra*) *porcellana*, sp. n. (Plate, fig. 21).

M. (V.) testa eleganter fusiformi, nitidissima, candida, porcellana, anfractibus ad 6 (?), apicalibus . . . ? cæteris nequaquam suturaliter impressis, politissimis, ultimo prolongato, apertura angusté oblonga, labro tenui, columella obliquante, quadriplicata, plicis obliquis.

Long. 14, lat. 6 mm. (sp. imperfecta).

Hab.—Scotia Bay, South Orkneys, 9–10 fathoms, Station 325; also trawl, Burdwood Bank, 56 fathoms, Station 346.

Only two examples of this beautiful, polished white porcellanous shell have as yet occurred, one from each locality, widely differing from other *Volutomitræ* known to us; its narrow aperture, obliquely quadriplicate columella, are distinguishing characteristics. Very unfortunately, in neither specimen, owing to breakage, do the apical whorls appear, so several points remain for the present a matter of conjecture.

(*e*) **Toxoglossa.**

Family *Conidæ.*

Bela anderssoni, Strebel.

Bela anderssoni, H. Strebel, *Schwed. Sudpolar Exped.*, p. 14, Taf. ii. fig. 24 *a-d* (1908).

Hab.—Station 346, at 56 fathoms, December 1, 1903.

Judging from figure and description quoted above, this interesting *Bela* is identical with specimens found at Seymour Island, Grahamland, by the Swedish expedition.

Bela fulvicans, Strebel.

Bela fulvicans, H. Strebel, *Schwed. Sudpolar Exped.*, p. 15, Taf. ii. fig. 25 *a–d* (1908).

Hab.—Burdwood Bank, from Sponge, at 56 fathoms. Station 346.

An imperfect, bleached specimen seems, from the sculpture, to be the above species, which occurred both in South Georgia Islands and in Grahamland.

? *Thesbia* sp.

Hab.—Burdwood Bank, from Sponge, at 56 fathoms. Station 346.

One example, more imperfect than the preceding, of a bleached shell, showing faint flexuous oblique longitudinal costellation, mouth narrow oblong, whorls fairly smooth, hardly impressed at the sutures. Dimensions: long. 13, lat. 5 mm. It is quite impossible to differentiate it further.

Savatieria concinna, sp. n. (Plate, fig. 17).

S. testa ovato-fusiformi, compacta, solidula, subpellucente, albida, anfractibus 6, quorum apicales duo bulbosi, vitrei, nitidi, perlæves, cæteris apud suturas impressis, subventricosis, longitudinaliter arctè costulatis, costis crassiusculis, gemmatis, ultimo anfractu infra medium evanidis, deinde ad basim spiraliter sulculoso, numero costularum anfractus ultimi circa 22, apertura ovata, labro simplice, columella parum incrassata, canali vix prolongata.

Long. 4·55, lat. 2 mm.

Hab.—Trawl, Burdwood Bank, Station 346, 56 fathoms, December 1, 1903.

Savatieria is a small genus, peculiar to these regions, diagnosed by ROCHEBRUNE and MABILLE. It is nearly allied to *Bela*, differing principally in the abbreviated canal, whorls peculiarly impressed suturally, and more distinct elaboration of sculpture. Several species have lately been published by Dr HERMANN STREBEL, and to one of them, *S. molinæ*, our species is akin, differing mainly in sculpture, being supplied with nearly double the number of longitudinal ribs, while the gemmate beading is more pronounced in *S. concinna*. Only one example, happily in first-class condition at the time of description, was procured, though unfortunately it was accidentally broken at the mouth before it could be figured. We consider that *Lachesis meridionalis*, E. A. Sm.,* is synonymic with *Savatieria molinæ*, Strebel, 1905, and has priority of twenty-four years over it.

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* *Proc. Zool. Soc. Lond.*, 1881, p. 28, pl. iv. fig. 3.

Family *Cancellariidæ*.

Paradmete typica, Strebel.

Paradmete typica, H. Strebel, *Schwed. Sudpolar Exped.*, Band vi., 1, p. 22, Taf. iii. fig. 35 *a–f* (1908).

Hab.—Burdwood Bank, Station 346, at 56 fathoms, December 1, 1903.

Thus showing a considerable extension in range. Only one specimen, but in good condition.

Admete limneæformis, Sm.

?*Admete limneæformis*, E. A. Smith, *Phil. Trans. Roy. Soc. Lond.*, clxviii. p. 172, pl. ix. fig. 4 (1879).

Hab.—Trawl, Burdwood Bank, at 56 fathoms. Station 346.

One example, in good condition, exactly agreeing with the type, from Kerguelen Land. We should hardly be prepared to suggest placing this in Dr STREBEL's new genus *Paradmete.* Mr CHARLES HEDLEY has lately hinted at its possible reception into the genus *Odostomiopsis*, Thiele, and this is well worthy of consideration. The shell is small, white, semi-transparent, and, as the trivial name, so well chosen, suggests, almost an exact reproduction of *Limnæa peregra*, Müll., in miniature.

Order OPISTHOBRANCHIATA.

Sub-order TECTIBRANCHIATA.

(*a*) **Bulloidea.**

Family *Tornatinidæ*.

Retusa antarctica, sp. n. (Plate, fig. 20).

R. testa delicata, parva, ovato-fusiformi, rimata, pallidissimé livido-virescente, perlævi, subpellucida, anfractibus 4, quorum apicales duo tumescentes, cæteris ad suturas rotundé gradatim impressis, ultimo magno, lævi, apertura ovata, labro sinuato, vix crassiusculo, columella obliqua.

Alt. 3·25, diam. 1·75 mm.

Hab.—Scotia Bay, South Orkneys, 9–10 fathoms. Station 325.

A small, plain, greenish-livid species, translucent, very smooth, with swollen nuclear whorls, and roundly shouldered at the sutures.

Retusa truncatula (Brug.).

This widely distributed species, the full synonymy of which we gave in our last paper (*loc. cit.*, p. 141), and which is hardly distinguishable from the British form, also occurred at the Burdwood Bank locality, Station 346, 56 fathoms.

Fragments of others of this order, belonging to the genera *Cylichna* and *Philine*, were dredged either from the same or neighbouring localities, but none in a condition to examine seriously.

Sub-order PTEROPODA.

Section **Thecosomata**, de Blainville.

Cavolinia tridentata (Forskål).

1773. *Anomia tridentata*, Forskål, *Descriptiones animalium quæ in itinere orientali observavit*, p. 124.
1791. *Cavolinia natans*, Abildgaard, "Nyere Efterretning om det Skaldyr som Forskål har beskrevet under Navnet Anomia tridentata," *Skriv. naturhist. Selsk.*, Bd. i., Heft 2, pl. x.
1801. *Hyalæa cornea*, Lamarck, *Système des animaux sans vertèbres*, p. 140.
1804. *Hyalæa papilionacea*, Bary de St Vincent, *Voyage dans les quatre principales îles des mers d'Afrique*, t. i. p. 137, pl. v. fig. 1.
1810. *Hyale teniobranche*, Péron et Lesueur, "Histoire de la famille des Mollusques Ptéropodes," *Ann. Mus. Hist. Nat. Paris*, t. xv., pl. ii. fig. 13.
1813. *Hyalæa peroni*, Lesueur, "Mémoire sur quelques animaux mollusques, etc.," *Nouv. Bull. Soc. Philom.*, t. iii. p. 284.
1813. *Hyalæa chemnitziana*, Lesueur, *ibid.*, p. 284.
1816. *Hyalæa australis*, Péron, *Voyage de découvertes aux terres australes*, t. i., pl. xxxi. fig. 5 (*sine descriptione*).
1821. *Hyalæa forskahlii*, Lesueur, MS., in de Blainville, "Hyale," *Dict. d. Sci. Nat.*, t. xxii. p. 79.
1836. *Hyalæa affinis*, d'Orbigny, *Voyage dans l'Amérique méridionale*, t. v. p. 91, pl. v. figs. 6–10.
1848. *Hyalæa truncata*, Krauss, *Süd-africanische Mollusken*, p. 34, pl. ii. fig. 12 (*non* Lesueur).
1859. *Cavolinia telemus*, A. Adams, "On the Synonyms and Habits of Cavolinia, Diacria, and Pleuropus," *Ann. and Mag. Nat. Hist.*, ser. 3, t. iii. p. 44.
1877. *Hyalæa cumingii*, Sowerby, in Reeve, *Conchologia iconica*, t. xx., Pteropoda, fig. 5.

Hab.—Lat. 39° 58′ S., long. 8° 36′ W., tow-net, surface, temp. 55°·2. Many living specimens, large and fine. Between Stations 470 and 471.

Class SCAPHOPODA.

Dentalium eupatrides, M. and St.

Dentalium eupatrides, Melvill and Standen, *Trans. Roy. Soc. Edin.*, vol. xlvi., part i., p. 142, pl. fig. 12 (1907).

Hab.—The original locality of this fine smooth abyssal species was accidentally omitted in our first paper. It occurred, with the other species chronicled, *D. megathyris*, Dall, in lat. 71° 22′ S., long. 16° 34′ W., at 1410 fathoms, Station 417. Many fragmentary portions of probably the same shells have been dredged up from Station 420, at 2620 fathoms.

Dentalium megathyris, Dall.

Dentalium megathyris, Dall, *Proc. U.S. Nat. Mus.*, xii. p. 293, pl. ix. fig. 1 (1889).
„ „ Stearns, *Proc. U.S. Nat. Mus.*, xvi. p. 424 (1893).

Hab.—Lat. 71° 22′ S., long. 16° 34′ W., 1410 fathoms. Station 417.

In our first report we allocated a large Dentalium dredged from 1410 fathoms to *D. Shoplandi*, Jouss., as it agreed with specimens so named in the British Museum from "near Aden." We have since received from the same station a large fragment of the upper part of a living specimen, evidently snapped off by the dredge, and a number of smaller fragments. Critical examination of these has led us to conclude that our specimens are identical with *D. megathyris*, Dall, which has occurred off Chiloe Island and south-east Chili in 1050 and 1342 fathoms, in the Gulf of Panama in 2282 fathoms, and other localities in the Panamic region. It is significant that in company with this Dentalium, both in the Gulf of Panama and in the 1410 fathoms locality, the Brachiopod, *Macandrevia diamantina*, Dall, should also occur. The descriptions and figures of *D. megathyris* and *D. Shoplandi*, as given by Tryon, are so widely different in every respect, both as to dimensions and sculpture, and other minor details, that although our specimens agree so well with the British Museum examples purporting to come from Aden, we now are inclined to refer them to *D. megathyris*, as, even if this species should ultimately be proved to be an extreme form of *D. Shoplandi*, that specific name would become a synonym—*D. megathyris*, Dall, having priority of five years. From a careful study of the material and literature at our command we cannot help thinking that *D. megathyris*, Dall, *D. Shoplandi*, Jouss., *D. ceras*, Watson, and perhaps *D. majorinum*, Rocheb. and Mab., may eventually prove to be but forms of one variable gigantic longitudinally costate Dentalium in the southern hemisphere, radiating towards the Atlantic as well as the Pacific Ocean, and inhabiting everywhere very deep water, where the great pressure, darkness, and equable temperature render it possible for it to range through many degrees of latitude.

Class PELECYPODA.

Order PROTOBRANCHIATA.

Family *Nuculidæ*.

Yoldia profundorum, sp. n. (Plate, figs. 18, 18*a*, 18*b*).

Y. testa parva, tumida, nitida, lævi, inæquilaterali, periostraco plumbeo-olivaceo contecta, anticé rotundata, posticé paullulum producto, umbonibus erosis, approximatis, haud prominulis, ligamento obscuro, lineari, cardinibus utriusque valvæ decem denticulis utrinque præditis, pagina interna nitida, albo-lactea, sinu palliali parvo.

Alt. 3, lat. 4·50 mm.

Hab.—Deposit No. 38, dredged March 18, 1904, lat. 71° 22′ S., long. 16° 34′ W., 1410 fathoms. Station 417.

A small, tumid, smoothish, slightly inequilateral *Yoldia*, the anterior side rounded, the posterior somewhat produced, to which *Y.* (*Sarepta*) *abyssicola*, Smith,* from Station 246, Challenger Expedition, Mid North Pacific, at 2050 fathoms, and also Station 281, Mid South Pacific, at 2385 fathoms, seems somewhat allied. That species, however, appears more distinctly abbreviate posteriorly, and higher in proportion to its width. *Y. ecaudata*, Pelseneer,† may likewise be compared, a species which is closely akin to *Y. abyssicola*. This was obtained during the voyage of the *Belgica* in the Antarctic region, at a depth of 400–500 metres. Again, *Y. Valettei*, Lamy, from the South Orkneys, where an example was found in the stomach of a penguin, is much of the same outward form, but less than half the dimensions (2·2 × 1·65 × 1·5 mm.), and the teeth are only six in number on either side. The epidermis is likewise named as "flava" in contradistinction to "plumbea" or "olivacea."

Nucula pisum, Sowb.

Nucula pisum, Sowerby, *Thes. Conch.*, iii. p. 153, pl. ccxxix. fig. 133.

Hab.—Falkland Islands, local, but gregarious. Station 118.

Order FILIBRANCHIATA.

Sub-order ARCACEA.

Family *Arcidæ*.

Arca (*Bathyarca*) *strebeli*, M. and St.

Arca (*Bathyarca*) *strebeli*, Melvill and Standen, *Trans. Roy. Soc. Edin.*, vol. xlvi., part i., p. 144, pl. figs. 13, 13*a* (1907).

Hab.—Two additional localities can be now given, as follows:—

Station 420. Dredged at 2620 fathoms. One specimen.
,, 291. Lat. 67° 33′ S., long. 36° 35′ W., 2500 fathoms, March 7, 1903.

Limopsis longipilosa, Pels.

Limopsis longipilosa, P. Pelseneer, *Voy. du S.Y.* "*Belgica*": *Zoologie*, p. 25, figs. 89, 90 (1903).

Hab.—Dredged in lat. 71° 22′ S., long. 16° 34′ W., at 1410 fathoms, March 18, 1904. Station 417.

One fairly perfect specimen, probably referable to the above.

[Very imperfect examples of another *Limopsis*, solid, small, equilateral, covered with thin, short-bristled epidermis, also occurred at Burdwood Bank, 50 fathoms.]

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* *Rep. Challenger Expedition*, "Lamellibranchia," pl. xx. figs. 6, 6*a*, 6*b*.

† *Voy. du S.Y.* "*Belgica*": *Zoologie*, par PAUL PELSENEER, p. 22, figs. 77, 78 (1903).

Sub-order MYTILACEA.

Family *Mytilidæ.*

Philobrya sublævis, Pels.

Philobrya sublævis, P. Pelseneer, *Voy. du S.Y.* "*Belgica*" *: Zoologie*, p. 25, figs. 93, 94 (1903).

Hab.—Station 346, lat. 54° 25′ S., long. 57° 32′ W., at 56 fathoms, January 1, 1903.

Philobrya wandelensis, Lamy.

Philobrya wandelensis, E. Lamy, *Expéd. Antarct. Française Charcot*, 1903–5, p. 16, pl. i. figs. 15, 16 (1906).

Hab.—Trawl, Burdwood Bank, 56 fathoms. Station 346.

Crenella decussata, Mont.

Mytilus decussatus,		Montagu, *Test. Brit. Suppl.*, p. 69 (1809).
,,	,,	Forbes and Hanley, ii. p. 210, pl. xlv. fig. 2.
Crenella	,,	Jeffreys, *Brit. Conch.*, ii. p. 133, *V.*, pl. xxviii. fig. 6.
,,	,,	Sowerby, *Ill. Index Brit. Shells*, pl. vii. fig. 17.

Hab.—Burdwood Bank, south of the Falkland Islands, at 56 fathoms, December 1, 1903. Station 346.

Very minute specimens, not exceeding 2 × 2 mm., the interior beautifully pale-nacreous; form precisely that of the European and Canadian type, the divaricating sculpture seemingly also identical, as well as the fine marginal crenellations.

Modiolarca mesembrina, M. and St.

Modiolarca mesembrina, Melvill and Standen, *Trans. Roy. Soc. Edin.*, vol. xlvi., part i., p. 146, pl. figs. 15, 15*a* (1907).

Modiolarca picturata, Cooper and Preston, *Ann. and Mag. N. Hist.*, ser. viii, vol. v., pl. iv. fig. 5 (1910).

Hab.—Falkland Islands. Station 118.

We received lately from Mr A. P. COBB examples of *M. picturata*, Cooper and Preston, and consider it the same as our *mesembrina*, from the same locality, described three years previously. In marking and coloration it is a most variable species: in form it is fairly constant.

Order EULAMELLIBRANCHIATA.

Sub-order SUBMYTILACEA.

Family *Carditidæ.*

Carditella pallida, Sm.

Carditella pallida, E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 43, pl. v. figs. 9, 9*b* (1881).

var. *duodecim-costata*, nov. (Plate, figs. 19, 19*a*).

Hab.—Station 346, Burdwood Bank, at 56 fathoms. Many full-grown specimens, but few perfect.

In all the specimens examined of our proposed variety, the ribs are but twelve in number; in typical *C. pallida*, Sm., they number fourteen to fifteen. The straight angular declivity on either side of the dorsal margin seems likewise more pronounced, the variety thereby assuming a more flabellate or quasi-triangular appearance. The general characters of the shells are identical. As Mr SMITH aptly remarks, the superficial aspect of *Cardita flabellum*, Reeve,* proves it to be nearly allied. This is a native of Valparaiso, Chili.

Cardita congelascens, sp. n. (Plate, fig. 23).

C. testa parva, trapezoide, solidula, umbonibus prominulis, inæquilaterali, æquivalvi, posticé dorsaliter recta, anticé breviter arcuata, deinde ventralem usque ad marginem, leniter subrotundata, superficie radiatim costulata, costulis incrassatis, numero ad 21, pulchré et regulariter nodulosis, nodulis imbricatulis, albis, nitidis pagina intus alba, valva dextra, cardinalibus dentibus duobus crassis, sinistra dente crasso, elongato, præditis.

Alt. 3, diam. 4 mm. (sp. maj.).

Hab.—Burdwood Bank, south of the Falkland Islands, at 56 fathoms. Station 346.

Only disassociated valves occurred of a species of *Cardita* which seems distinct. We have compared it with *C. modesta*, *velutina*, *antarctica*, *astartoides*, and other species of the genus inhabiting these same southern waters, and find it fails exactly to correspond with any of them. At the same time, we doubt if any of our examples are adult. Still, the character of the ribs, and the ornamentation and the general contour of the shell, give us hope that it may be proved eventually to have been established on a sound basis. The specific name alludes to the icy clime where it is endemic.

Family *Astartidæ*.

Astarte magellanica, Sm.

Astarte magellanica, E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 41, pl. v. fig. 7 (1881).
,, ,, ,, *Journ. of Conch.*, iii. p. 227.

Hab.—Burdwood Bank, south of the Falkland Islands, at 56 fathoms. Station 346.

All disassociated valves, but some in good condition, and showing the olivaceous epidermis. The majority possess fewer concentric ribs than the type, but we consider them all referable to *magellanica*. The allied *A. longirostra*, Orb., also found in this region, is more pronouncedly beaked, and the ribbing is far finer. The crenulation of the inner margin of the valves is, as pointed out by the author of the species, another distinctive factor in *A. magellanica*.

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* Reeve, *Conch. Icon.*, i., Cardita, pl. ix. fig. 47 (1843).

Family *Lucinidæ*.

Diplodonta lamellata, Sm.

Diplodonta lamellata, E. A. Smith, *Proc. Zool. Soc. Lond.*, p 38, pl. v. figs 1–1 *c* (1881).

Hab.—Burdwood Bank, south of the Falkland Islands, at 56 fathoms. Station 346.

A right and left valve, hardly adult, but showing the characteristic generic dentition, as well as the concentric lamellar ornamentation, which led to the bestowal of the trivial name. These lamellæ appear in our small specimens more numerous, but we can but believe them identical, as they agree in form, and every other detail. The type was discovered during the survey of H.M.S. *Alert* in the Straits of Magellan and Patagonian coast.

Cyamium denticulatum, Sm.

Cyamium denticulatum, E. A. Smith, *Nat. Antarct. Exped.: Nat. Hist.*, vol. ii. p. 3, pl. iii. figs. 4, 4*b* (1907).

Hab.—Burdwood Bank, 56 fathoms. Station 346.

A curious though minute species, conspicuous for its marginal denticulation and radiating impressed lines, which are seen more clearly with the aid of a lens.

Cyamium falklandicum, M. and St.

Cyamium falklandicum, Melvill and Standen, *Journ. of Conch.*, ix. p. 104, pl. i. fig. 12 (1898).

? *Cyamium iridescens*, Cooper and Preston, *Ann. and Mag. N.H.*, ser. viii., vol. v. p. 112, pl. iv. fig. 6 (1910).

This is a variable species, and we consider *C. iridescens*, Coop. and Prest., probably one of its extreme forms. We have examined a large number of examples, in all stages of growth. The specimens collected at Hearnden Water, Station 349, are as iridescent as those so named by Messrs COOPER and PRESTON.

Family *Erycinidæ*.

Kellyia cycladiformis (Desh.).

Erycina cycladiformis, Deshayes, *Trait. élém.*, pl. xi. figs. 6–9; *Proc. Zool. Soc. Lond.*, p. 181 (1855).

Hab.—Burdwood Bank, at 56 fathoms. Station 346.

We have already recorded this (*loc. cit.*, p. 149), but it is worthy of record that nearly all the subsequent specimens from the same locality that have since come into our hands were found living inside the valves of defunct Brachiopoda, and are therefore in first-class condition. *Saxicavæ* occurred with them.

Kellyia magellanica, Sm.

Kellyia magellanica, E. A. Smith, *Proc. Zool. Soc. Lond.*, p. 41, pl. v. figs. 6, 6 *a*, *b* (1881).

Hab.—Burdwood Bank, with *K. cycladiformis* (Desh.). Station 346. Only one perfect valve, agreeing exactly with the figure 6*a* above quoted.

Davisia cobbi, Coop. and Prest.

Davisia cobbi, J. E. Cooper and H. B. Preston, *Ann. and Mag. N. Hist.*, ser. viii., vol. v. pp. 113, 114, pl. iv. figs. 9, 10 (1910).

Hab.—Burdwood Bank, Station 346, at 56 fathoms.

A small species with peculiar hinge. It would be unfortunately impossible, from the very indistinct photogravure plates, to tell the generic characteristics, and we wish it had been possible to figure both this and the *Malvinasia*, described at the same opportunity, in a more satisfactory fashion.

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[*Rossia patagonica, Loligo patagonica, Onychoteuthis ingens, Pleurotoma* (*Bela*) *Cunninghami, Pl.* (*Mangilia*) *Coppingeri, Lachesis meridionalis, Euthria atrata, E. meridionalis, Nassa* (*Tritia*) *Coppingeri, Lamellaria patagonica, Collonia Cunninghami, Trochus* (*Zizyphinus*) *consimilis, Tectura* (*Pilidium*) *Coppingeri, Chiton* (*Ischnochiton*) *imitator, Diplodonta lamellata, Mactra* (*Mulinia*) *levicardo, Loripes pertenuis, Kellia magellanica, Astarte magellanica, Cardita* (*Actinobolus*) *velutina, Carditella* (n. g.) *pallida*, spp. nov. marinæ.]

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[*Tugalia antarctica, Littorina* (*Lævilitorina*) *coriacea, Lacuna notorcadensis, Rissoa Edgariana, R. scotiana, Cerithiopsis malvinarum, Trophon minutus, Nassa* (*Ilyanassa*) *Vallentini, Chrysodomus* (*Sipho*) *archibenthalis, C.* (*Sipho*) *crassicostatus, Columbarium benthocallis, Dentalium eupatrides, Arca* (*Bathyarca*) *Strebeli, Lissarca notorcadensis, Modiolarca mesembrina, Pecten pteriola, Amussium* 18-*liratum, Lima goughensis, Kellia Lamyi* (nom. nov.), *Cuspidaria Brucei, Scacchia plenilunium, Pecten multicolor*, spp. n.]

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[New species of genera *Actæonina, Retusa, Cylichnina, Anderssonia, Philine, Bela* 6 spp., *Surcula, Mangilia, Pleurotomella, Admete, Paradmete* n. g. 3 spp., *Ancillaria, Glypteuthria, ? Sipho* 2 spp., *Neobuccinum, Pfefferia* n. g. 4 spp., *Trophon* 4 spp., *Bittium* 3 spp., *Cerithiopsis, Rissoia* 5 spp., *Eatoniella, Natica* 3 spp., *Scalaria, Volutaxiella* n. g. 2 spp., *Eulima, Odostomia, Calliostoma* 5 spp., *Photinula, Promargarita* n. subgen., *Submargarita* n. subgen., *Margarita* 2 spp., *Cyclostrema, Scissurella, Thilea.*]

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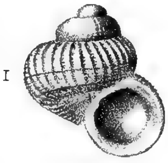
EXPLANATION OF PLATE.

1. *Scissurella eucharista.*
2. ,, *timora.*
3. *Cyclostrema calypso.*
4. ,, *coatsianum.*
5. ,, *gaudens.*
6. ,, *meridionale.*
7. *Trichotropis antarctica.*
8. *Lacuna abyssicola.*
9. *Rissoa* (*Onoba*) *filostria.*
10. ,, ,, *paucilirata.*
11. *Bittium brucei.*
12. ,, *burdwoodianum.*
13. *Cerithiopsis macroura.*
14. *Turritella algida.*
15. *Mathilda rhigomaches.*
16. *Turbonilla xenophyes.*
17. *Savatieria concinna.*
18. *Yoldia profundorum.*
19. *Carditella pallida*, Sm., var. 12-*costata* nov.
20. *Retusa antarctica.*
21. *Mitra* (*Volutomitra*) *porcellana.*
22. *Cyclostrema meridionale* (cum operculo).
23. *Cardita congelascens.*
24. *Chætopleura brucei*, Iredale.


1.


1a.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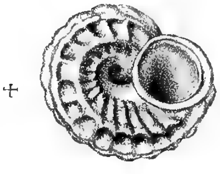
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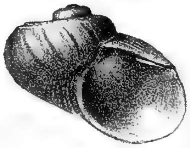
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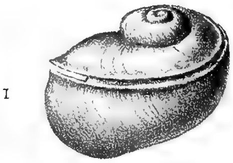
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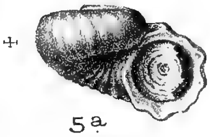
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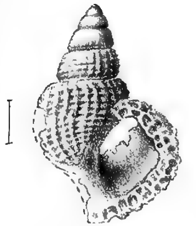
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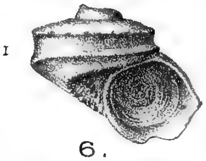
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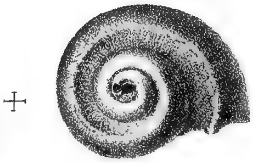
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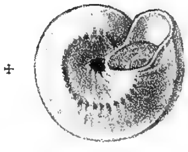
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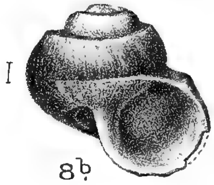
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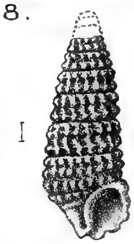
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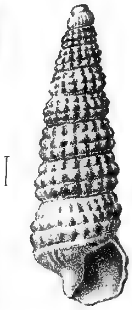
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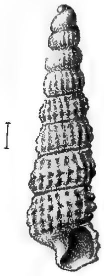
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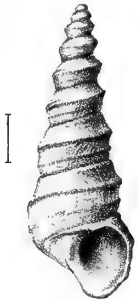
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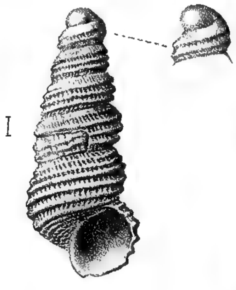
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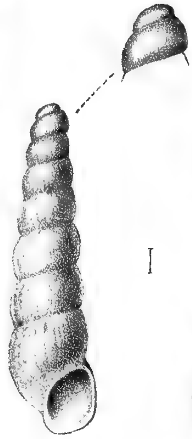
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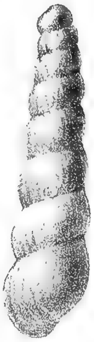
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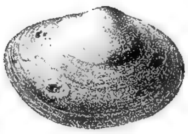
17.


18a.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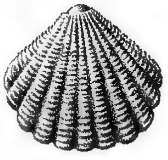
18b.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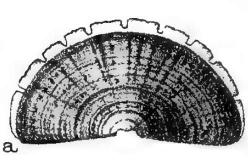
19a.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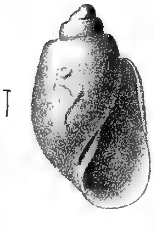
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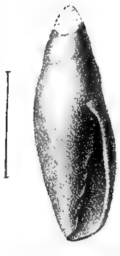
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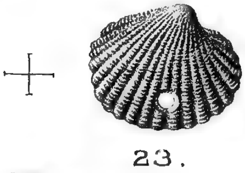
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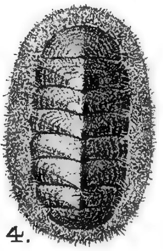
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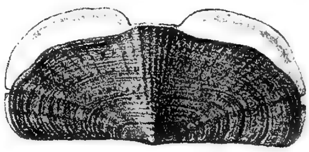
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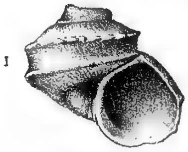
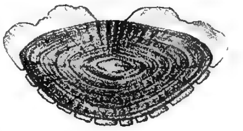

22.


22a.


24d.


24c.

A. H. Searle del. et lith.

AL HISTOR

XIX.—The Brachiopoda of the Scottish National Antarctic Expedition (1902 to 1904).

By **J. Wilfrid Jackson**, F.G.S., Assistant Keeper, Manchester Museum. *Communicated by* Dr W. S. Bruce. (With Two Plates.)

(MS. received May 6, 1912. Read June 17, 1912. Issued separately August 28, 1912.)

The Brachiopoda of the Scottish National Antarctic Expedition of the S.Y. *Scotia* (1902–1904), though in some cases somewhat scanty in number of individuals, are of particular interest, mainly on account of increasing very materially our knowledge in regard to the geographical range of certain forms, as well as of adding other species to those already known from the Antarctic coast-line.

Representatives of this class were dredged at three stations, viz.: Station 325 (Scotia Bay, South Orkneys), 9–10 fathoms; Station 346 (Burdwood Bank, south of the Falkland Islands), 56 fathoms; and Station 417 (off Coats Land, Antarctica), 1410 fathoms.

The Scotia Bay dredgings resulted only in the acquisition of one species, which, though possessing certain characteristics of *Liothyrina uva*, differs in many other respects from that widely distributed form, and may possibly be ultimately regarded as a distinct species. As sufficient material for a complete study is not available, the specimens are referred, in this report, to a new variety of *L. uva*, viz. *notorcadensis.*

At Burdwood Bank were obtained some interesting forms of *Terebratella dorsata* and *Liothyrina uva*, both being well-known Magellanic species, as well as some young forms which may possibly represent a new species of *Terebratella.*

At this station some interesting examples of a new *Cephalodiscus* were also dredged, which have provided welcome material in the form of very young stages of *Liothyrina uva*, as well as of others referable to *Terebratella dorsata* and *Magellania venosa.*

The dredging at Station 417 yielded four forms, all of them being of extreme interest, coming as they do from so southerly a latitude, and from the neighbourhood of the newly discovered Coats Land.

The species met with here comprise an interesting form of *Macandrevia* (*M. diamantina*), hitherto only recorded from the Gulf of Panama and Northern Peru; *Pelagodiscus atlanticus*, a typical abyssal form and a species of almost cosmopolitan distribution; *Liothyrina blochmanni*, n. sp.; and some fragmentary remains of an undoubtedly new Rhynchonelloid, unfortunately too imperfect for accurate specific description. These, being deep-water forms, are all thin-shelled animals, and do not attain a very large size.

It is particularly fortunate that amongst the specimens of *Macandrevia dia-*

mantina are examples which have afforded the much-desired opportunity for studying the developmental stages of the loop.

With regard to *Pelagodiscus atlanticus*, although of almost world-wide distribution, its probable existence in Antarctic waters has only recently been demonstrated by Eichler (1911),* who, with some hesitation, refers to this species two larval forms of a *Disciniscа* obtained in March 1903 by the "Gauss" Expedition, at a depth of about 1640 fathoms in the neighbourhood of their winter station, Kaiser Wilhelmland II.

Although it is, to some extent, a matter for regret that this report is so late in its publication, owing to the material having only recently come into my hands for study, the long delay has not been without its compensations, as I have been able to derive some benefit from, and make comparisons with, collections made by other Antarctic expeditions whose reports are already published.

Before proceeding with the detailed description of the species I must here express my great indebtedness to the numerous friends who have assisted in one way or another during the preparation of this report.

To Dr F. Blochmann, of Tübingen University, I am especially indebted for his very material help in the discrimination of critical forms, and for his kind interest and valuable assistance. To Dr W. H. Dall I am also grateful for his great kindness and confidence in submitting to me a type specimen of his *Macandrevia diamantina* for comparison with the *Macandrevia* obtained in 1410 fathoms off Coats Land. Amongst the various friends who have assisted in sorting out the smaller Brachiopoda from the Burdwood Bank material, I wish to particularly mention my colleague Mr R. Standen, the Rev. L. J. Shackleford, and Messrs B. R. Lucas, F.G.S., and F. G. Pearcey. And in conclusion I must tender my sincere thanks to Dr W. S. Bruce, F.R.S.E., for entrusting his Brachiopod collections to me, and for placing maps and much general information at my disposal.

List of species contained in the *Scotia* collections :—

Class BRACHIOPODA.

Pelagodiscus atlanticus (King), off Coats Land, 1410 fathoms.
Hemithyris, n. sp., off Coats Land, 1410 fathoms.
Liothyrina uva (Brod.), Burdwood Bank, 56 fathoms.
,, var. *notorcadensis*, nov., Scotia Bay, South Orkneys, 9–10 fathoms.
L. blochmanni, n. sp., off Coats Land, 1410 fathoms.
Macandrevia diamantina, Dall., off Coats Land, 1410 fathoms.
Terebratella dorsata (Gm.), Burdwood Bank, 56 fathoms.
,, n. sp.?, Burdwood Bank, 56 fathoms.
Magellania venosa (Sol.), Burdwood Bank, 56 fathoms.

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* See bibliography at end of report.

Description of Species.

The literature in the main is restricted to the more important papers. Further synonymy will be found in Davidson's *Recent Brachiopoda* (1886–1888); Fischer and Oehlert (1892); and Blochmann (1912).

Pelagodiscus atlanticus (King).

Discina atlantica, King, 1868, *Proc. Nat. Hist. Soc. Dublin*, vol. v. pp. 170–173.
,, ,, ,, 1880, Davidson, "*Challenger*" *Report*, pp. 62 and 65, pl. iv. figs. 17–18.
Discinisca atlantica (King), 1888, Davidson, *Mon. Recent Brach.*, pt. iii. p. 200, pl. xxvi. figs. 18–22.
,, ,, ,, 1891, Fischer and Oehlert, *Exped. Scient. du* "*Travailleur*" *et du* "*Talisman*," Brachiopodes, p. 120.
,, ,, ,, Section *Pelagodiscus*, 1908, Dall, *Bull. Mus. Comp. Zool.*, vol. xliii. p. 440.
Discinisca , 1911, Eichler, *Deutschen S.-P. Exped.*, xii., Zool., iv. p. 87, pl. xliv. fig. 22.

Hab.—Station 417; lat. 71° 22′ S., long. 16° 34′ W. (off Coats Land, Antarctica). Depth, 1410 fathoms. March 18, 1904. Sea bottom, blue mud and stones. Temperature 29°·9 F.

Obs.—Four upper valves of this interesting species were trawled at this station. The largest specimen measures 6·75 by 6 mm.; the others, 5 by 5, 4·75 by 4, and 3·5 by 3·5 mm. respectively.

All are in a good state of preservation. The shell is thin, semi-transparent, yellowish-brown in colour, and marked by numerous close-set concentric growth lines. The protegulum in each example is well defined, and situated somewhat posteriorly.

Pelagodiscus (formerly *Discinisca*) *atlanticus* is a typical cold-water species with a bathymetric range from 200 to 2425 fathoms. Its geographic range is almost world-wide, as it is known from the North and Mid-Atlantic Ocean, the Pacific, and off Australia. Some seven or eight different localities were established for it by the *Challenger* Expedition.

Off Valparaiso it was obtained by this Expedition in 2160 fathoms, on a mud bottom; temperature 34° F.

It has also been taken south-west of the Galapagos Islands, in 2035 fathoms; temperature 35°·3 F. (*Albatross*).

As mentioned in the prefatory remarks, its probable existence in Antarctic waters has recently been alluded to by Eichler (1911), who describes two larval forms of a Discinoid from a depth of about 1640 fathoms, Kaiser Wilhelmland II. These appear to have strong affinities with *P. atlanticus*, and in all probability are referable to this widely dispersed form.

The present discovery of the species well within the Antarctic Circle is highly interesting, as it increases the known range to a considerable extent geographically, though not bathymetrically.

The very wide range of this species is, in all probability, due to larval transportation, as the larvæ are known to live in a free and floating condition for nearly a month, and have been taken in a drag-net not far from land (SCHUCHERT, 1911).

Hemithyris sp. (Pl. II. fig. 14.)

Hab.—Station 417; lat. 71° 22′ S., long. 16° 34′ W. (off Coats Land, Antarctica). Depth, 1410 fathoms. March 18, 1904. Sea bottom, blue mud and stones. Temperature 29°·9 F.

Obs.—Some fragmentary remains of a probable new Rhynchonelloid were met with at the above station. These consist of hinge portions only of one ventral and two dorsal valves, but are, unfortunately, too small and imperfect for accurate specific description.

The material at my disposal appears to belong to a small trigonal form possessing a thin, translucent test. The colour is a yellowish-brown, and the outer surface smooth with very faint growth lines.

The ventral valve possesses dental plates, as in the type species *Hemithyris psittacea*, and from the evidence of the fragment the beak appears to be somewhat produced, and to possess a moderately large foramen.

The dorsal valve exhibits a short, feeble, median septum separating well-marked muscular impressions. There is no cardinal process. Hinge plate divided and consisting of two short, flattened, curved lamellæ, which are widely divergent.

Shell-mosaic similar in character to but larger in size than that of *R. cornea* figured by BLOCHMANN (1908; pl. xxxvii. fig. 16).

Fig. 14 (Pl. II.) in the present report is taken from a fairly well-preserved fragment.

The above description, of course, applies only to the posterior portion; the anterior end of the shell is quite unknown, hence one cannot say if the species is plicated or not.

Two new species of *Rhynchonella* (*R. racovitzæ* and *R. gerlachei*), and several indefinite forms too imperfect for identification, have been described from the Western Antarctic by JOUBIN (1901), but these all come from a less depth than the Coats Land form. This latter may, however, be intimately related with one or other of these forms, but owing to the paucity of material in both cases a decision on this point is for the present out of the question.

It is most unfortunate that the fragments of the Coats Land example are so small and indefinite, as this prevents a comparison being made, not only with the above-mentioned recent forms, but also with the fossil examples of *Hemithyris* recently described by BUCKMAN (1910) from Antarctica (Swedish Expedition), especially *H. antarctica*, Buck., from the Pleistocene beds of Cockburn Island, off Graham Land, to which species the Coats Land form presents some points of resemblance.

There is also the possibility of relationship with two other fossil species, viz. *Hemithyris plicigera* (Jhering) and *H. australis*, Buckman, from the Miocene-Oligocene beds of the same island.

Liothyrina uva (Broderip). (Pl. I. fig. 9.)

Terebratula uva, Broderip, 1833, *Proc. Zool. Soc. London*, pt. i., p. 124.
" " 1835, *Trans. Zool. Soc. London*, vol. i. p. 142, pl. xxiii. fig. 2.
" " 1880, Davidson, "*Challenger*" *Report*, p. 31, pl. ii. figs. 4–4*a* (figs. 3–3*b* are *Liothyrina fulva*, Bl.).
Liothyris uva (Brod.), 1886, Davidson, *Mon. Recent Brach.*, pl. ii. figs. 5–7.
Terebratula (*Liothyrina*) *moseleyi*, Dav., 1892, Fischer and Oehlert, *Bull. Soc. d'hist. nat. Autun*, vol. v. p. 264, pl. viii. figs. 9–23.
Liothyrina uva (Brod.), 1906, Blochmann, *Zool. Anzeiger*, vol. xxx. p. 698.
" " 1907, Oehlert, *Bull. Mus. d'hist. nat. Paris* (1906), vol. xii. p. 555, text-figs.
" " 1908, Oehlert, *Expédition antarctique Française*, 1903–1905, *Sciences nat. Brachiopodes*, pl. i. and text-figs.
" " 1908, Blochmann, *Zeitschr. f. wiss. Zool.*, Bd. xc. p. 615.
" " 1908, Dall, *Bull. Mus. Comp. Zool. Harvard Coll.*, vol. xliii. p. 443.
" " 1909, Dall, *Proc. U.S. Nat. Mus.*, vol. xxxvii. p. 279.
" " 1911, Eichler, *Deutsche S.-P. Expedition* (Brachiopoden), Bd. xii. (Zoologie iv.), Berlin, p. 338.
" " 1912, Blochmann, *Die Brach. der Schwed. S.-P. Expedition*, Bd. vi. (Zoologie ii.), No. 7, Stockholm, p. 1, pl. i. figs. 1–13; pl. ii. figs. 16–18; pl. iii. figs. 20–28.

Hab.—Station 346; lat. 54° 25′ S., long. 57° 32′ W. (Burdwood Bank), 56 fathoms. December 1, 1903. Sea bottom, Bryozoa. Temperature 41°·8 F.

Obs.—Several dead examples of a small species of *Liothyrina* were trawled at the above station at 56 fathoms.

The largest example (Pl. I. fig. 9) measures: length, 15·5 mm.; breadth, 13 mm., and agrees very closely with the specimen figured by FISCHER and OEHLERT (*op. cit.*, pl. viii. fig. 23) under the name of *Terebratula* (*Liothyrina*) *moseleyi*, Dav. The two vascular sinuses show very clearly in the interior of the ventral valve, as in their figured example. The dorsal valve of this specimen is also interesting as showing a very distinct trace of a median septum, as well as a strongly developed hinge apophysis, which occupies a considerable portion of the posterior end of the valve.

Other noteworthy features are the remarkable thickness of both valves, and the abundance of coarse growth lines, which would lead one to infer that the shell had attained an adult, or even a gerontic, condition.

Most of the other examples, though smaller in size, also show a considerable thickness in their shells, which renders the test quite opaque.

All are similar in form, being somewhat pyriform, and attaining their maximum diameter a little anterior to the middle of the valves.

The colour of the specimens is milk-white.

The examples of *Liothyrina* obtained from the colony of a new *Cephalodiscus*, dredged at this station, range in size from 1 mm. to 7 mm., and furnish ample material for a study of the gradual development of the shell and brachial support.

Though the development of the latter organ is well known in the genus *Liothyrina*, through the careful studies by DESLONGCHAMPS (1884) of young forms of *L. vitrea*, it may be of interest to give here a detailed description of the various stages in the development of this appendage, based upon a study of the young examples in my possession.

In the smallest example (L., 1 mm.) the brachial support has only just commenced to make its appearance, and is represented by two small sharp points* descending from the rudimentary crural bases, which consist of two short raised diverging bosses bordering the dental sockets. The apical portion of the ventral valve of this specimen shows a somewhat triangular peduncular opening, which is slightly notched on each side. No deltidial plates are apparent, but the teeth are fairly well-developed. The shell-mosaic of both valves is quite clear, but irregular in its development. The shell-perforations are large and well rounded, and show on an average 256 punctæ per square millimetre.

The shell at this stage is very linguloid in appearance, and recalls to mind the early stage of *Terebratulina septentrionalis* figured by MORSE (*Mem. Bost. Soc. Nat. Hist.*, vol. v., 1902, pl. li. fig. 16).

At 1·5 mm. in length the shell has assumed a more pear-shaped outline; the descending branches of the loop have increased slightly in length and diverge strongly from each other. The peduncular opening is more normal in shape, and traces of deltidial plates are slightly visible.

At 1·75 mm. the deltidial plates are still further developed and the descending branches of the loop exhibit slight traces, near their bases, of the crural points.

At 2·5 mm. the branches of the loop are curved slightly backwards and inwards towards the bottom of the valve; they are here more ribbon-like in form than in previous stages. The deltidial plates show increased development; the shell-mosaic is very irregular and wavy or flow-like in arrangement.

At 3 and 3·5 mm. the crural points exhibit greater development and the loop branches show a stronger convergence towards each other.

At 4 mm. the converging branches are almost in contact at their extremities, but no angle, as yet, is present on their surface.

At 5 mm. the deltidial plates are larger and seen to be highly punctate, and the cardinal process of the dorsal valve has appeared. The loop is still unjoined, and there is no sign of angulation. In the umbonal cavity of both valves a thin dark line is apparent (visible through the shell) which probably represents the median septum. The mosaic of the muscular impressions in the dorsal valve is clear and scale-like, but in remainder of the shell is very irregular. The punctæ in this specimen range from 224 to 280 per square millimetre.

At 6·5 mm. the characteristic angulation, at the junction of the descending branches

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* Visible only under a high-power microscopic objective.

with the transverse band, has appeared, but the loop is still unconnected. The cardinal process is well developed and very rugose. The deltidial plates are joined at their posterior extremities, thus defining the peduncular opening, which is round. At this stage the shell has increased considerably in thickness, being quite opaque in the older portions. Its shape is essentially the same as in the adult examples.

Some difference of opinion appears to exist amongst scientific observers as to the specific identification of this southern form.

FISCHER and OEHLERT (1893), in their report on the brachiopods of Cape Horn, figure a number of specimens under the name of *Liothyrina moseleyi*, Dav., a species originally met with at Kerguelen by the *Challenger* Expedition. BLOCHMANN (1906), however, having received one of FISCHER and OEHLERT'S specimens from the Paris Museum, refers the Cape Horn shells to *L. uva*, an identification upon which DALL (1908) throws some doubt, basing his argument chiefly upon differences in temperature. He points out that the type specimen of *L. uva*, from the Gulf of Tehuantepec, came from water of a high temperature, probably about 65° F., whereas the examples from Cape Horn came from much colder water, viz. between 42°·8–44°·4 F.

BLOCHMANN, in his later paper (1912), satisfactorily dismisses this argument by calling attention to the range of temperature in other well-known species of brachiopods.

In this excellent memoir BLOCHMANN also clearly proves, from a careful examination of original examples from Kerguelen and from the Magellanic region, that FISCHER and OEHLERT'S specimens cannot be referred to *L. moseleyi* on account of important differences in the brachial support and in the composition and arrangement of the spiculæ. He considers their specimens to be undoubtedly referable to *L. uva*, to which species he also unhesitatingly refers the Burdwood Bank examples obtained by the *Scotia* and Swedish South-Polar Expeditions.

The geographical distribution of *L. uva* has recently been worked out by the same authority (BLOCHMANN, 1908 and 1912) with the greatest care.

The original example, upon which BRODERIP founded the species, was obtained in the Gulf of Tehuantepec attached to a dead valve of *Meleagrina margaritifera*, at a depth of 10–12 fathoms.

The type specimen formerly in the Cuming collection is now in the British Museum. This specimen is somewhat abnormally developed, as will be seen by DAVIDSON'S figure (*Recent Brach.*, pl. ii. figs. 5–5*b*). In the same work (pl. ii. figs. 6–6*b*) DAVIDSON also figures another more normal example from the same place.

In his report on the Brachiopoda of the *Challenger* Expedition, DAVIDSON refers to further discoveries of this species as follows :—One dead example ("*Chall.*" *Rept.*, pl. ii. figs. 3–3*b*) trawled in 120 fathoms off Twofold Bay, South-East Australia. A second example ("*Chall.*" *Rept.*, pl. ii. figs. 4–4*a*), obtained off Buenos Ayres, at a depth of 600 fathoms ; bottom temperature, 2°·7 C. A third specimen, or rather two fragments of a dead shell, dredged off Heard Island, near Kerguelen,* in 150 fathoms ; bottom

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* Not Heard Island, east of Magellan Straits, as given by OEHLERT (1907, 1908).

temperature 1°·8 C. DAVIDSON further states that "in the British Museum there are likewise some white specimens stated to have been dredged near the Falkland Islands."

With regard to the Twofold Bay example, BLOCHMANN (1906, 1908), from a study of the original specimen, states that it is clearly distinct from *L. uva*, and on the grounds of differences in the brachial support and the number of pores in the shells of both forms, considers it an entirely new species, to which he has given the name of *L. fulva*.

Regarding the Buenos Ayres example, I am of the opinion that this also is a different species from *L. uva*. According to DAVIDSON'S figure ("*Chall.*" *Rept.*, pl. ii. fig. 4) it differs widely in outline from that of the type specimen and the additional example figured by him from the Gulf of Tehuantepec (*R. B.*, pl. ii. figs. 5–6). The beak is less produced and less compressed laterally, and the foramen is smaller. Moreover, the depth (600 fathoms) from which the specimen came is greater than that at which *L. uva* is known with certainty to live.

In the above respects the Buenos Ayres example also differs from any of the specimens illustrated by FISCHER and OEHLERT (1892) and BLOCHMANN (1912) from the Magellanic region, in which the outline of the shell is more pyriform.

OEHLERT (1907 and 1908), in his report on the Brachiopoda of the French Antarctic Expedition, figures and describes under the name of *L. uva* some extraordinarily large examples obtained presumably from the West Antarctic. For some unexplained reason, no particulars are given in either of these papers as to the exact place of discovery or the depth from which the specimens came.

The largest example measures: length, 45; breadth, 30; thickness, 25 mm.

The species is further recorded for the coast of Guatemala, South Peru, and Galapagos by DALL (1909), but no further particulars are given.

Recently BLOCHMANN (1912) has described and figured some interesting forms from a depth of 122 fathoms at South Georgia (Swedish Expedition), which up to the present appears to be the limit of its eastern range.

It would appear, therefore, that the species is widely distributed from Tehuantepec to Cape Horn, Falkland Islands, South Georgia, West Antarctic, and has crept north along the eastern coast of South America as far as Buenos Ayres, if the identification of this example is correct.

In addition to the Twofold Bay record referred to above, the species has been further recorded from Australian waters.

HEDLEY (*Mem. Aust. Mus.*, iv., 1902, p. 289) cites it from Coogee (49–50 fathoms) and Botany Bay (79–80 fathoms), both in the neighbourhood of Sydney.

BLOCHMANN (1912), however, from a study of one of HEDLEY'S specimens, has been able to satisfactorily demonstrate that the reference in question is due to an error in identification, the specimen being referable to *Terebratulina cancellata*, Koch.

It is possible also that the later record by HEDLEY (*Records Aust. Mus.*, vi., 1905,

p. 43)* of specimens of *L. uva* from 111 fathoms, East Cape Byron, Australia, may be founded on a similar error in determination.

Liothyrina uva (Brod.), var. *notorcadensis*, nov.† (Pl. I. figs. 1–3.)

Hab.—Station 325; lat. 60° 43′ 42″ S., long. 44° 38′ 33″ W. (Scotia Bay, South Orkneys), 6 fathoms. February 1, 1904. Sea bottom, sand. Temperature 32°·5 F.

Obs.—At this station some remarkably large oval forms of a *Liothyrina* were obtained in very shallow water. These, for reasons given below, and in order to call greater attention to them, I have ventured to describe under the above heading.

Four specimens in all were obtained here, two large, one of medium size, and one very young.

The measurements of these examples are as follows:—

	Length.	Breadth.	Thickness.
No. 1 (dead)	39	28·5	25 mm.
„ 2 (live)	29	22	18 „
„ 3 (dead)	21·5	16	11 „
„ 4 (dead)	2·75	2·5	

Examples Nos. 1, 2, and 3 are all very thick-shelled; No. 4, being a juvenile, is almost transparent.

Example No. 2, which was attached by means of its peduncle to the larger specimen (No. 1), is almost covered on its exterior with small coiled Serpulæ and Polyzoa. The marginal portion exhibits curious radiating descending grooves.

The largest specimen is very similar in general appearance to those obtained by the French Antarctic Expedition, figured by Oehlert (*op. cit.*, pl. i.). The shell is remarkably robust, and, judging from the crowding together of the growth-lines at the margins, it is evidently a very old (gerontic) individual (Pl. I. fig. 1).

The interior of the dorsal valve exhibits a very distinct median septum extending a third the length of the valve, as well as strongly marked muscular impressions. The brachial support is, unfortunately, somewhat broken (see Pl. I. fig. 3), but sufficient remains for comparisons to be made with other forms.

Outwardly this example presents the appearance of having been bored by an agency similar to *Cliona* or one of the perforating Polyzoa, as the surface of the shell is covered with branching vermiform groovings, some of which penetrate to the interior.

The living example (No. 2), which was attached to the above, has provided material for the study of the general characters of the spiculæ, etc., and I am much indebted to Dr F. Blochmann, to whom I submitted this and other examples, for his kindness in comparing these with the specimens obtained by the Swedish Expedition at South Georgia.

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* Not referred to by Blochmann (1912).

† From the locality.

I have also to thank him for very generously sending me several preparations made from this specimen.

Dr BLOCHMANN considers the specimens from South Georgia and from South Orkneys to be referable to *L. uva*, but points out certain peculiarities whereby they differ from typical examples from Burdwood Bank and elsewhere.

From the microscope preparations it is seen that the spiculæ are somewhat weaker in their development than is usual; the spicules penetrating into the bases of the cirri, too, are in most places not ordinarily developed.

In the visceral membrane (dorsal and ventral) and in the spiral arms the spiculæ are completely absent. They are also somewhat less developed than usual in the side arms, being confined to the anterior portion of the ventral side.

The Scotia Bay examples, therefore, present a considerable difference in the form of the spiculæ when compared with the characters exhibited by the examples of *L. uva* figured by BLOCHMANN (1912, pl. ii. figs. 16–18).

In these latter, which come from the Falkland Islands, Magellan Straits, and Cape Horn, the spiculæ are normally developed in the visceral membrane, but in other particulars they conduct themselves as in the above-mentioned examples.

Unfortunately my specimens arrived too late for Dr BLOCHMANN to study them before the publication of his recent report on the examples from South Georgia (Swedish Expedition). He has since, however, made a careful comparison of the forms from both localities, and reports that, as in the Scotia Bay examples, the spicules are also absent from the visceral membrane in those from South Georgia. Consequently, his remark that "the spiculæ exhibit no differences" (1912, p. 3), now requires modification.

It would appear from this fact that we are possibly dealing here with an interesting geographic variant, if not with an entirely new species. The study of a larger number of examples, however, would be necessary before one could arrive at a definite conclusion as to whether the absence of spiculæ from the visceral membrane is a constant character or not. Hence it remains purely a matter of opinion whether this eastern form is to be regarded as a variety or as a distinct species.

The brachial support presents the characteristics of *L. uva* (see fig. 3, and BLOCHMANN, 1912, pl. i. fig. 12); the outer appearance, too, agrees fairly well with this species, with the exception that the specimens are larger than usual and the characteristic fine radiating striæ of *L. uva* are scarcely perceptible.

The difference in size in the Scotia Bay examples might, of course, be due to the very shallow depth (6 fathoms) from which these specimens came. The same argument does not apply, however, to the South Georgia examples, which were obtained in about 122 fathoms.

Owing to the unfortunate omission of particulars relating to depth, etc., in OEHLERT'S reports (1907 and 1908) on the specimens obtained by the French Antarctic Expedition, whose area of research was off the western Antarctic continent, south-west of the South Shetlands, the possibility of the large size being influenced by shallowness in depth cannot be determined.

The specimens obtained by this Expedition are very oval in shape, like the Scotia Bay examples, and, as in the latter, they also possess a curious labiate prolongation of the foramen over the dorsal umbo (see fig. 1, and OEHLERT, 1908, pl. i.), which does not appear to be present in the South Georgia examples or in normal specimens of *L. uva* from Burdwood Bank and neighbouring stations.

The shells, too, possess a greater vertical diameter owing to the rotundity of their valves, and the angular appearance of the lateral margins, present in *L. uva*, is absent (compare BLOCHMANN, 1912, pl. i.).

To the above-mentioned differences must also be added an important variation in the composition of the shell-mosaic and the perforations of the test, based upon a study of the Scotia Bay examples.

Here the number of pores per square millimetre in specimens Nos. 2 and 3 is 96 to 128. These examples are, unfortunately, too opaque for a detailed study of the mosaic.

An examination of different portions of both valves of the young example No. 4, shows a range from 88 to 128 pores per square millimetre. The shell-mosaic is here clearly visible and consists almost throughout of a well-developed imbricating structure, with scarcely any trace of the irregular character exhibited in young examples of *L. uva* (2·75 and 5 mm. in length) from the Burdwood Bank material. The number of pores in the latter specimens ranges from 200 to 256 per square millimetre.

It may be of some interest here to call attention to a number of fossil forms of Terebratulidæ which have recently been described from the immediate neighbourhood of Graham Land, to the south-west of the South Orkneys.

In the report on the Antarctic fossil Brachiopoda collected by the Swedish South Polar Expedition, BUCKMAN (1910) describes, under the generic name of *Terebratula*, several very interesting forms, which appear to me to have some bearing on the recent species now inhabiting the neighbouring seas.

Amongst the coarsely punctate series three forms are described, two of which are referred to previously described fossil species; the other, owing to its fragmentary character, is not specifically determined.

One of these forms is referred by BUCKMAN to *Terebratula bulbosa*, Tate (a species met with in Australian Tertiary strata), with certain slight modifications in the description to suit the Antarctic specimens.

Without a comparative study of the Australian and Antarctic forms it is impossible to say if this identification is correct or not, but it appears to me possible that the two forms are in no way related to each other.

BUCKMAN'S figure* (pl. iii. fig. 7), which is a restoration, and his revised description present, in my opinion, striking resemblances, so far as external appear-

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* The labiation of the foramen has been overlooked by the artist.

ances are concerned, with the recent examples described above from South Orkneys. The shell-punctæ and internal characters (the latter unfortunately unknown so far in the fossil form), may, however, prove them to be quite distinct.

The fossil examples were obtained at Cockburn Island, off Graham Land, in strata referred by BUCKMAN to Miocene-Oligocene age.

Liothyrina blochmanni, n. sp. (Pl. I. figs. 4–8.)

Shell somewhat pear-shaped, longer than wide, reaching its greatest diameter towards the anterior margin. Sides of beak elongate, subrectilinear; lateral margins convex, merging insensibly into the frontal border, which is rounded. Line of joining of valves somewhat flexuous. Valves swollen, without plication or sinus; the ventral slightly deeper than the dorsal.

Surface smooth, with numerous very fine growth lines and traces of extremely fine radiating striæ which appear to arise from the radial arrangement of the punctæ.*

Test very thin, glassy, and almost transparent; visibly punctate. Colour whitish.

Shell-mosaic very clear and distinct; regularly developed. Pores per square millimetre = 60 to 80.

Ventral valve with a short beak, incurved, truncated by a moderately large, circular, collared foramen, bounded below by two joined deltidial plates. Sides of the beak well rounded. In the interior, teeth small and placed in immediate contact with the basal angles of the deltidial plates. No dental plates. Umbonal cavity very deep. Internal surface completely smooth. Muscular impressions very weak.

Dorsal valve very convex, with a linguloid nucleus. Interior smooth. Slight median septum extending from adductor muscular impressions almost to the apex of umbonal cavity, its total length being about a quarter the length of the valve. Muscular impressions clear but not deeply marked. Cardinal process small but quite distinct; flattened and transverse. Cardinal apophysis weak, composed of two divergent and flattened triangular plates, the external borders of which limit the dental sockets; the inner borders form the base of the crura. The brachial apparatus commences with short crura, which bear wide, triangular crural processes with their points directed somewhat ventrally. The descending limbs are remarkably parallel.† The transverse band is short but fairly broad, and is slightly indented in the middle portion; point of junction with descending branches well rounded.

Dim.—Size of the largest example (type): length, 23 mm.; breadth, 19 mm.; thickness, 12·5 mm.

Hab.—Station 417; lat. 71° 22′ S., long. 16° 34′ W. (off Coats Land). Depth, 1410 fathoms. March 18, 1904. Sea bottom, blue mud and stones. Temperature 29°·9 F.

Obs.—Two almost perfect examples, together with a single dorsal valve and the hinge portion of another, were brought up by the trawl at this station.

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* This radiating striation can only be seen in a good light and when the shell is held at a certain angle.

† Recalling DAVIDSON's figure of *L. sphenoidea* in *Recent Brachiopoda*, pl. ii. fig. 18.

The well-preserved examples fortunately possessed the dried-up remains of the brachiæ and other parts of the animal, by means of which a study of the spiculæ has been made possible.

These latter bodies are entirely absent in the cirri as well as in the visceral membrane. In the arms the spiculæ are very feebly developed and restricted to the hinder portion of the dorsal side.

This species has some resemblance externally to some forms of the Magellanic Liothyrinæ referred to *L. uva*, but differs entirely from these in the extreme thinness of the adult shell, the smaller number of pores per square millimetre, and the difference in the form of the brachial support and the spiculæ of the arms.

Owing to the many differences existing between this form and other known Liothyrinæ, I venture to describe it as an entirely new species, to which I have very great pleasure in attaching the name of Professor F. Blochmann, of Tübingen, to whom all students of recent Brachiopoda are so much indebted.

Macandrevia diamantina, Dall. (Pl. II. figs. 15–19.)

Dall, 1895, *Proc. U.S. Nat. Mus.*, vol. xvii. p. 723, pl. xxx. fig. 5; pl. xxxii. figs. 3 and 6.
„ 1908, *Bull. Mus. Comp. Zool. Harv. Coll.*, vol. xliii. p. 443.

Hab.—Station 417; lat. 71° 22′ S., long. 16° 34′ W. (off Coats Land), 1410 fathoms. March 18, 1904. Sea bottom, blue mud and stones. Temperature 29°·9 F.

Obs.—A fair number of living adult examples of this interesting species were brought up in the trawl at the above station. Along with these were a few dead examples, badly broken, and a quantity of small fragments which would point to the fact that a large number of specimens had been broken up by the numerous pebbles in the trawl net.

All the living examples were closely attached by their peduncles to pebbles of granitoid and other rocks, the pebbles varying in size from that of a hazel-nut to that of a walnut (see Pl. II. fig. 15). Some of the pebbles, especially the smaller ones, are worn almost round, while others are somewhat angular. However large the size of the pebbles, only one example of this species was observed on each. In several instances tubes of Serpulæ are present on both valves.

The specimens are very uniform in size and show no appreciable variation in shape.

Sizes of some of the specimens:—

Length.	Breadth.	Depth.
18·5	16	9·5 mm.
19	17	8·5
19·5	16	9·5
20	17·5	
20·5	15·5	10

I am quite unable to separate the Antarctic form from Dall's species, as it agrees word for word with his description (*op. cit.*, p. 723).

DALL however, gives no particulars of the shell-mosaic and the number of pores per square millimetre. Through his generosity in lending me the pedicle valve of his type specimen I have been enabled to study these points and make comparisons with the Antarctic form.

DALL'S type shows 104 to 112 punctæ per square millimetre. In the "Coats Land" adult examples these range from 92 to 110, with an average of 99.

Other known species: *M. cranium*, Müll., = 188 to 272 (adults 192 to 216); *M. vanhöffeni*, Bloch., = 120–132.

The shell-mosaic in both forms is practically identical, and consists of the usual overlapping scale-like structure.

Several of the specimens exhibit very clearly the vascular sinuses in the pallium.

In the dorsal valve there are two; these curve round the adductor muscular impressions and then diverge widely from each other, ceasing some little distance from the lateral margins of the valve. In the specimen examined these sinuses do not appear to bear any ramifications.

In the ventral valve there are four sinuses; the two median ones almost straight, slightly diverging near their anterior extremities, somewhat broad posteriorly and narrowing gradually towards the anterior, where they end abruptly without ramifications. These terminate some little distance from the anterior margin of the valve. The two lateral sinuses are slightly arched and send off four or five ramifications on their exterior sides, two or three of which again subdivide near the extreme lateral edge of the valve. These two sinuses are connected with the two median ones at a point about a quarter the length of the valve, whence they diverge.

Compared with the pallial sinuses of *Terebratella dorsata*, those of the ventral valve of *M. diamantina* present a striking resemblance to the illustrations given by FISCHER and OEHLERT (1892), more especially fig. 28 of plate x. They are quite distinct from those of *Magellania venosa* depicted by these authors (*loc. cit.*, pl. xii. figs. 5 and 15).

(*Note.*—The dorsal and ventral valves referred to above are not of the same individual.)

As previously mentioned, the examples brought up by the trawl at this station were in an adult condition; they all exhibit the final development of the brachial support, which is figured for the first time in this report (Pl. II. fig. 16).

In some samples, however, of deposit (No. 38) brought up later from the same depth and station, I was pleased to find two examples of this species which exhibit interesting stages in the development of this organ.

The smallest specimen measures (dorsal valve): length, 4 mm.; breadth, 4 mm., and shows the loop in its platidiform stage (Pl. II. fig. 17). It here consists of two descending branches, which converge towards the centre of the valve, where they become attached to a laterally compressed tube-like septal pillar possessing a few spinous processes on its anterior edge. This stage agrees almost exactly with the figure of the same stages depicted by FRIELE in the ontogeny of the type species, *M. cranium* (FRIELE, 1877, pl. i. figs. 2–2*b*), the only point of difference being in the possession of a less number of spinules on the septal pillar.

The number of pores per square millimetre in this specimen ranges from 120 to 124. The scale-like structure of the shell-mosaic is very clear.

The second specimen from the same deposit, though slightly damaged, is interesting as showing a very advanced terebratelliform (or pre-adult) stage (Pl. II. fig. 18). The dorsal valve of this example measures: length, 8·75 mm.; breadth, 8·5 mm., and shows the final development of the loop almost achieved. The descending branches are broad, and possess two internal triangular apophyses indicating the position occupied by the transverse (jugal) band attached to the septum in the terebratelliform stage; also very prominent spinules at the recurvation. The stage of this specimen is almost equivalent to that of *M. cranium* figured by FRIELE (1877, pl. iii. fig. 10) and BEECHER (1895, pl. ii. fig. 1: 1901, pl. xxiv. fig. 1).

The descending lamellæ are supported at their origin by vertical, slightly converging, crural plates; no cardinal process is yet present.

The median septum is only very slightly visible and takes its rise immediately below the apex of the valve, whence it runs a distance of half the length of the valve and then ceases midway between the transverse band and the point of recurvation of the loop.

In none of the fully adult specimens of *M. diamantina* which I have examined is there any trace of the connecting bands on the descending branches, though the spinules at the recurvation are still apparent but much reduced. The median septum, which is only feebly developed, is also much reduced in length and confined to the umbonal region, where it supports the rather prominent cardinal process. On either side are two short parallel median septa supporting the convergent, but not united, crural plates.

The ventral valve of the above specimen (length, 10 mm.) shows a large foramen with rudimentary deltidial plates, beneath the anterior angles of which are the two rather prominent teeth.

On the exterior of both valves several conspicuous growth-halts are visible; the shell-punctæ = 112 per square millimetre (middle of the ventral valve).

Though the material at my disposal is so scanty, it does not seem improbable that, judging from the stages just described, the intermediate phases in the metamorphosis of the loop will show considerable similarity to those described by FRIELE in *M. cranium.*

The correct relationship of *M. diamantina* with the sub-family Dallininæ, a group so characteristic of the northern hemisphere, is thus clearly established by the transformations undergone by the brachial support.

This fact, which is, I believe, the first recorded instance of the "Dallinoid" type of development in austral waters, is of great importance, as it has hitherto been considered that the two phyla, of common origin, of the section *Terebratella*, *i.e.* the sub-families

Dallininæ and Magellaninæ, were geographically separated into two provinces, one (Dallininæ) being restricted to boreal, the other (Magellaninæ) to austral seas (SCHUCHERT, in Zittel, 1900, p. 329).

It can now be shown that the sub-family Dallininæ is well represented in the austral region.

This discovery is of still further interest as being highly confirmatory of DALL's observations when first describing this and two other species of *Macandrevia* from the Gulf of Panama (DALL, 1895, p. 721).

He remarks: "As regards the partly austral species about to be described, since there is no means of deciding whether their development agrees with those forms referable to Magellaninæ or not, and as the adult shells exhibit no characters which could not be regarded as diagnostic of a genus different from *Eudesia*,* I feel obliged for the present to refer them to that group. It may be observed that there is nothing to prevent the free migration of northern forms into the South Pacific along the coast of the Americas. The writer has already the evidence to show that several species, in deep water, do extend from Bering Sea south to the vicinity of the Galapagos Islands and, in the case of one species, *Solemya johnsoni*, Dall, more than a thousand miles further south; with the known great range of many brachiopods, there would be no apparent reason why species of the Panamic region, for instance, belonging to the northern type of development, should not extend their range southward, if opportunity arose. I regard it then as quite likely that the species I refer to may be Macandrevian in their development as well as in their adult state, though, for the mass of characteristically austral species, the reverse might be the case."

The prescience of this eminent American author has thus been amply justified.

Macandrevia diamantina was originally described from two specimens obtained in deep water, 1175 fathoms, mud, Gulf of Panama; bottom temperature 36°·8 F., and was again met with later in 2222 fathoms, mud, off Sechura Point, Northern Peru; temperature 35°·2 F.

The discovery, therefore, of this species in deep and cold water off the coast of the Antarctic continent is highly interesting as showing a very considerable range southward.

Furthermore, it forms a connecting link in the distribution of the genus *Macandrevia*, which now ranges from the North Atlantic (*M. cranium*), Davis Strait (*M. tenera*), *via* the Gulf of Panama (three species, viz. *M. americana*, *M. craniella*, and *M. diamantina*), Peru (*M. diamantina*), West Patagonian coast (*M. americana*), Coats Land (*M. diamantina*), to Kaiser Wilhelmland II., Antarctica (*M. vanhöffeni*).

Though the distance between the recorded stations for *M. diamantina* appears to be so great, it is not at all improbable that it will ultimately be met with in other stations off the long South American coast as further dredgings are carried out in that area. *Macandrevia americana*, one of the Panamic species, has already been found

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* DALL regarded *Macandrevia* as a sub-genus of *Eudesia*.

on the West Patagonian coast; while *Liothyrina uva* also extends from the Gulf of Panama to the Antarctic.

As a similar, and, in fact, parallel instance of wide distribution in another group of animals, I might mention the case of *Dentalium megathyris*, Dall (=*D. shoplandi*, M. and S., *non* Jouss.).

This interesting scaphopod was dredged along with another new species (*D. eupatrides*, M. and S.) at the same station and depth (Coats Land, 1410 fathoms). It has been met with in deep water at several stations on the western coast of Central and South America, viz. off Chiloe Island, and South-East Chili, in 1050 and 1342 fathoms; near Galapagos Island in 812 fathoms; off Ecuador in 1740 fathoms; Gulf of Panama, south-west of Tehuantepec, in 2282 fathoms; off Mazatlan in 995 fathoms.

Terebratella dorsata (Gmelin). (Pl. II. figs. 11–13.)

Anomia dorsata, Gmelin, 1788, *Syst. nat.*, ed. xiii., p. 3348.
Terebratella dorsata (Gmelin), 1887, Davidson, *Mon. Recent. Brach.*, p. 75, pl. xiv. figs. 9–11, 13–19 (fig. 12 looks like a young *Magellania venosa*).
„ „ 1889, Dall, *Proc. U.S. Nat. Mus.*, vol. xii. p. 231.
„ „ 1892, Fischer and Oehlert, *Bull. Soc. d'hist. nat. Autun*, vol. v. p. 272, pl. ix., x., xi., figs. 1–6.
„ „ 1908, Dall, *Bull. Mus. Comp. Zool. Harvard Coll*, xliii. p. 444.
„ „ 1909, Dall, *Proc. U.S. Nat. Mus.*, vol. xxxvii. p. 279.
„ „ 1912, Blochmann, *Die Brach. der Schwed. S.-P. Expedition*, Bd. vi. (Zoologie ii.), No. 7, Stockholm, p. 11.

Hab.—Station 346; lat. 54° 25′ S., long. 57° 32′ W. (Burdwood Bank), 56 fathoms. December 1, 1903. Sea bottom, Bryozoa. Temperature 41°·8 F.

Obs.—Dead examples only of this well-known Magellanic species were obtained at the above station. These consist, in most cases, of fairly perfect specimens; in others, of loose valves only. All are quite white in colour.

The examples, for the most part, are representative of adult individuals, and are interesting as exhibiting a considerable amount of variation, both in shape and size. The smallest fully-adult example measures: length, 22 mm; breadth, 23 mm.; the largest adult is: length, 38 mm.; breadth, 36 mm.

Several of the specimens differ from the typical transverse form in being almost round, and one example is curious in presenting quite an elongate appearance, calling to mind the well-known Australian species, *Magellania flavescens* (Pl. II. fig. 13).

The beak is largely produced, recurved, as is usual, and truncated by a relatively large foramen. One side of the specimen is somewhat distorted in growth, giving the shell an asymmetrical appearance. The size of this specimen is: length, 25 mm.; breadth, 18·5 mm.; thickness, 12·5 mm.

In all the examples obtained the test is remarkably thick and, consequently, quite opaque. The radiating ribs on the surface, which in most examples are also visible in a reversed order in the interior, differ very largely in the various individuals, some possessing fine, and others coarse, ribbing. In some cases the ribbing is almost entirely obsolete, even in adult examples, a feature already noted by FISCHER and OEHLERT, and described and figured by them as var. *submutica* (1892, p. 279, pl. xi. figs. 5–6).

Internally the specimens present many interesting features. In some examples indications of senile conditions are very apparent. The teeth of the ventral valve show considerable enlargement, the muscular impressions are remarkably deep, and the peduncular passage is considerably narrowed by thick deposits of calcareous matter on either side, forming a deep and narrow channel. The foramen is reduced to a very small size (Pl. II. fig. 11).

In no case, however, are the deltidial plates absorbed, as is often the case during senile decay.

In the dorsal valve similar conditions are to be seen. Here the cardinal process is of notable size and the brachial support of extreme tenuity. (See FISCHER and OEHLERT, 1892, pl. ix. fig. 6).

Similar evidences of senility are present externally in the thickening of the lateral and frontal margins and the crowding together of the growth lines (Pl. II. fig. 12). (See also FISCHER and OEHLERT, 1892, pl. ix. figs. 3–4.)

The various young examples of this species, obtained mostly from the tests of *Cephalodiscus*, range in size from 1 to 6 mm. and show an interesting series of growth-stages in the brachial support. This feature has already been very ably described by FISCHER and OEHLERT (1892), and as the above specimens exhibit no important points of difference, it will not be necessary to deal with them again here.

Terebratella dorsata appears to be restricted to the immediate neighbourhood of South America. It is an abundant species in the Magellan Straits, the littoral of Tierra del Fuego, and Falkland Islands. On the east coast of Patagonia it does not appear to range further north than latitude 52° S. (near Cape Virgins) and the Falkland Islands. On the West Patagonian coast it seems to possess a more considerable extension, having been recorded from Valparaiso and Coquimbo, Chili.

A more distant locality has been recorded for this species by DAVIDSON ("*Chall.*" *Report*, p. 44), viz. Royal Sound, Kerguelen, but BLOCHMANN (1906), from a study of the original examples, has shown this record to be erroneous, the specimens in question being an entirely new species, *Terebratella enzenspergeri*, Blochmann.

The bathymetric range of *T. dorsata*, according to recent authorities, is from about 5 to 120 fathoms.

In the report on the fossil Brachiopoda of the Swedish S.-P. Expedition, BUCKMAN (1910) has described a new species of *Magasella* (*M. antarctica*) which appears to me to present certain definite resemblances to *Terebratella dorsata* (Gmelin).

The fossil species, which comes from the Glauconitic Bank formation (Pleistocene) at Cockburn Island, off Graham Land, West Antarctic, is described and figured by BUCKMAN (1910, p. 18, pl. i. figs. 17–17*d*), with the remark that *Terebratella* *rubicunda* * is possibly its nearest ally, but, owing to the strongly developed septum, its place in the genus *Terebratella* is precluded, and therefore it might possibly be described as the magaselliform ancestor of *T. rubicunda.*

In my opinion, judging from Buckman's figure, the original of which would appear to be partly a cast, this form is more closely allied to one or other of the numerous variations of the polymorphic *T. dorsata.*

If comparisons be made with *T. dorsata,* var. *submutica,* F. and O. (*op. cit.,* p. 279, pl. xi. figs. 1–6), a very striking resemblance is noticeable. In this variety the radiating sculpture is almost absent, and the appearance of the shell is less transverse than in the typical form.

It might be argued, however, that the deltidial plates in these specimens are fully developed, thus denoting an adult condition, but in examples of this form from Burdwood Bank there are specimens which show the deltidial plates only partially developed, and, as is usual in *T. dorsata,* the radiating ribs of the exterior are visible also on the interior of the valves and would thus be impressed upon a fossil cast of this species.

To my mind it would be much more reasonable to refer the Cockburn Island fossil to a magaselliform stage of *Terebratella dorsata,* and more especially to the var. *submutica,* F. and O., than to go so far away as New Zealand for a comparison.

According to Fischer and Oehlert (1892), *T. dorsata* is not cited among the fossils of Patagonia by d'Orbigny, Darwin, and Sowerby, but on the contrary is given by Hutton (1873) and Hector (1886) for the New Zealand Tertiaries (Lower Miocene-Ahuriri formation) from Cape Rodney, Auckland, N. Island, associated with the recent *Rhynchonella nigricans,* Sow.

This reference, if authentic, is of considerable importance as indicating significant climatic changes during the deposition of these beds.

One feels disposed, however, in the light of present knowledge, to question the correct identification of the New Zealand species, and to consider the possibilities of the form in question being referable to the well-known and variable *T. cruenta* or a probable ancestor of that species.

Terebratella sp. (Pl. II. fig. 10.)

Hab.—Station 346; lat. 54° 25′ S., long. 57° 32′ W. (Burdwood Bank), 56 fathoms. December 1, 1903. Sea bottom, Bryozoa. Temperature 41°·8 F.

Obs.—Amongst the smaller specimens of Brachiopoda from this station are one or two examples whose generic and specific positions are somewhat doubtful.

The two largest and most perfect of these questionable forms measure :—

	Length.	Breadth.	Thickness.
No. 1	13·25	10·5	6·75 mm.
„ 2	16	14	8·5 „

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* A New Zealand recent species.

Both specimens (Pl. II. fig. 10) exhibit a terebratelliform condition in the brachial support. The descending branches, which extend two-thirds the length of the valve, are very thin and are attached to the median septum by a slender jugal band nearly at right angles with the descending branches.

The ascending branches follow much the same course as those below, and are united by means of a short transverse band which is slightly inflected in its median portion.*

The crural points are very short and not turned inwards towards each other, as in *Magellania venosa* and *Terebratella dorsata*, but are directed upwards in the direction of the ventral valve. The jugal band is situated about the middle of the length of the loop, and is fixed to the terminal part of the septum; it is quite as slender as the other portions of the apparatus.

It would appear from certain indications on the descending branches that the metamorphosis of the loop is still uncompleted, as the inside edges of these, at their junction with the jugal band, exhibit traces of an oblique suture, a feature hitherto not observed in adult *Terebratella dorsata*.

The umbonal cavity of this valve is occupied by a well-developed cardinal plateau fixed to the bottom of the valve, and depressed longitudinally in its median part in the form of a trough, from the anterior end of which extends a thin-edged median septum. The posterior extremity of the plateau carries a well-developed transverse cardinal process; the lateral parts form two somewhat triangular plates bordering the dental sockets.

Externally the shell is of an oval form, longer than broad, attaining its maximum diameter about the middle of the valves (Pl. II. fig. 10). Line of joining slightly flexuous at the frontal and lateral margins. Valves swollen, the ventral being deeper than the dorsal. Surface roughened by numerous well-pronounced growth-lines, which are close set. Specimen No. 2 exhibits very numerous close-set growth-lines at the margins similar to those seen in specimens which have attained a senile condition.

The test is very solid and opaque. Beak of ventral valve moderately produced, incurved, and truncated by a large foramen, with rudimentary deltidial plates. Sides of the beak carinated, forming a flattened area below the foramen. The test is covered with very numerous perforations, but owing to the difficulty in lighting I have been unable to count them satisfactorily under the microscope.

Owing to the want of further material the exact identification of this interesting form is extremely difficult. It can scarcely be regarded as a terebratelliform stage of *Magellania venosa*, as at this stage in its ontogeny the latter species is much more transverse and the branches of the loop broader (see especially FISCHER and OEHLERT, 1892, pl. xi. fig. 8).

Neither can it be looked upon as a small adult *Terebratella dorsata*, on account of the entire absence of the characteristic surface sculpture of that species, as well as the distinct difference in shape and the discordance in the composition of the brachial support.

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* These are broken off in photograph.

Blochmann (1912) has referred to one of these specimens in dealing with a probably new species of *Magellania* obtained by the Swedish South-Polar Expedition at the same locality (Burdwood Bank), and remarks on its correspondence with his described example, with the exception that whereas the *Scotia* specimen possesses a distinctly pronounced angulation of the beak, his *Magellania* specimen exhibits no such character, the sides of the beak being well-rounded, without any indication of an angle.

From the thickness of the test he is inclined to regard the form as a possibly new *Terebratella*.

Magellania venosa (Solander).

Anomia venosa, Solander, 1788, *Dixon's Voy.*, p. 355, pl. xi.
Waldheimia venosa (Sol.), 1886, Davidson, *Mon. Recent Brach.*, p. 49, pl. viii. figs. 1–5; pl. ix. fig. 1.
Eudesia venosa (Sol.) 1889, Dall, *Proc. U.S. Nat. Mus.* vol. xii. p. 231.
Magellania venosa (Sol.), 1892, Fischer and Oehlert, *Bull. Soc. d'hist. nat. Autun*, vol. v. p. 312, pl. xi. figs. 7–16; pl. xii. figs. 1–17.
" " 1909, Dall, *Proc. U.S. Nat. Mus.*, vol. xxxvii. p. 279.
" " 1912, Blochmann, *Die Brach. der Schwed. S.-P. Exped.*, Bd. vi. (Zoologie ii.), No. 7, Stockholm, p. 9.

Hab.—Station 346; lat. 54° 25′ S., long. 57° 32′ W. (Burdwood Bank), 56 fathoms. December 1, 1903. Sea bottom, Bryozoa. Temperature 41°·8 F.

Obs.—Amongst the young examples obtained from *Cephalodiscus* dredged at this station are several which appear to be referable to the above species. One or two of these examples are less than 3 mm. in length.

One specimen, which measures 4 mm., shows 256 punctæ per square millimetre; another, 6 mm. long, shows a range from 240 to 256 punctæ, both examinations being made about the middle of the ventral valve.

In *M. venosa*, according to Blochmann (1912), the perforations per square millimetre range from 240 to 280.

The various specimens are interesting as showing some of the very early stages in the development of the brachial support of this species, which were first made known through the admirable work of Fischer and Oehlert (1892).

The geographical range of *M. venosa* is very much the same as that of *Terebratella dorsata*, with which it is often accompanied.

It has been met with abundantly by many expeditions in the neighbourhood of Tierra del Fuego (35 to 80 fathoms); Magellan Straits (7 to 20 fathoms), and Falkland Islands, where the largest specimens, so far known, were obtained by Rear-Admiral Sulivan in 1843, near Fort William, in 6 to 7 fathoms (see pl. viii. figs. 2 to 2*c*, Davidson, *Rec. Brach.*).

The species is recorded also from the west coast of Patagonia (from 1 to 30 fathoms) and from Coquimbo, Chili.

Full particulars, up to 1892, of the various recorded stations, will be found in FISCHER and OEHLERT's memoir on the *Brachiopodes du Cap Horn* (1892), where also is given the most complete description of the species.

One citation, however, calls for special remark.

Like *Terebratella dorsata*, this species has also been recorded from Kerguelen.

E. A. SMITH (1879) mentions *Waldheimia dilatata*, Lam. (a synonym of *M. venosa*, Sol.), as having been obtained at Observatory Bay, Kerguelen, on rocks at 4 fathoms.

DAVIDSON (*R. B.*, p. 52), however, remarks that the *Challenger* did not bring back a single specimen of SOLANDER's species.

Without an examination of the original specimens it is impossible to say whether these are rightly referred to *M. venosa*, but I am disposed to doubt the correct determination, in the light of recent research on the Brachiopoda of both regions. As BLOCHMANN (1906) has shown, the specimens formerly recorded from Kerguelen as *Terebratella dorsata* have proved to belong to a new species, viz. *T. enzenspergeri*, Bl. It does not seem unlikely, therefore, that the Magellaniæ in question may likewise have been erroneously referred to the characteristic Magellanic species.

With regard to the fossil distribution of this species, little appears to be known.

PILSBRY (1898, p. 329), in a reference to a collection of Tertiary fossils from Cape Fairweather, Patagonia, remarks that *M. venosa* (Sol.) is abundant.

According to ORTMANN (1902), however, this identification is incorrect, the species in question being named by this author *Terebratella gigantea*.

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EXPLANATION OF PLATES

PLATE I.

Figs. 1–3. *Liothyrina uva* (Brod.), var. *notorcadensis* nov.—Scotia Bay, South Orkneys; 9–10 fathoms.

Fig. 1. Dorsal view showing labiate prolongation of foramen over dorsal umbo; also vermiform groovings caused by *Cliona* or perforating Polyzoa. Slightly above natural size.

Fig. 2. Side view of same example.

Fig. 3. Interior views of both valves of same example as fig. 1, showing brachial support (broken) and position of teeth.

Figs. 4–8. *Liothyrina blochmanni*, n. sp.—Station 417, off Coats Land; 1410 fathoms.

Fig. 4. Dorsal view of type-specimen. × 1⅓.

Fig. 5. Side view of same example. × 1⅓.

Fig. 6. Interior views of both valves of same example, showing the weak character of the brachial support, also position of teeth. × 1⅓.

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* According to BUCKMAN (1910), 1896 is date of off-print, 1900 date of volume.

Fig. 7. Front view of same example. × 1⅓.

Fig. 8. Shell-mosaic, etc., of another example. × 175.

Fig. 9. *Liothyrina uva* (Brod.).—Burdwood Bank, south of Falkland Islands; 56 fathoms. Interior views of both valves, showing brachial support and median septum in dorsal and pallial sinuses in ventral valve. × 1⅓.

PLATE II.

Fig. 10. *Terebratella* sp.—Burdwood Bank, south of Falkland Islands; 56 fathoms. Interior views showing terebratelliform stage of loop, etc. × 1⅗. (The ascending branches, unfortunately, broke away before photograph was taken.)

Fig. 11. *Terebratella dorsata* (Gmelin).—Burdwood Bank, 56 fathoms. Interior view of fragment of ventral valve showing small size of the foramen, muscular impressions, etc. × 1½.

Fig. 12. *Terebratella dorsata* (Gmelin).—Burdwood Bank, 56 fathoms. Typical example showing shape and surface sculpture. Natural size.

Fig. 13. *Terebratella dorsata* (Gmelin).—Burdwood Bank, 56 fathoms. Elongate variety showing produced beak, etc. × 1½.

Fig. 14. *Hemithyris* sp.—Station 417, off Coats Land, 1410 fathoms. Shell-mosaic, ventral valve. × 166 about.

Figs. 15–19. *Macandrevia diamantina*, Dall.—Station 417, off Coats Land, 1410 fathoms.

Fig. 15. Specimens attached to pebbles of granite rocks; slightly larger than natural size.

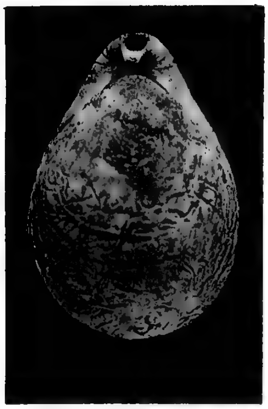
Fig. 16. Interior views of dorsal and ventral valves, showing adult loop, etc. × 1⅔.

Fig. 17. Platidiform stage of loop in example 4 mm. in length. × 12.

Fig. 18. Pre-adult stage of loop in example 9 mm. in length. × 4½.

Fig. 19. Shell-mosaic, etc., from middle of ventral valve of an adult individual. × 175.

JACKSON: "SCOTIA" BRACHIOPODA—PLATE I.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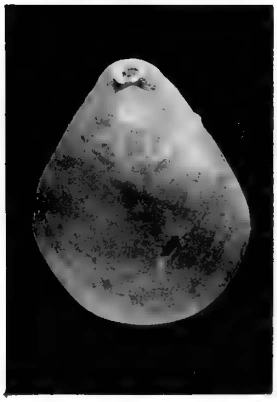
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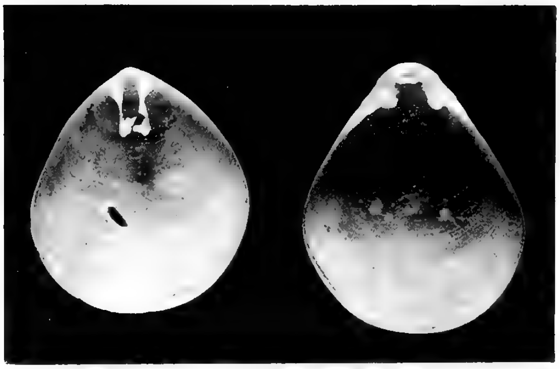
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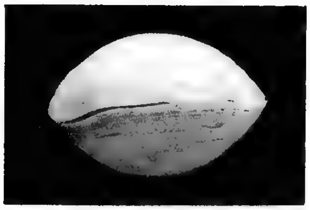
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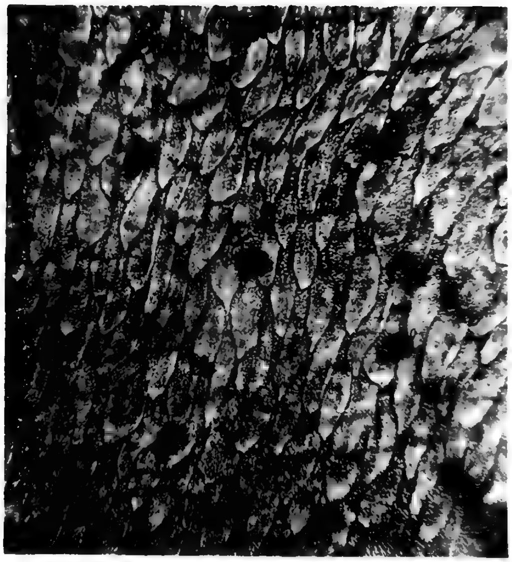
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Photo, J. W. Jackson.

M^c Farlane & Erskine, Lith. Edin^r

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JACKSON: "SCOTIA" BRACHIOPODA—PLATE II.

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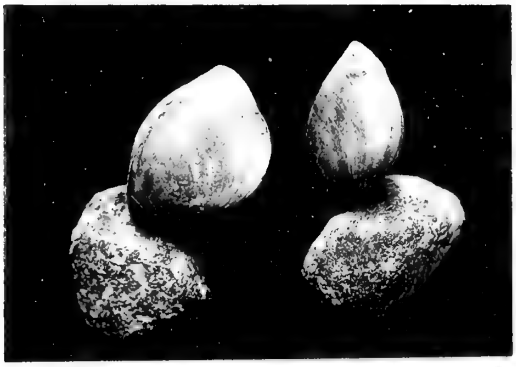

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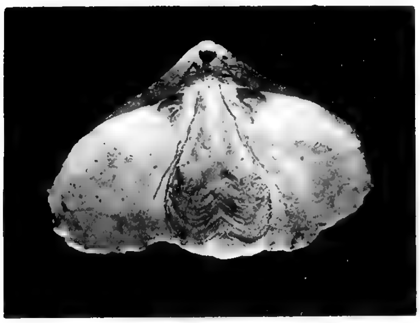

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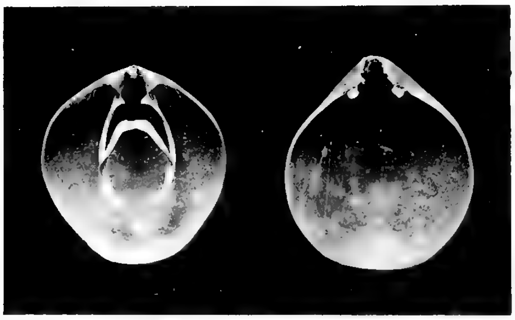

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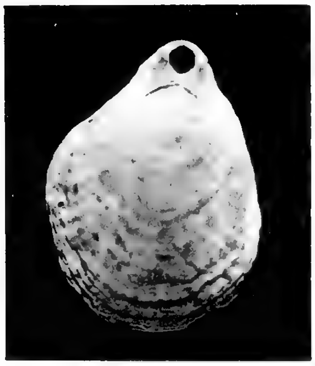

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XX.—The Equilibrium of the Circular-Arc Bow-Girder. By Prof. A. H. Gibson, D.Sc., A.M.I.C.E., University College, Dundee. (With Eleven Diagrams.)

(MS. received March 2, 1912. Read June 3, 1912. Issued separately August 17, 1912.)

CONTENTS.

§ 1. Introduction.

A girder built in to supports at one or at both ends and forming an arc of a circle in plan, is subjected, at each section, to both bending and twisting moments. At the supports, fixing moments of both kinds are called into play, and until these are known the resultant moment tending to cause rupture at any section is indeterminate. The following investigation is devoted to a consideration of the general state of elastic equilibrium of such a girder under various systems of loading.

The investigation is based on the theorem that in a straight beam, fixed horizontally at some point, the slope at any other point distant S is given by the area of the $\frac{M}{EI}$ diagram between the two points. Where a girder is circular in plan and is subjected to both bending and twisting moments this theorem requires modification. Thus (fig. 1) if M_θ and T_θ be the bending and twisting moments at a point distant θ (in angular measure) from the support, since a given slope at θ in the direction of the tangent at this point only gives rise to a slope of $\cos(\theta_1-\theta)$ times its magnitude at θ_1 in the direction of the tangent at θ_1, while an angular displacement γ at θ, due to a torque between the support and this point, produces a slope $\gamma\sin(\theta_1-\theta)$ at θ_1, in the direction of the tangent at θ_1, the resultant slope at the latter point, assuming the slope at the support to be zero, is given by

$$\left(\frac{dy}{ds}\right)_{\theta_1}=\int_0^{\text{arc }\theta_1}\frac{M^\theta}{EI_\theta}\cos(\theta_1-\theta)ds+\int_0^{\text{arc }\theta_1}\frac{T_\theta}{CJ_\theta}\sin(\theta_1-\theta)ds.$$

Here E and C are respectively the moduli of elasticity and of shear for the material of the beam, while I_θ and J_θ are the moments of inertia of its section at θ about the axes of bending and of twisting.

Where the beam is of uniform section, the only case here considered in detail, this becomes

$$\left(\frac{dy}{ds}\right)_{\theta_1}=\frac{1}{\mathrm{EI}}\int_0^{\text{arc }\theta_1}\mathrm{M}_\theta\cos(\theta_1-\theta)ds+\frac{1}{\mathrm{CJ}}\int_0^{\text{arc }\theta_1}\mathrm{T}_\theta\sin(\theta_1-\theta)ds\,;$$

or, since, if r is the radius of the arc,

$$\frac{dy}{ds}=\frac{1}{r}\cdot\frac{dy}{d\theta}\,;\quad ds=rd\theta\,;$$

$$\therefore\quad\left(\frac{dy}{d\theta}\right)_{\theta_1}=\frac{r^2}{\mathrm{EI}}\int_0^{\theta_1}\mathrm{M}_\theta\cos(\theta_1-\theta)d\theta+\frac{r^2}{\mathrm{CJ}}\int_\theta^{\theta_1}\mathrm{T}_\theta\sin(\theta_1-\theta)d\theta\,.$$

§ 2. Circular-Arc Cantilever with Load W at Free End.

Let α (fig. 1) be the angle subtended by the arc.

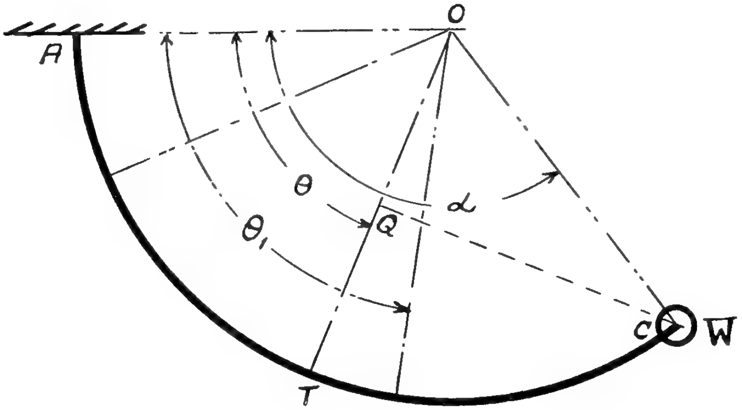


Fig. 1.

Then,

$$\mathrm{M}^\theta=\mathrm{W}\times\overline{\mathrm{CQ}}=\mathrm{W}r\sin(\alpha-\theta),$$

$$\mathrm{T}^\theta=\mathrm{W}\times\overline{\mathrm{QT}}=\mathrm{W}r\{1-\cos(\alpha-\theta)\}\,;$$

$$\therefore\quad\left(\frac{dy}{d\theta}\right)_{\theta_1}=\frac{\mathrm{W}r^3}{\mathrm{EI}}\int_0^{\theta_1}\sin(\alpha-\theta)\cos(\theta_1-\theta)d\theta+\frac{\mathrm{W}r^3}{\mathrm{CJ}}\int_0^{\theta_1}\{1-\cos(\alpha-\theta)\}\sin(\theta_1-\theta)d\theta.$$

On integrating and simplifying, this becomes—

$$\left(\frac{dy}{d\theta}\right)_{\theta_1}=\frac{\mathrm{W}r^3}{2\mathrm{EI}}\Big[\theta_1\sin(\alpha-\theta_1)+\sin\theta_1\sin\alpha\Big]+\frac{\mathrm{W}r^3}{2\mathrm{CJ}}\Big[2(1-\cos\theta_1)+\theta_1\sin(\alpha-\theta_1)-\sin\theta_1\sin\alpha\Big]\quad.\quad(1)$$

As θ_1 is any angle between o and α, on writing $\theta_1=\theta$ in this expression and integrating between the limits θ_1 and o, we get the deflection at θ_1.

$$\therefore\quad y_{(\theta_1)}=\frac{\mathrm{W}r^3}{2\mathrm{EI}}\int_0^{\theta_1}\{\theta\sin(\alpha-\theta)+\sin\theta\sin\alpha\}d\theta+\frac{\mathrm{W}r^3}{2\mathrm{CJ}}\int_0^{\theta_1}\{2(1-\cos\theta)+\theta\sin(\alpha-\theta)-\sin\theta\sin\alpha\}d\theta$$

$$=\frac{\mathrm{W}r^3}{2\mathrm{EI}}\Big[\theta_1\cos(\alpha-\theta_1)-\cos\alpha\sin\theta_1\Big]+\frac{\mathrm{W}r^3}{2\mathrm{CJ}}\begin{bmatrix}2(\theta_1-\sin\theta_1)+\theta_1\cos(\alpha-\theta_1)\\+\sin(\alpha-\theta_1)+\sin\alpha(\cos\theta_1-2)\end{bmatrix}\quad.\quad(2)$$

At the free end $\theta_1 = \alpha$, and we have—

$$y_W = \frac{Wr^3}{2EI}\Big[\alpha - \cos\alpha\sin\alpha\Big] + \frac{Wr^3}{2CJ}\Big[3\alpha - 4\sin\alpha + \sin\alpha\cos\alpha\Big] \quad . \quad . \quad . \quad . \quad . \quad (3)$$

As a check on the validity of the reasoning leading to these results the deflection at the weight may be calculated by equating the resilience of the beam to the work done during deflection. Taking, for convenience, the origin at the free end (fig. 2),

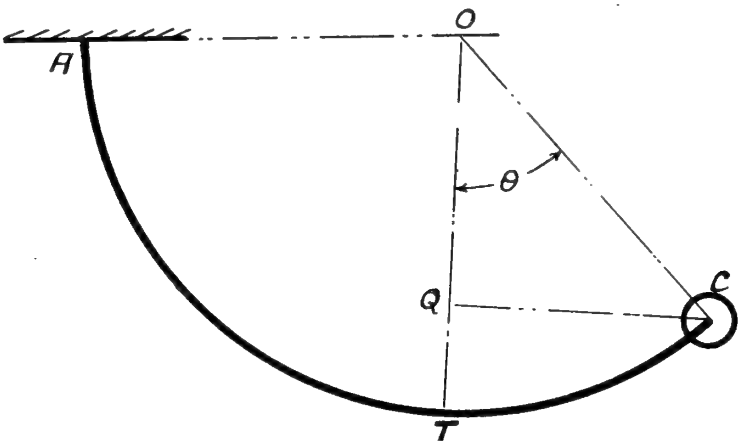


FIG. 2.

$$M_\theta = Wr\sin\theta\,;\ T_\theta = Wr(1-\cos\theta)\,;$$

and, if l be the length of the beam, the resilience is given by—

$$\frac{1}{2EI}\int_0^l M_\theta^2 ds + \frac{1}{2CJ}\int_0^l T_\theta^2 ds = \frac{W^2r^3}{2EI}\int_0^\alpha \sin^2\theta d\theta + \frac{W^2r^3}{2CJ}\int_0^\alpha (1-2\cos\theta+\cos^2\theta)d\theta$$

$$= \frac{W^2r^3}{4}\left[\frac{\alpha-\cos\alpha\sin\alpha}{EI} + \frac{3\alpha - 4\sin\alpha+\sin\alpha\cos\alpha}{CJ}\right],$$

and, since this $= \frac{W}{2} \times$ deflection at weight,

$$\therefore\ y_W = \frac{Wr^3}{2}\left[\frac{\alpha-\cos\alpha\sin\alpha}{EI} + \frac{3\alpha - 4\sin\alpha+\sin\alpha\cos\alpha}{CJ}\right]$$

which is identical with equation (3).

E.g., $\alpha = \frac{\pi}{2} = 90°$,

$$y_W = \frac{Wr^3}{2}\left[\frac{\pi}{2EI} + \frac{1\cdot5\,\pi - 4}{CJ}\right] = Wr^3\left[\frac{\cdot7854}{EI} + \frac{\cdot3562}{CJ}\right].$$

If $\alpha = \frac{3\pi}{4} = 135°$,

$$y_W = \frac{Wr^3}{2}\left[\frac{3\pi+2}{4EI} + \frac{9\pi - \frac{16}{\sqrt{2}} - 2}{4CJ}\right] = Wr^3\left[\frac{1\cdot4281}{EI} + \frac{1\cdot8716}{CJ}\right].$$

Experimental Verification.—Further verification was obtained by the results of a series of experiments on such a cantilever of round wire ·1624 inch diameter. This was formed to a radius of 10·10 inches. The values of $\frac{1}{\mathrm{EI}}$ and of $\frac{1}{\mathrm{CJ}}$ were obtained directly by loading a straight piece of the same wire as a cantilever 16 inches long and measuring its deflection under an end load, and by measuring its angle of twist in a torsion-meter under a known torque. As a result the mean values $\frac{1}{\mathrm{EI}} = \cdot 00116$; $\frac{1}{\mathrm{CJ}} = \cdot 001438$, in inch-lb. units, were obtained. This makes

$$\frac{r^3}{\mathrm{EI}} = 1\cdot 194 \,; \quad \frac{r^3}{\mathrm{CJ}} = 1\cdot 480,$$

and these values have been adopted in the various calculations. The following are experimental and calculated values of the deflection at the weight, for an applied load of 1 lb. at the free end.

	Deflection (ins.).	
a	Calculated.	Measured.
90°	1·469	1·475
135°	4·475	4·475

§ 3. Circular-Arc Cantilever with Uniform Loading—w Lbs. per Unit Length.

Taking the origin at the free end, we have, at any point θ (fig. 3),

$$\mathrm{M}_\theta = \int_0^\theta wr^2 \sin\phi d\phi = wr^2(1 - \cos\theta),$$

$$\mathrm{T}_\theta = \int_0^\theta wr^2(1 - \cos\phi)d\phi = wr^2(\theta - \sin\theta),$$

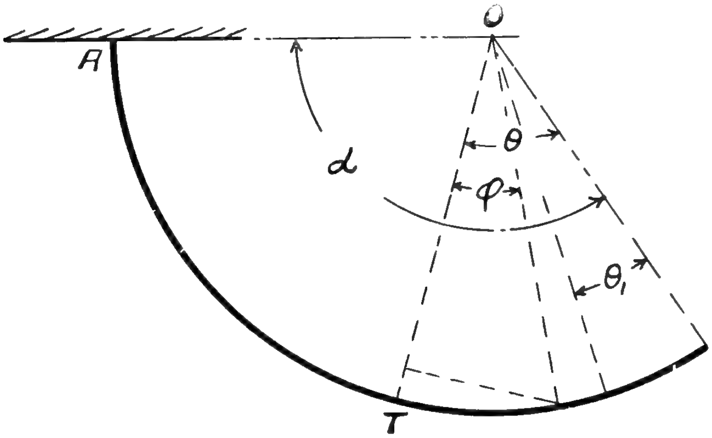


Fig. 3.

as the moments produced at T by the loading on that portion of the beam between T and the free end.

$$\therefore \left(\frac{dy}{d\theta}\right)_{\theta_1} = \frac{wr^4}{\mathrm{EI}}\int_{\theta_1}^{a}(1-\cos\theta)\cos(\theta-\theta_1)d\theta + \frac{wr^4}{\mathrm{CJ}}\int_{\theta_1}^{a}(\theta-\sin\theta)\sin(\theta-\theta_1)d\theta,$$

where a is the total angle subtended by the beam. Integrating this expression and simplifying gives—

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \left[\begin{aligned} &\frac{wr^4}{\mathrm{EI}}\left[\sin(a-\theta_1) - \cos\theta_1\left\{\frac{a-\theta_1}{2} + \frac{\sin 2a - \sin 2\theta_1}{4}\right\} - \frac{\sin\theta_1\sin^2 a - \sin^3\theta_1}{2}\right] \\ &+\frac{wr^4}{\mathrm{CJ}}\left[\begin{aligned} &\sin(a-\theta_1) - a\cos(a-\theta_1) + \theta_1 - \cos\theta_1\left\{\frac{a-\theta_1}{2} - \frac{\sin 2a - \sin 2\theta_1}{4}\right\} \\ &+\frac{\sin\theta_1\sin^2 a - \sin^3\theta_1}{2}\end{aligned}\right]\end{aligned}\right].$$

$$\therefore (y)_{\theta_1} = \left[\begin{aligned} &\frac{wr^4}{\mathrm{EI}}\int_{\theta_1}^{a}\left[\sin(a-\theta) - \cos\theta\left\{\frac{a-\theta}{2} + \frac{\sin 2a - \sin 2\theta}{4}\right\} - \frac{\sin\theta\sin^2 a - \sin^3\theta}{2}\right]d\theta \\ &+\frac{wr^4}{\mathrm{CJ}}\int_{\theta_1}^{a}\left[\begin{aligned} &\sin(a-\theta) - a\cos(a-\theta) + \theta - \cos\theta\left\{\frac{a-\theta}{2} - \frac{\sin 2a - \sin 2\theta}{4}\right\} \\ &+\frac{\sin\theta\sin^2 a - \sin^3\theta}{2}\end{aligned}\right]d\theta\end{aligned}\right]$$

$$= \left[\begin{aligned} &\frac{wr^4}{2\mathrm{EI}}\left[\begin{aligned} &2 - 2\cos(a-\theta_1) + (a-\theta_1)\sin\theta_1 + \cos a - \cos\theta_1 + \frac{\sin\theta_1\sin 2a}{2} \\ &-\tfrac{1}{3}(\cos^3 a - \cos^3\theta_1) - \cos\theta_1\sin^2 a + \frac{a-\theta_1}{2} - \frac{\sin 2a - \sin 2\theta_1}{4}\end{aligned}\right] \\ &+\frac{wr^4}{2\mathrm{CJ}}\left[\begin{aligned} &2 - 2\cos(a-\theta_1) - 2a\sin(a-\theta_1) + a^2 - \theta_1^2 + (a-\theta_1)\sin\theta_1 \\ &+\cos a - \cos\theta_1 - \frac{\sin\theta_1\sin 2a}{2} + \tfrac{1}{3}(\cos^3 a - \cos^3\theta_1) \\ &+\cos\theta_1\sin^2 a - \frac{a-\theta_1}{2} + \frac{\sin 2a - \sin 2\theta_1}{4}\end{aligned}\right]\end{aligned}\right].$$

At the free end $\theta_1 = 0$, and the deflection becomes—

$$y_o = \left[\begin{aligned} &\frac{wr^4}{2\mathrm{EI}}\left[1 - \cos a - \tfrac{1}{3}(\cos^3 a - 1) - \sin^2 a + \frac{a}{2} + \frac{\sin 2a}{4}\right] \\ &+\frac{wr^4}{2\mathrm{CJ}}\left[1 - \cos a - 2a\sin a + a^2 + \tfrac{1}{3}(\cos^3 a - 1) + \sin^2 a - \frac{a}{2} + \frac{\sin 2a}{4}\right]\end{aligned}\right];$$

e.g., if $a = \frac{\pi}{2}$, the deflection at the free end becomes

$$y_o = wr^4\left[\frac{\cdot 5594}{\mathrm{EI}} + \frac{\cdot 1035}{\mathrm{CJ}}\right].$$

Experimental Verification. — The experimental cantilever, $r = 10{\cdot}10$ ins., $\frac{1}{\mathrm{EI}} = 1{\cdot}16 \times 10^{-3}$, $\frac{1}{\mathrm{CJ}} = 1{\cdot}438 \times 10^{-3}$, $a = \frac{\pi}{2}$, was loaded uniformly by a series of washers, giving $w = {\cdot}0605$ lb. per inch run. Under these conditions

$$y_o \text{ (calculated)} = {\cdot}502 \text{ in.}; \quad y_o \text{ (measured)} = {\cdot}510 \text{ in.}$$

§ 4. Circular-Arc Girder, Built in at Two Ends, with Single Load W.

Let the arc subtend an angle $(\pi - 2\phi)$, and let O (fig. 4) be its centre; AB the line of supports; $AOW = \alpha$; $BOW = \beta$; R_a and R_b the vertical reactions at A and B; M_a and M_b, T_a and T_b the bending and twisting moments at the supports A and B, the axes of these moments being respectively parallel to and perpendicular to OA and OB.

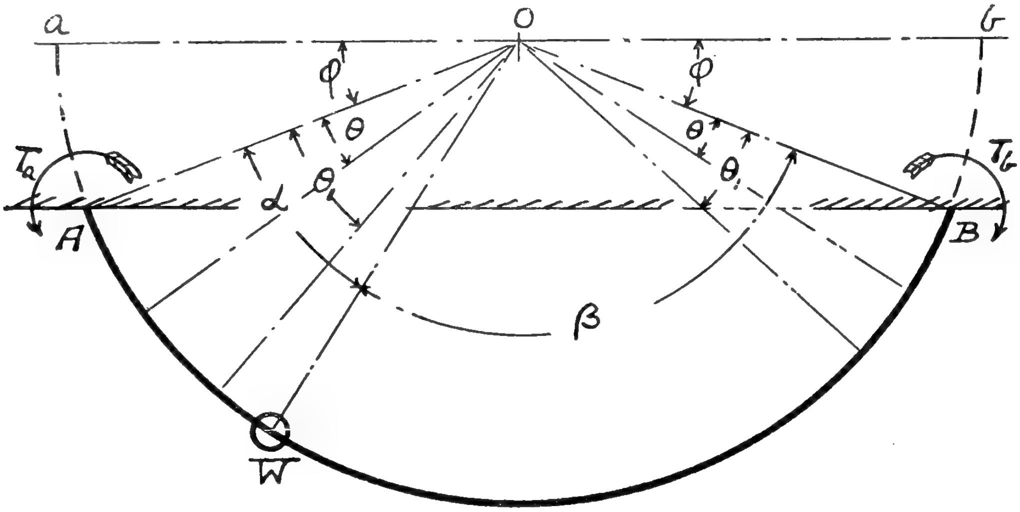


FIG. 4.

The bending and twisting moments at any point between A and W, distant θ from OA, are now given by

$$M_\theta = M_a \cos\theta - R_a r \sin\theta + T_a \sin\theta \quad . \quad . \quad . \quad (4)$$

$$T_\theta = T_a \cos\theta + R_a r(1 - \cos\theta) - M_a \sin\theta \quad . \quad . \quad . \quad (5)$$

while the moments at a point between B and W, distant θ from OB, are given by similar expressions, with suffix *b* taking the place of suffix *a*.

Before these moments can be calculated for any particular case, the values of the six unknowns, M_a, M_b, T_a, T_b, R_a, R_b, are to be ascertained; and for this, six relationships between these unknowns are necessary.

Taking moments about B, of the forces and couples acting in a vertical plane we have, for equilibrium :—

$$R_a(2r\cos\phi) - T_a\cos\phi - M_a\sin\phi - Wr\{\cos\phi + \cos(\alpha+\phi)\} + T_b\cos\phi + M_b\sin\phi = 0$$

$$\therefore R_a = \frac{W}{2}\left\{1 + \frac{\cos(\alpha+\phi)}{\cos\phi}\right\} + \frac{T_a - T_b}{2r} + \frac{M_a - M_b}{2r}\tan\phi \quad . \quad . \quad . \quad (6)$$

while

$$R_b = \frac{W}{2}\left\{1 - \frac{\cos(\alpha+\phi)}{\cos\phi}\right\} + \frac{T_b - T_a}{2r} + \frac{M_b - M_a}{2r}\tan\phi \quad . \quad . \quad . \quad (7)$$

Again, taking moments about the line AB,

$$(M_a + M_b)\cos\phi - (T_a + T_b)\sin\phi = Wr\{\sin(\alpha+\phi) - \sin\phi\} \quad . \quad . \quad . \quad (8)$$

while, equating the torques at the weight, as obtained by working from both ends of the girder,

$$T_a \cos\alpha + R_a r(1-\cos\alpha) - M_a \sin\alpha = -T_b\cos\beta - R_b r(1-\cos\beta) + M_b\sin\beta \quad . \quad . \quad . \quad (9)$$

The other two necessary relationships are obtained by expressing the fact that both slope and deflection at the weight are the same, whether the latter is considered as being at one extremity of the arc AW, or of the arc BW.

The slope at any point θ_1 between A and W is given by

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \frac{r^2}{\mathrm{EI}}\int_0^{\theta_1} \mathrm{M}_\theta \cos(\theta_1-\theta)d\theta + \frac{r^2}{\mathrm{CJ}}\int_0^{\theta_1} \mathrm{T}_\theta \sin(\theta_1-\theta)d\theta,$$

and, on substituting for M_θ and T_θ from (4) and (5) and integrating,

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_a\{\theta_1\cos\theta_1+\sin\theta_1\} - (\mathrm{R}_a r - \mathrm{T}_a)\theta_1\sin\theta_1\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_a - \mathrm{R}_a r)\theta_1\sin\theta_1 + 2\mathrm{R}_a r(1-\cos\theta_1) - \mathrm{M}_a\{\sin\theta_1 - \theta_1\cos\theta_1\}\Big] \end{array}\right].$$

Similarly at any point between B and W, distant θ_1 from OB,

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_b\{\theta_1\cos\theta_1+\sin\theta_1\} - (\mathrm{R}_b r - \mathrm{T}_b)\theta_1\sin\theta_1\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_b - \mathrm{R}_b r)\theta_1\sin\theta_1 + 2\mathrm{R}_b r(1-\cos\theta_1) - \mathrm{M}_b\{\sin\theta_1 - \theta_1\cos\theta_1\}\Big] \end{array}\right].$$

The slope at the weight is obtained by writing $\theta_1=\alpha$ in the first, or $\theta_1=\beta$ in the second of these expressions, and is thus given by :—

$$\left(\frac{dy}{d\theta}\right)_{\mathrm{W}} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_a\{\alpha\cos\alpha+\sin\alpha\} - (\mathrm{R}_a r - \mathrm{T}_a)\alpha\sin\alpha\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_a - \mathrm{R}_a r)\alpha\sin\alpha + 2\mathrm{R}_a r(1-\cos\alpha) - \mathrm{M}_a\{\sin\alpha - \alpha\cos\alpha\}\Big] \end{array}\right] \quad . \quad (10)$$

or by

$$\left(\frac{dy}{d\theta}\right)_{\mathrm{W}} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_b\{\beta\cos\beta+\sin\beta\} - (\mathrm{R}_b r - \mathrm{T}_b)\beta\sin\beta\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_b - \mathrm{R}_b r)\beta\sin\beta + 2\mathrm{R}_b r(1-\cos\beta) - \mathrm{M}_b\{\sin\beta - \beta\cos\beta\}\Big] \end{array}\right] \quad . \quad (11)$$

according as the point W is considered as forming part of span AW or of span BW.

On equating these two expressions, with the sign of the second changed since θ is measured in opposite directions in the two sections, a further relationship between the unknowns is obtained.

Deflections.—Assuming the supports to be at the same level, integrating $\frac{dy}{d\theta}$ to obtain the deflection, gives between A and W :—

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\int_0^{\theta_1}\Big[\mathrm{M}_a\{\theta\cos\theta+\sin\theta\} - (\mathrm{R}_a r - \mathrm{T}_a)\theta\sin\theta\Big]d\theta \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\int_0^{\theta_1}\Big[(\mathrm{T}_a - \mathrm{R}_a r)\theta\sin\theta + 2\mathrm{R}_a r(1-\cos\theta) - \mathrm{M}_a\{\sin\theta - \theta\cos\theta\}\Big]d\theta \end{array}\right]$$

as the deflection at a point distant θ_1 from A. On integrating and simplifying, this becomes—

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_a\theta_1 \sin\theta_1 - (\mathrm{R}_a r - \mathrm{T}_a)(\sin\theta_1 - \theta_1\cos\theta_1)\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_a - \mathrm{R}_a r)(\sin\theta_1 - \theta_1\cos\theta_1) + 2\mathrm{R}_a r(\theta_1 - \sin\theta_1) + \mathrm{M}_a(\theta_1\sin\theta_1 + 2\cos\theta_1 - 2)\Big] \end{array} \right] \quad (12)$$

Similarly for a point between B and W, distant θ_1 from B,

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_b\theta_1 \sin\theta_1 - (\mathrm{R}_b r - \mathrm{T}_b)(\sin\theta_1 - \theta_1\cos\theta_1)\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_b - \mathrm{R}_b r)(\sin\theta_1 - \theta_1\cos\theta_1) + 2\mathrm{R}_b r(\theta_1 - \sin\theta_1) + \mathrm{M}_b(\theta_1\sin\theta_1 + 2\cos\theta_1 - 2)\Big] \end{array} \right] \quad (13)$$

At the weight, θ_1 becomes α in (12) and β in (13) and these expressions give (A to W)—

$$y_{\mathrm{W}} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_a\alpha \sin\alpha - (\mathrm{R}_a r - \mathrm{T}_a)(\sin\alpha - \alpha\cos\alpha)\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_a - \mathrm{R}_a r)(\sin\alpha - \alpha\cos\alpha) + 2\mathrm{R}_a r(\alpha - \sin\alpha) + \mathrm{M}_a(\alpha\sin\alpha + 2\cos\alpha - 2)\Big] \end{array} \right] \quad . \ (14)$$

and (B to W)—

$$y_{\mathrm{W}} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[\mathrm{M}_b\beta \sin\beta - (\mathrm{R}_b r - \mathrm{T}_b)(\sin\beta - \beta\cos\beta)\Big] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\Big[(\mathrm{T}_b - \mathrm{R}_b r)(\sin\beta - \beta\cos\beta) + 2\mathrm{R}_b r(\beta - \sin\beta) + \mathrm{M}_b(\beta\sin\beta + 2\cos\beta - 2)\Big] \end{array} \right] \quad . \ (15)$$

On equating the identities (14) and (15) the final relationship is obtained, and from the six equations (6), (7), (8), (9), $(10 = -11)$, $(14 = 15)$, the six unknown fixing moments and reactions may be determined in any particular case. These moments depend somewhat on the relative values of EI and of CJ, except where the load is in the middle of the span. Comparatively large differences in the ratio EI : CJ, however, only produce small changes in their values, particularly when the angle α is large. An increase in this ratio is accompanied by an increase in both bending and twisting moments at the ends. The alteration in the fixing bending moment, accompanying any such change in this ratio as is likely to be found between extreme cases in practice is very small—in general, not more than 1 per cent. The alteration in the fixing torque is more pronounced, but as this is always a comparatively small fraction of the bending moment at the supports, the effect on the resultant moment is very slight.

In order to facilitate the application of the results of this analysis, and to make it more useful in practice, the foregoing equations have been solved for a series of values of α and of ϕ, and the values of the end moments and reactions have been calculated for the case where $\mathrm{EI} = 1{\cdot}24\mathrm{CJ}$. For purposes of practical design these values may be taken as being substantially accurate for any other probable value of the ratio.

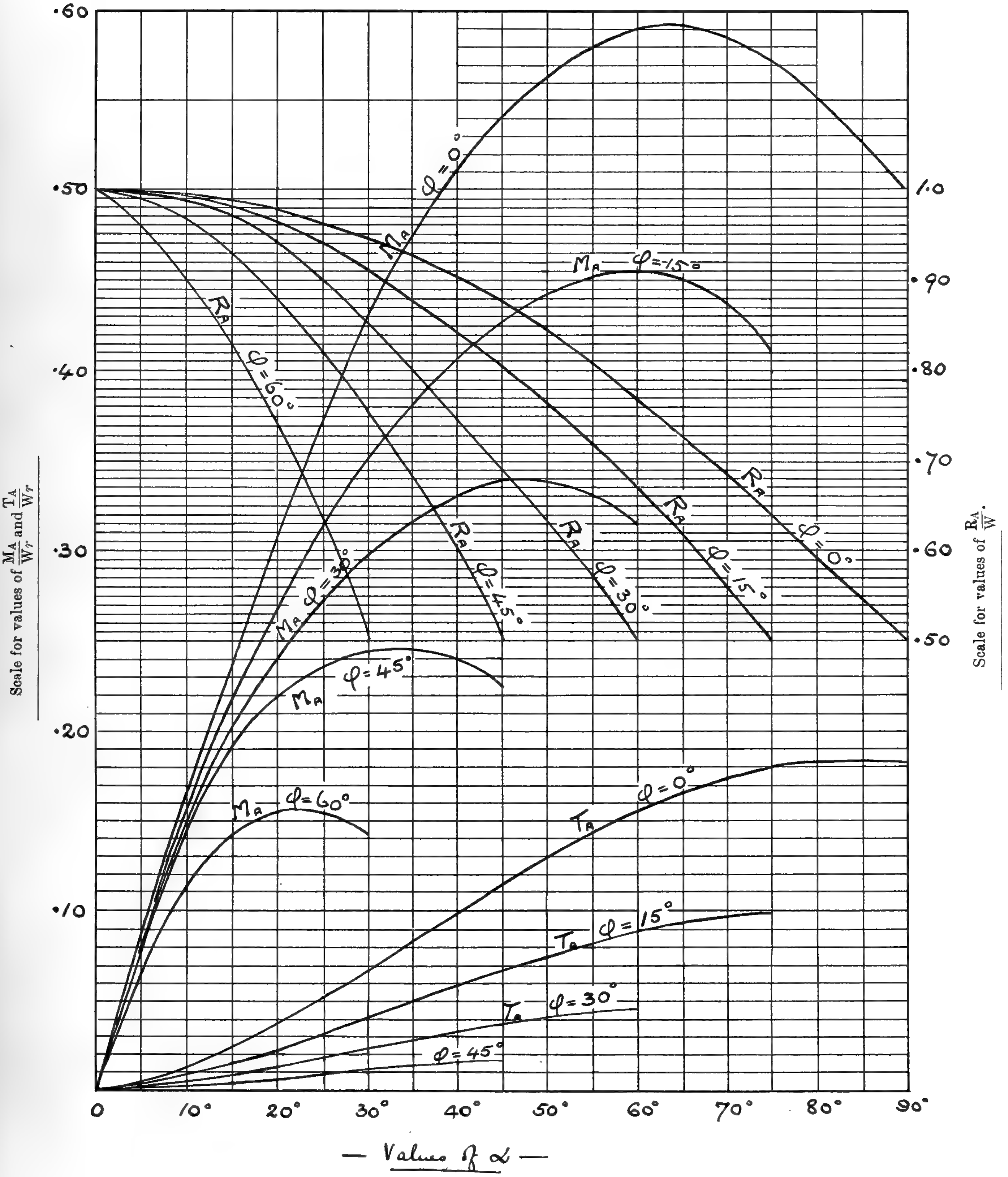


FIG. 5.—Values of R_A, M_A, and T_A, for a bow-girder built in at both ends, subtending an angle $180° - 2\phi$, and with a single load W distant $\alpha°$ from the end A.

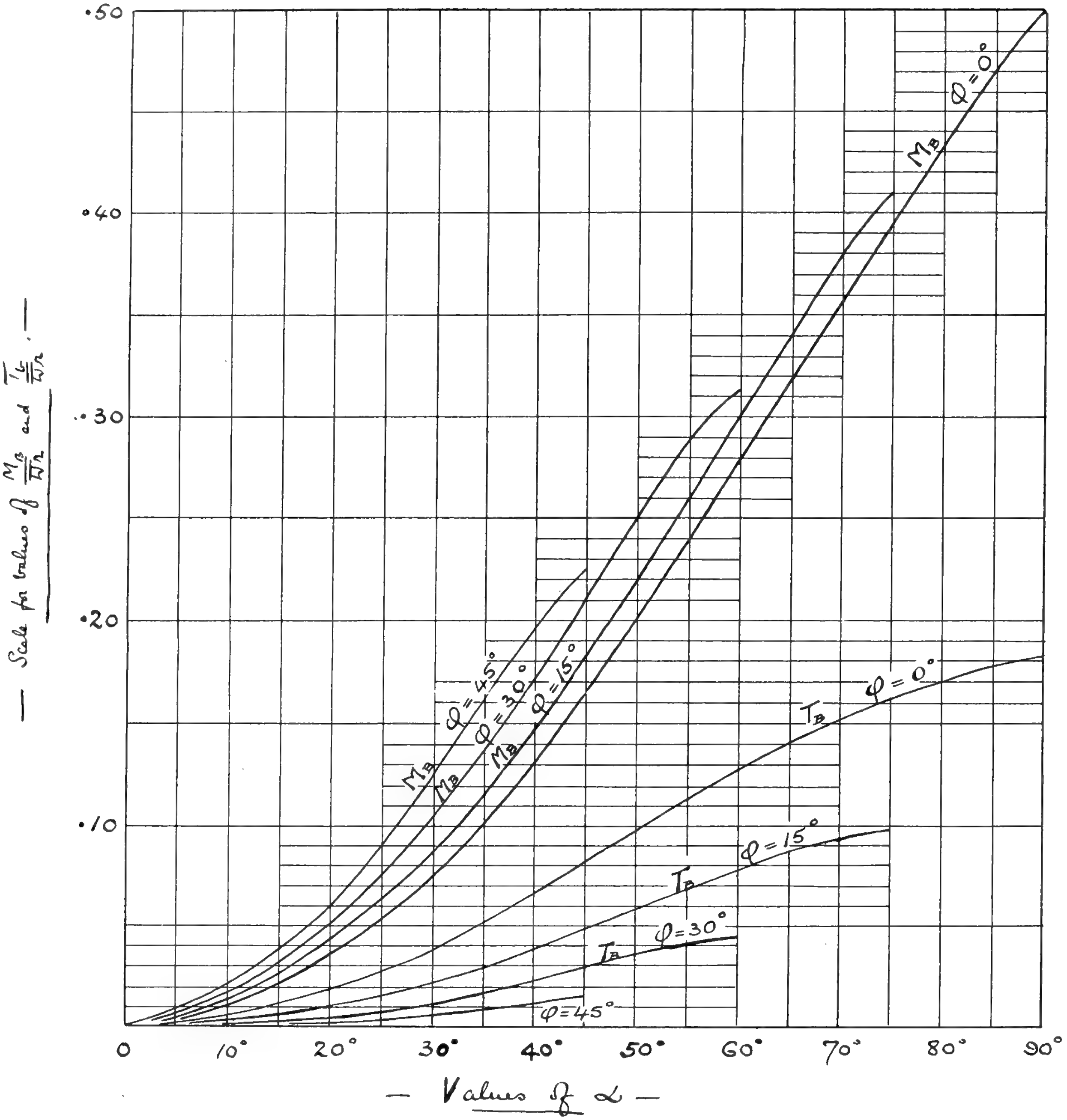


FIG. 6.—Values of M_b and T_B for a bow-girder built in at both ends, subtending an angle $180° - 2\phi$, and with a single load W distant $\alpha°$ from the end A.

The results are plotted as curves in figs. 5 and 6, and by substitution from these in equations (4), (5), (12), and (13), the values of the bending and twisting moments and of the deflections at any point of the girder, may be obtained.

Special Cases.

Semicircular Bow-Girder with single load W in any position.—Here $\alpha+\beta=180^\circ$; $\phi=0$; and the foregoing equations simplify. The values of the various constants for such a girder have been calculated for the case where $EI=1{\cdot}24CJ$, and are given in the following table.

α	0°	15°	30°	45°	60°	75°	90°
$\frac{R_a}{W}$	1·00	·990	·940	·870	·764	·640	·500
$\frac{R_b}{W}$	0·0	·0104	·060	·131	·236	·361	·500
$\frac{M_a}{Wr}$	0·0	·239	·428	·542	·590	·571	·500
$\frac{M_b}{Wr}$	0·0	·0200	·0725	·165	·276	·395	·500
$\frac{T_a}{Wr}$	0·0	·0251	·0662	·115	·155	·181	·182
$\frac{T_b}{Wr}$	0·0	·0118	·0382	·082	·128	·161	·182

In the particular case where $\alpha=90^\circ=1{\cdot}5708$ radians (*i.e.* weight at centre of span) from symmetry,

$$\begin{cases} R_a=R_b={\cdot}500W \\ M_a=M_b={\cdot}5Wr \\ T_a=T_b \end{cases}$$

From (10) the value of $\frac{dy}{d\theta}$ at the weight $\left(\alpha=\frac{\pi}{2}\right)$ is given by

$$\frac{r^2}{2EI}\left\{Wr\left(1-\frac{\pi}{2}\right)+\pi T_a\right\}-\frac{r^2}{2CJ}\left\{Wr\left(1-\frac{\pi}{2}-2\right)-\pi T_a\right\}=\left\{\frac{r^2}{2EI}-\frac{r^2}{2CJ}\right\}\left\{Wr\left(1-\frac{\pi}{2}\right)+\pi T_a\right\}.$$

From symmetry this equals zero;

$$\therefore\ T_a=Wr\left(\frac{\pi-2}{2\pi}\right)={\cdot}182Wr.$$

and in this case both M_a and T_a are independent of the relative values of EI and CJ.

Experimental Verification.—As a check, a series of measurements of deflection were made on a small semicircular bow-girder, 10·10 ins. in radius. $\frac{EI}{CJ}=1{\cdot}24$.

The following are the deflections corresponding to a load of 1 lb., as obtained by measurement and by calculation from formulæ (12) or (14), with values of T_a, M_a, etc., taken from the table on p. 401.

a	Deflection at Weight (ins.).		Deflection at Centre of Span.	
	Calculated.	Measured.	Calculated.	Measured.
30°	·0430	·0432	...	...
45°	·115	·117	·148	·150
60°	·204	·202	...	...
90°	·3075	·3075	·3075	·3075

Circular-Arc Girder, subtending an angle less than 180°, *and carrying a single weight at the centre of the span.*—Let $2a = \pi - 2\phi$ be the angle subtended (fig. 4). The moment of the weight about $AB = Wr(1 - \sin\phi)$, and as, from symmetry, $M_a = M_b$; $T_a = T_b$; equation (8) becomes:—

$$M_a \cos\phi - T_a \sin\phi = \frac{Wr}{2}(1 - \sin\phi)$$

or

$$M_a = \frac{Wr}{2\cos\phi}(1 - \sin\phi) - T_a \tan\phi,$$

also

$$R_a = R_b = \frac{W}{2}$$

On substituting these values of M_a and R_a, equation (10) becomes

$$\left(\frac{dy}{d\theta}\right)_W = \left[\begin{array}{l} \frac{Wr^3}{2EI}\left[\left(\frac{1-\sin\phi}{2\cos\phi} - \frac{T_a}{Wr}\tan\phi\right)\{a\cos a + \sin a\} - \left(\frac{1}{2} - \frac{T_a}{Wr}\right)a\cos\phi\right] \\ \quad + \frac{Wr^3}{2CJ}\left[\left(\frac{T_a}{Wr} - \frac{1}{2}\right)a\cos\phi + 1 - \sin\phi - \left(\frac{1-\sin\phi}{2\cos\phi} - \frac{T_a}{Wr}\tan\phi\right)\{\sin a - a\cos a\}\right] \end{array}\right].$$

From symmetry this equals zero, and, on substituting for a and ϕ and equating to zero, the value of T_a is obtained. Except in a semicircular girder ($\phi = 0$), this value depends on the ratio of EI : CJ. The following table has been calculated for the cases in which this ratio equals 1·24 and 2·0:—

$\phi°$		0°	15°	30°	45°	60°
$\frac{M_a}{Wr}$	EI = 1·24CJ	·50	·410	·314	·223	·140
	EI = 2CJ	·50	·411	·317	·225	·141
$\frac{T_a}{Wr}$	EI = 1·24CJ	·182	·099	·045	·0157	·0032
	EI = 2·0CJ	·182	·103	·050	·0185	·0041

Knowing M_a and T_a, the deflection at the weight may be obtained by substituting these values in equation (14).

Experimental Verification.—The experimental girder ($\phi = 30^\circ, r = 10{\cdot}10$ inches) was loaded with a central weight, and the deflection measured. Under these conditions the measured deflection for a weight of 1 lb., and the deflection calculated from (14) with $M_a = {\cdot}3145 Wr$; $T_a = {\cdot}045 Wr$, were as follows:—

Deflection (measured) = ·0747 inch; (calculated) = ·0743 inch.

§ 5. Circular-Arc Bow-Girder, Built in at Both Ends, with Uniform Loading—w lbs. per Unit Length.

Let $\pi - 2\phi$ be the angle subtended by the arc (fig. 4). The total load $= wr(\pi - 2\phi)$ lbs.

$$\therefore \ R_a = R_b = wr\left(\frac{\pi}{2} - \phi\right).$$

The centre of gravity of the load is at a distance from the line of supports given by—

$$r\left\{\frac{\sin\left(\frac{\pi}{2} - \phi\right)}{\frac{\pi}{2} - \phi} - \sin\phi\right\} = 2r\left\{\frac{\cos\phi - \left(\frac{\pi}{2} - \phi\right)\sin\phi}{\pi - 2\phi}\right\}$$

Let M_a, M_b, T_a, T_b, have the same meanings as before. Then, from symmetry, $M_a = M_b$, $T_a = T_b$; and, on taking moments about the line AB:—

$$2M_a\cos\phi - 2T_a\sin\phi = 2wr^2\left\{\cos\phi - \left(\frac{\pi}{2} - \phi\right)\sin\phi\right\}$$

$$\therefore \ M_a = wr^2\left\{1 - \left(\frac{\pi}{2} - \phi - \frac{T_a}{wr^2}\right)\tan\phi\right\}.$$

Taking the origin of ϕ at the supports,

$$\begin{aligned} M_\theta &= M_a\cos\theta - R_a r\sin\theta + T_a\sin\theta + wr^2(1 - \cos\theta)^* \\ &= (M_a - wr^2)\cos\theta - (R_a r - T_a)\sin\theta + wr^2 \quad . \quad . \quad . \quad . \quad . \quad . \quad (18) \\ T_\theta &= T_a\cos\theta + R_a r(1 - \cos\theta) - M_a\sin\theta - wr^2(\theta - \sin\theta)^* \\ &= (T_a - R_a r)\cos\theta - (M_a - wr^2)\sin\theta + R_a r - wr^2\theta \quad . \quad . \quad . \quad . \quad . \quad (19) \end{aligned}$$

If the girder is fixed horizontally at the ends,

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \frac{r^2}{EI}\int_0^\theta M_\theta\cos(\theta_1 - \theta)d\theta + \frac{r^2}{CJ}\int_0^{\theta_1} T_a\sin(\theta_1 - \theta)d\theta$$

and, on substituting for M_θ and T_θ from (18) and (19), this gives

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2EI}\left[(M_a - wr^2)\{\theta_1\cos\theta_1 + \sin\theta_1\} - (R_a r - T_a)\theta_1\sin\theta_1 + 2wr^2\sin\theta_1\right] \\ \quad + \frac{r^2}{2CJ}\left[\begin{array}{l} (T_a - R_a r)\theta_1\sin\theta_1 - (M_a - wr^2)\{\sin\theta_1 - \theta_1\cos\theta_1\} \\ \qquad + 2R_a r(1 - \cos\theta_1) - 2wr^2(\theta_1 - \sin\theta_1) \end{array}\right] \end{array}\right] \quad . \quad (20)$$

---

* The last terms, representing the moments due to the portion of the load between A and θ, being obtained as at the beginning of § 3.

Writing θ for θ_1 in this expression, and integrating between the limits θ_1 and 0, we have :—

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\Big[(\mathrm{M}_a - wr^2)\theta_1 \sin\theta_1 - (\mathrm{R}_a r - \mathrm{T}_a)(\sin\theta_1 - \theta_1\cos\theta_1) - 2wr^2(\cos\theta_1 - 1)\Big] \\ \quad + \frac{r^2}{2\mathrm{CJ}}\left[\begin{array}{l}(\mathrm{T}_a - \mathrm{R}_a r)(\sin\theta_1 - \theta_1\cos\theta_1) + (\mathrm{M}_a - wr^2)\{\theta_1\sin\theta_1 + 2\cos\theta_1 - 2)\} \\ \qquad\qquad + 2\mathrm{R}_a r(\theta_1\sin\theta_1) - 2wr^2\left(\frac{\theta_1^{\ 2}}{2} + \cos\theta_1 - 1\right)\end{array}\right] \end{array} \right] \quad (21)$$

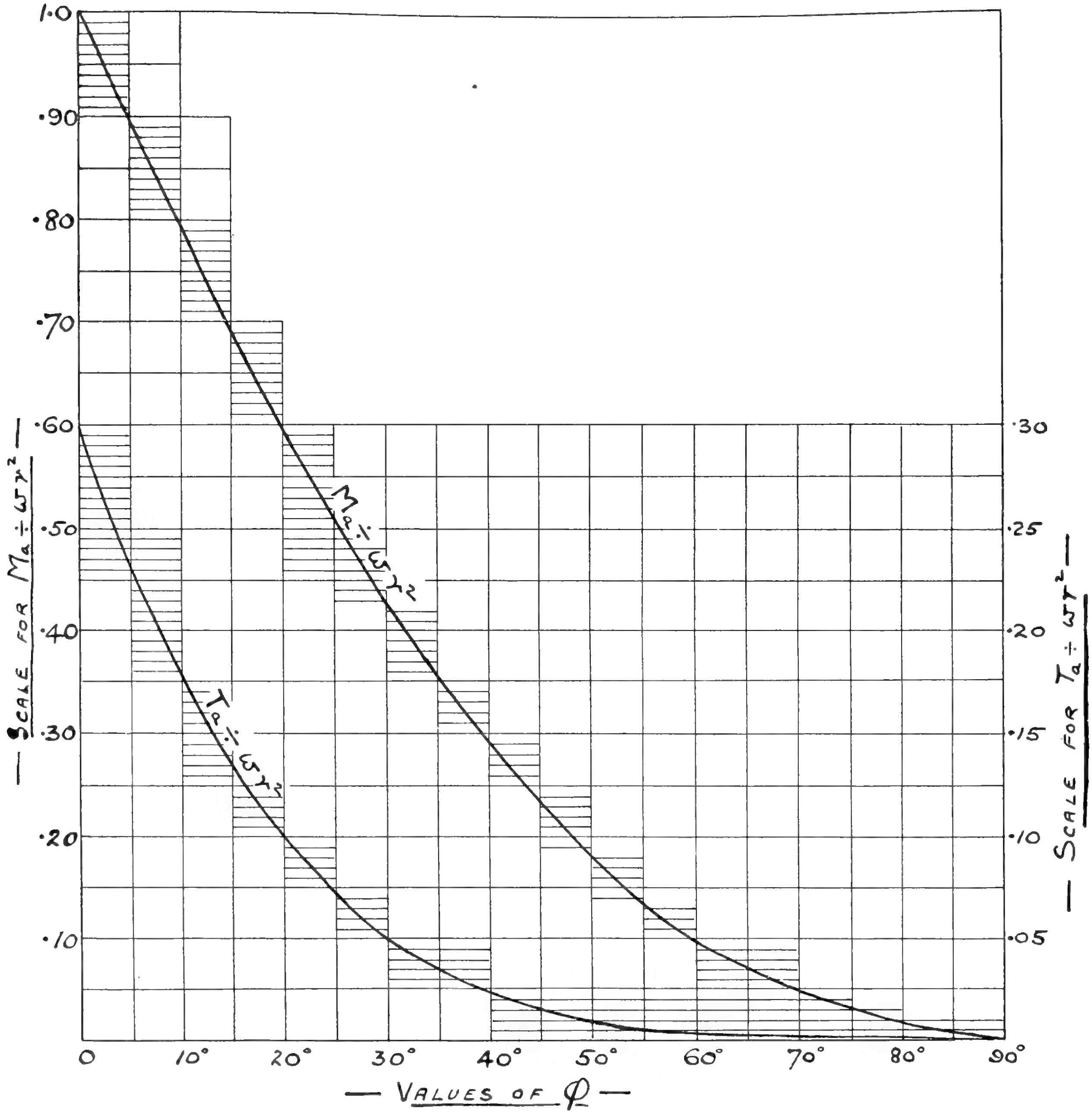


FIG. 7.—Values of M_a and T_a for a uniformly loaded circular arc subtending an angle (180° − 2ϕ).

From symmetry $\frac{dy}{d\theta}$ is zero at the centre of the span where $\theta_1=\frac{\pi}{2}-\phi$, and by substituting this value for θ_1 in (20), and by also substituting for M_a its value $wr^2\left\{1-\left(\frac{\pi}{2}-\phi-\frac{T_a}{wr^2}\right)\tan\phi\right\}$ and equating to zero, the value of T_a may be obtained, after which the values of M_θ and T_θ for any point on the girder may be obtained by substitution in (18) or (19).

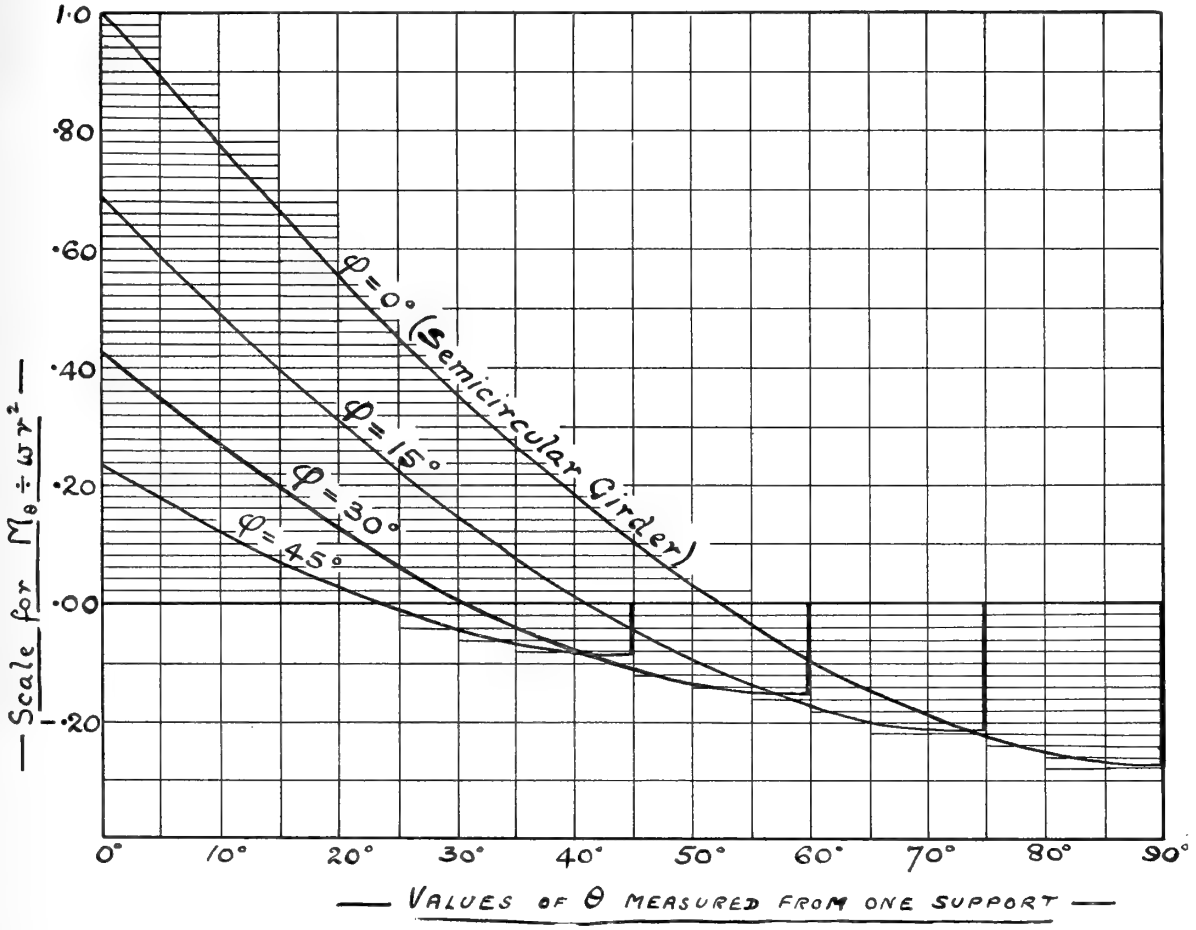


FIG. 8.—Bending Moment Diagrams for one-half of uniformly loaded circular arc subtending an angle of (180 – 2ϕ°).

The values of M_a, T_a, M_θ, T_θ have been calculated from the foregoing equations for one-half of a uniformly loaded girder for a series of values of ϕ, and of θ for each value of ϕ. These values depend slightly on the relative value of EI and of CJ, and in fig. 7 values of M_a and of T_a are plotted for the case in which the ratio of EI : CJ is 1·24. In figs. 8 and 9, values of M_θ and T_θ are plotted for the same case, and for purposes of practical design these values may be taken as sensibly accurate for any other likely values of the ratio. In the case of the semicircular girder, the moments are independent of this ratio. The following table shows values of M_a and T_a, also for the case where EI = 2CJ :—

ϕ		0°	15°	30°	45°	60°
$\frac{M_a}{wr^2}$	EI = 1·24CJ	1·00	·686	·424	·230	·0974
	EI = 2CJ	1·00	·688	·427	·232	·0983
$\frac{T_a}{wr^2}$	EI = 1·24 CJ	·298	·135	·0490	·0156	·00199
	EI = 2CJ	·298	·140	·0542	·0178	·00251

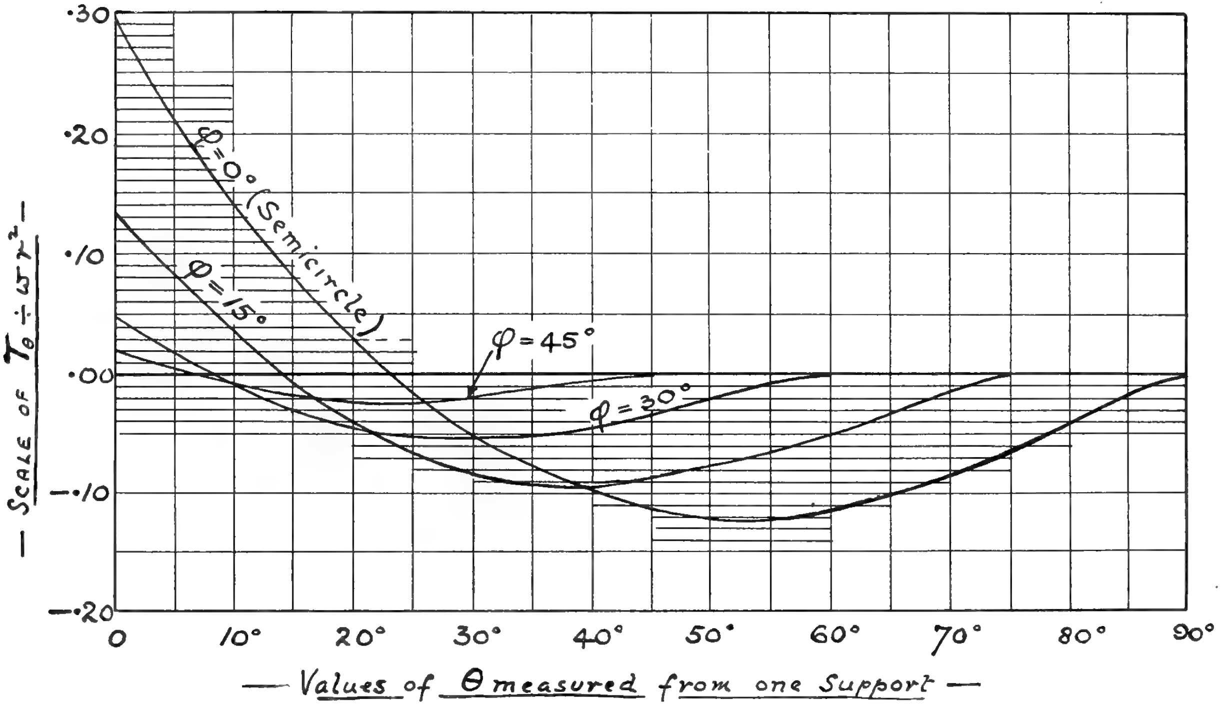


FIG. 9.—Twisting Moment Diagrams for one-half of uniformly loaded circular arc subtending an angle of (180 – 2ϕ).

Special Case.

Semicircular Girder with uniform load.—Here $\phi = 0$, and we have :—

$$M_a = M_b = wr^2 \ : \ R_a = R_b = \frac{\pi}{2} \cdot wr :$$

$$\left(\frac{dy}{d\theta}\right)_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2EI}\Big[(T_a - R_a r)\theta_1 \sin\theta_1 + 2wr^2 \sin\theta_1\Big] \\ \qquad + \frac{r^2}{2CJ}\Big[(T_a - R_a r)\theta_1 \sin\theta_1 + 2R_a r(1 - \cos\theta_1) - 2wr^2(\theta_1 - \sin\theta_1)\Big] \end{array}\right] \quad . \quad . \quad . \quad (20')$$

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2EI}\Big[(T_a - R_a r)(\sin\theta_1 - \theta_1\cos\theta_1) - 2wr^2(\cos\theta_1 - 1)\Big] \\ \qquad + \frac{r^2}{2CJ}\Big[(T_a - R_a r)(\sin\theta_1 - \theta_1\cos\theta_1) + 2R_a r(\theta_1 - \sin\theta_1) - 2wr^2\Big(\frac{\theta_1^{\,2}}{2} + \cos\theta_1 - 1\Big)\Big] \end{array}\right] \quad (21')$$

Substituting for M_a and R_a in (20′), and equating to zero, gives

$$T_a = wr^2 \times \frac{2}{\pi}\left(\frac{\pi^2}{4} - 2\right) = \cdot 298wr^2 ,$$

and on substituting in (18) and (19)

$$M^{\theta} = wr^2(1 - 1{\cdot}2728 \sin \theta),$$
$$T^{\theta} = wr^2(1{\cdot}5708 - 1{\cdot}2728 \cos \theta - \theta).$$

This makes $M_{\theta} = 0$ when $\sin \theta = \dfrac{1}{1{\cdot}2728} = {\cdot}7850$; *i.e.* when $\theta = 51°43'$, and makes $T_{\theta} = 0$ when $\theta = 22°40'$, and again when $\theta = 90°$. M_{θ} is a maximum when $\dfrac{dM_{\theta}}{d\theta} = 0$; *i.e.* when $\cos \theta = 0$, and therefore at the supports. T_{θ} is a maximum when $\dfrac{dT_{\theta}}{d\theta} = 0$, *i.e.* when $\sin \theta = {\cdot}7850$, or when $\theta = 51°43'$.

Writing $\theta_1 = \dfrac{\pi}{2}$ in (21′) and substituting for T_a and M_a, the deflection at the centre is given by

$$y_{(\text{centre})} = wr^4\left[\frac{{\cdot}7272}{2EI} + \frac{{\cdot}053}{2CJ}\right].$$

Experimental Verification. — An experimental semicircular girder, 10·1 ins. radius, loaded so as to give $w = {\cdot}0636$ lb. per inch run, gave the following results :—

Deflection (calculated) = ·306 in. : (measured) = ·310 in.

A comparison of a straight encastré girder with a semicircular bow-girder of the same length l ($= \pi r$), each being loaded with w lbs. per foot run, shows the following results :—

	Bending Moment at Supports.	Bending Moment at Centre.	Distance from Centre, of the Point where BM = 0.
Bow-Girder . . .	$\cdot 1014wl^2$	$-\cdot 0282wl^2$	$\cdot 212l$
Straight Girder . . .	$\cdot 0833wl^2$	$-\cdot 0417wl^2$	$\cdot 289l$

§ 6. CIRCULAR-ARC BOW-GIRDER, SUBTENDING AN ANGLE $(180 - 2\phi)°$, BUILT IN AT THE ENDS AND CARRYING A UNIFORMLY LOADED PLATFORM.

Let w lb. per unit area be the load on the platform whose area will be $\dfrac{r^2}{2}\left\{\pi - 2\phi - \sin 2\phi\right\}$. Imagine the latter to be divided into a series of strips parallel to AB, each of these strips transmitting its load to the girder at its ends. The length of the particular strip resting on the girder at points distant θ from A and B, is $2r \cos(\theta + \phi)$ (fig. 10). If this strip covers a length $\delta s = r\delta\theta$ of the girder, its width is $r\delta\theta \cos(\theta + \phi)$, and the load on it is $2wr^2 \cos^2(\theta + \phi)\delta\theta$.

Its moment about $AB = 2wr^3 \cos^2(\theta + \phi)\{\sin(\theta + \phi) - \sin \phi\}\delta\theta$,

$$\therefore \text{ Moment of whole load, about AB} = 2wr^3 \int_0^{\frac{\pi}{2}\ \phi} \cos^2(\theta + \phi)\{\sin(\theta + \phi) - \sin \phi\}\delta\theta$$
$$= 2wr^3 \left\{\frac{\cos^3 \phi}{3} - \frac{\sin \phi}{4}(\pi - 2\phi - \sin 2\phi)\right\}$$

Since, from symmetry, $M_a = M_b$; $T_a = T_b$; it follows that :—

$$M_a \cos\phi - T_a \sin\phi = wr^3 \left\{ \frac{\cos^3\phi}{3} - \frac{\sin\phi}{4}(\pi - 2\phi - \sin 2\phi) \right\}$$

$$\therefore\ M_a = wr^3 \left\{ \frac{\cos^2\phi}{3} - \frac{\tan\phi}{4}(\pi - 2\phi - \sin 2\phi) \right\} + T_a \tan\phi.$$

Again, since the total load is

$$2wr^2 \int_0^{\frac{\pi}{2}-\phi} \cos^2(\theta+\phi)\,d\theta$$

$$= \frac{wr^2}{2}\left\{ \pi - 2\phi - \sin 2\phi \right\}$$

$$\therefore\ R_a = R_b = \frac{wr^2}{4}\left\{ \pi - 2\phi - \sin 2\phi \right\}.$$

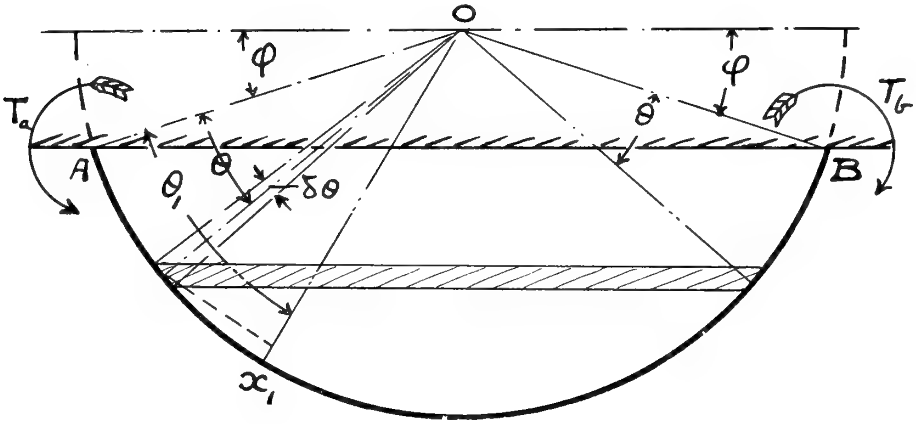


FIG. 10.

The bending and twisting moments at a point x_1 distant θ_1 from OÁ are given by :—

$$M_{\theta_1} = M_a \cos\theta_1 - (R_a r - T_a)\sin\theta_1 + \int_0^{\theta_1} wr^3 \cos^2(\theta+\phi)\sin(\theta_1-\theta)\,d\theta.$$

$$T_{\theta_1} = (T_a - R_a r)\cos\theta - M_a \sin\theta + R_a r - \int_0^{\theta_1} wr^3 \cos^2(\theta+\phi)\{1-\cos(\theta_1-\theta)\}\,d\theta,$$

the last term in each case representing the moment, bending or twisting, about the point x_1 (fig. 10), of the load between A and x_1.

On integrating these terms and writing θ for θ_1, the general expressions for M_θ and T_θ become :—

$$M_\theta = M_a\cos\theta - (R_a r - T_a)\sin\theta + \frac{wr^3}{3}\Big[(\cos\theta - 1)\{\cos\theta - \sin^2\phi + \sin 2\phi \sin\theta\} + 2\sin^2\theta\cos^2\phi\Big]. \qquad (22)$$

$$T_\theta = (T_a - R_a r)\cos\theta - M_a\sin\theta + R_a r - wr^3 \left[\begin{array}{r} \frac{\theta}{2} + \sin\theta\left\{ \frac{\cos 2\phi\cos\theta}{2} + \frac{2}{3}(1-\cos\theta) - \cos^2\phi \right\} \\ - \frac{\sin 2\phi}{6}(1-\cos\theta)^2 \end{array} \right] \qquad (23)$$

As before, if the girder be fixed horizontally at the ends:—

$$\left(\frac{dy}{d\theta}\right)_{\theta_1}=\frac{r^2}{\mathrm{EI}}\int_0^{\theta_1}\mathrm{M}_\theta\cos(\theta_1-\theta)d\theta+\frac{r^2}{\mathrm{CJ}}\int_0^{\theta_1}\mathrm{T}_\theta\sin(\theta_1-\theta)d\theta,$$

and, on substituting the foregoing values of M_θ and T_θ and integrating, this gives the value of $\frac{dy}{d\theta}$ at any point θ_1. Thus,

$$\left(\frac{dy}{d\theta}\right)_{\theta_1}=\left[\begin{array}{l}\frac{r^2}{2\mathrm{EI}}\left[\begin{array}{l}\mathrm{M}_a(\theta_1\cos\theta_1+\sin\theta_1)-(\mathrm{R}_ar-\mathrm{T}_a)\theta_1\sin\theta_1\\ \quad+\frac{wr^3}{3}\left\{\sin\theta_1\left(\frac{7}{3}-\sin^2\phi\{3+\theta_1\}\right)-\theta_1\cos\theta_1(1+\sin^2\phi)-\frac{2}{3}\sin 2(\theta_1+\phi)\right\}\end{array}\right]\\ +\frac{r^2}{2\mathrm{CJ}}\left[\begin{array}{l}(\mathrm{T}_a-\mathrm{R}_ar)\theta_1\sin\theta_1-\mathrm{M}_a(\sin\theta_1-\theta_1\cos\theta_1)+2\mathrm{R}_ar(1-\cos\theta_1)\\ -wr^3\left\{\begin{array}{l}\theta_1-\sin\theta_1\left(\frac{7}{9}+\cos^2\phi-\frac{\cos 2\phi}{3}+\frac{\sin 2\phi}{6}+\frac{\cos\theta_1\cos 2\phi}{3}-\frac{4}{9}\cos\theta_1\right)\\ +\theta_1\cos\theta_1\left(\cos^2\phi+\frac{\sin 2\phi}{6}-\frac{2}{3}\right)+\frac{\sin 2\phi}{9}(3\theta_1\sin\theta_1-\sin^2\theta_1+\cos\theta_1-1)\end{array}\right.\end{array}\right]\end{array}\right] \qquad (24)$$

From symmetry the slope is zero at the centre of the beam where $\theta_1=\frac{\pi}{2}-\phi$, and, on substituting this value for θ_1 in (24), and also substituting the values of M_a and R_a as given on p. 408, and equating to zero, the value of T_a may be obtained.

E.g., Semicircular Girder ($\phi=0$).

In this case, on putting $\phi=0$ in (24):—

$$\therefore\left(\frac{dy}{d\theta}\right)_{\theta_1}=\left[\begin{array}{l}\frac{r^2}{2\mathrm{EI}}\left[\begin{array}{l}\mathrm{M}_a\{\theta_1\cos\theta_1+\sin\theta_1\}-(\mathrm{R}_ar-\mathrm{T}_a)\theta_1\sin\theta_1\\ \quad+\frac{wr^2}{3}\left\{\frac{7}{3}\sin\theta_1-\cos\theta_1\left(\frac{4}{3}\sin\theta_1+\theta_1\right)\right\}\end{array}\right]\\ \quad+\frac{r^2}{2\mathrm{CJ}}\left[\begin{array}{l}(\mathrm{T}_a-\mathrm{R}_ar)\theta_1\sin\theta_1-\mathrm{M}_a\{\sin\theta_1-\theta_1\cos\theta_1\}\\ +2\mathrm{R}_ar(1-\cos\theta_1)-wr^3\left\{\theta_1-\sin\theta_1\left(\frac{13}{9}-\frac{1}{9}\cos\theta_1\right)+\frac{1}{3}\theta_1\cos\theta_1\right\}\end{array}\right]\end{array}\right] \qquad (24')$$

At the centre, where $\theta_1=\frac{\pi}{2}$, the slope is zero, and $\mathrm{M}_a=\frac{wr^3}{3}$; $\mathrm{R}_a=wr^2.\frac{\pi}{4}$.

$$\therefore\quad\frac{wr^5}{2\mathrm{EI}}\left[\frac{1}{3}-\left(\frac{\pi}{4}-\frac{\mathrm{T}_a}{wr^3}\right)\frac{\pi}{2}+\frac{7}{9}\right]+\frac{wr^5}{2\mathrm{CJ}}\left[\left(\frac{\mathrm{T}_a}{wr^3}-\frac{\pi}{4}\right)\frac{\pi}{2}-\frac{1}{3}+\frac{13}{9}\right]=0$$

$$\therefore\quad\mathrm{T}_a=\left(\frac{\pi}{4}-\frac{20}{9\pi}\right)wr^3=\cdot 078wr^3.$$

It follows that, on substituting in (22) and (23):—

$$\mathrm{M}_\theta=wr^3\left\{\frac{1+\sin^2\theta}{3}-\cdot 7074\sin\theta\right\}$$

$$\mathrm{T}_\theta=wr^3\left\{\frac{\sin\theta\cos\theta}{6}+\frac{\pi}{4}-\cdot 7074\cos\theta-\frac{\theta}{2}\right\}$$

The deflection at any point θ_1 is obtained by writing $\theta_1=\theta$ in (24′) and integrating between the limits θ_1 and 0. Thus,

$$y_{\theta_1} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\left[\mathrm{M}_a\theta_1 \sin\theta_1 - (\mathrm{R}_a r - \mathrm{T}_a)(\sin\theta_1 - \theta_1\cos\theta_1) + \frac{wr^3}{9}\left\{10 - 10\cos\theta_1 - 2\sin^2\theta_1 - 3\theta_1\sin\theta_1\right\}\right] \\ + \frac{r^2}{2\mathrm{CJ}}\left[\begin{array}{l} (\mathrm{T}_a - \mathrm{R}_a r)(\sin\theta_1 - \theta_1\cos\theta_1) + 2\mathrm{R}_a r(\theta_1 - \sin\theta_1) \\ \qquad + \mathrm{M}_a(\theta_1\sin\theta_1 + 2\cos\theta_1 - 2) - \frac{wr^3}{9}\left\{\frac{9\theta_1^{\,2}}{2} + 16\cos\theta_1 - 16 + \frac{\sin^2\theta_1}{2} + 3\theta_1\sin\theta_1\right\} \end{array}\right] \end{array}\right] \tag{25}$$

At the centre, where $\theta_1 = \frac{\pi}{2}$:—

$$y_{\text{centre}} = \left[\begin{array}{l} \frac{r^2}{2\mathrm{EI}}\left[\mathrm{M}_a\frac{\pi}{2} - (\mathrm{R}_a r - \mathrm{T}_a) + {\cdot}3653wr^3\right] \\ \qquad + \frac{r^2}{2\mathrm{CJ}}\left[(\mathrm{T}_a - \mathrm{R}_a r) + \mathrm{R}_a r(\pi - 2) + \mathrm{M}_a\left(\frac{\pi}{2} - 2\right) - {\cdot}0350wr^3\right] \end{array}\right]$$

$$= \frac{wr^5}{2}\left[\frac{{\cdot}1815}{\mathrm{EI}} + \frac{{\cdot}0121}{\mathrm{CJ}}\right].$$

§ 7. GIRDER WITH UNSYMMETRICAL LOADING.

Where the loading of a girder does not admit of being represented by a simple trigonometrical expression, or where the girder is not of uniform cross section throughout its length, a solution is most readily obtained by dividing the load, including the dead load due to the girder itself, into a series of comparatively short lengths, and by calculating the moments due to each of these portions of the load separately, by an application of the reasoning and results of § 4. In practice a first approximation to the moments would be obtained by assuming a likely value for the cross section and weight at each point, and by then applying these results. A girder then designed to withstand the moments as thus calculated, with equal stresses at each section, would, in the majority of cases, be sufficiently near for all practical purposes. If greater accuracy were required, a second approximation could be made, taking into account the weights of the girder calculated from the sections found necessary by the first approximation.

§ 8. BOW-GIRDER BUILT IN AT THE ENDS AND RESTING ON INTERMEDIATE SUPPORTS.

Assuming all the supports to be at the same level, the reactions of the intermediate supports may be most readily obtained by expressing the fact that the upward deflections at these supports caused by their reactions, are equal to the downward deflections produced at the same points by the loading.

(a) *Girder with Uniform Loading and Central Support.*

Let P be the reaction of this support. Let $180 - 2\phi$, or 2α, be the angle subtended by the arc of the girder.

The upward deflection at the centre due to this reaction is given by equation (14), in which $\mathrm{W} = \mathrm{P}$, and in which M_a and T_a have the values given in the table on p. 12, or by the curves of fig. 5, for the corresponding value of α or $(90^\circ - \phi)$. The downward deflection at the centre due to the load is obtained by substituting α for θ_1, and by substituting the corresponding values of M_a and of T_a as given by the curves of fig. 7, in (21).

E.g., $\alpha = 90^\circ$; $\phi = \mathrm{o}$; (semicircular girder).

$$\text{The upward deflection at centre} = \frac{Pr^3}{2EI}\left[\frac{\pi}{4} - ({\cdot}500 - {\cdot}182)\right] + \frac{Pr^3}{2CJ}\left[({\cdot}182 - {\cdot}500) + \frac{\pi}{2} - 1 + \frac{\pi}{4}\left(\frac{\pi}{2} - 2\right)\right]$$

$$= Pr^3\left[\frac{{\cdot}4674}{2EI} + \frac{.0382}{2CJ}\right]$$

$$\text{The downward deflection at the centre, due to the loading} = wr^4\left[\frac{{\cdot}7272}{2EI} + \frac{{\cdot}053}{2CJ}\right]$$

and on equating these :—

$$P = wr\left[\frac{{\cdot}7272CJ + {\cdot}053EI}{{\cdot}4674CJ + {\cdot}0382EI}\right].$$

The value of this is sensibly independent of the ratio of EI to CJ. Taking this ratio as 1·24, as in the experimental girder, gives

$$P = wr\left\{\frac{{\cdot}7928}{{\cdot}5147}\right\} = 1{\cdot}54wr.$$

Again,

$$R_a + R_b + P = \pi wr$$

$$\therefore\quad R_a = R_b = \frac{wr}{2}\left\{\pi - 1{\cdot}54\right\}$$

$$= {\cdot}801wr.$$

Also

$$M_a + M_b = 2wr^2 - Pr$$

$$= {\cdot}46wr^2$$

$$\therefore\quad M_a = M_b = {\cdot}23wr^2.$$

The value of T_a is the difference between the values produced by the load and by the upward reaction P. The first of these is $\cdot 298wr^2$ (fig. 7); the second is $\cdot 182Pr$ (fig. 5).

$$\therefore\quad T_a = \{{\cdot}298 - ({\cdot}182 \times 1{\cdot}54)\}wr^2$$

$$= {\cdot}018wr^2.$$

This value may be obtained alternatively by substituting the foregoing values of M_a and of R_a in equation (20) with $\theta_1 = \frac{\pi}{2}$, and by equating to zero.

The values of M_θ and of T_θ at any point distant θ from the end then become, on substituting in equations (18) and (19) :—

$$M_\theta = wr^2\{1 - {\cdot}77\cos\theta - {\cdot}783\sin\theta\},$$

$$T_\theta = wr^2\{{\cdot}801 - {\cdot}783\cos\theta + {\cdot}76\sin\theta - \theta\}.$$

Where the girder subtends an angle less than 180°, the problem may be solved in an exactly similar manner by making use of the requisite relationships from curves figs. 5 and 7.

(*b*) *Circular-Arc Girder built in at the Ends, with Uniform Loading and with two Symmetrical Intermediate Supports.*

Let the angle subtended by the girder be $(180-2\phi)^\circ$ or 2α, and let the supports (at C and D, fig. 11) be distant γ from each end. Let the upward reaction at each support $=$ P. Let M_a'', T_a'', R_a'' represent such end conditions at A as would be produced by these two reactions alone, and let M_a', T_a', R_a' represent such end conditions as would be produced by the load alone, with supports removed.

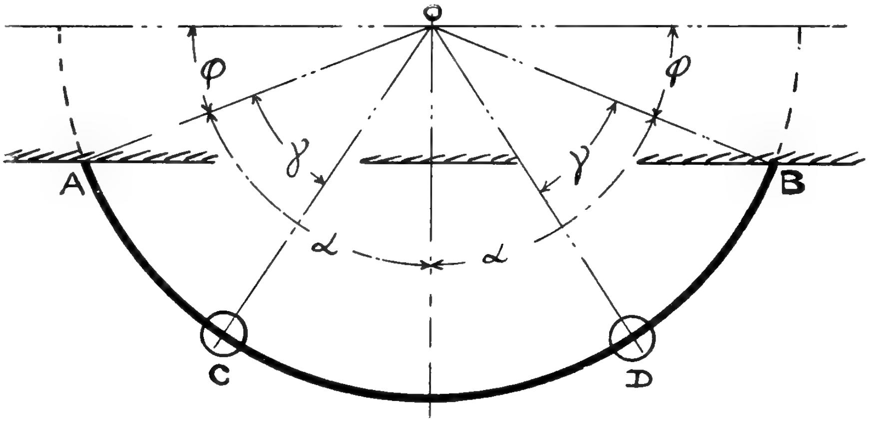


FIG. 11.

The downward deflection at C and D due to the loading would be, by equation (21):—

$$y_\theta = \left[\begin{array}{l} \dfrac{r^2}{2EI}\left[(M_a' - wr^2)\gamma\sin\gamma - (R_a'r - T_a')(\sin\gamma - \gamma\cos\gamma) - 2wr^2(\cos\gamma - 1)\right] \\ \quad + \dfrac{r^2}{2CJ}\left[\begin{array}{c}(T_a' - R_a'r)(\sin\gamma - \gamma\cos\gamma) + (M_a' - wr^2)\{\gamma\sin\gamma + 2\cos\gamma - 2\} \\ + 2R_a'r(\gamma - \sin\gamma) - 2wr^2(\frac{\gamma^2}{2} + \cos\gamma - 1)\end{array}\right]\end{array}\right] \quad . \quad (26)$$

where $R_a' = wr\left(\frac{\pi}{2} - \phi\right)$, and where M_a' and T_a' for the particular value of ϕ obtaining in the girder, are given by the curves of fig. 7.

The upward deflection at C and, from symmetry, at D, due to the two upward forces P is obtained by substituting γ for θ_1 in equation (12), which becomes:—

$$y_\gamma = \left[\begin{array}{l} \dfrac{r^2}{2EI}\left[M_a''\gamma\sin\gamma - (R_a''r - T_a'')(\sin\gamma - \gamma\cos\gamma)\right] \\ \quad + \dfrac{r^2}{2CJ}\left[(T_a'' - R_a''r)(\sin\gamma - \gamma\cos\gamma) + 2R_a''r(\gamma - \sin\gamma) + M_a''(\gamma\sin\gamma + 2\cos\gamma - 2)\right]\end{array}\right] \quad (27)$$

The values of M_a'', R_a'', and T_a'' for use in this expression are the sum of the corresponding values produced by each of the two forces P acting at points distant γ from A and from B, and may evidently be obtained by adding the values of M_a and M_b, R_a and R_b, T_a and T_b, as obtained from the curves of figs. 5 and 6 for a girder having the correct value of ϕ, and having the force P at γ from A.

On substituting these values, each of which is given in terms of P, in (27) and equating to (26), the resultant expression contains P as the only unknown and enables this to be calculated.

E.g., Semicircular Girder with uniform loading and with two piers at 60° *from the ends of the span.*

From fig. 7 the values of M_a', and T_a' for substitution in (26) are $M_a' = wr^2$; $T_a' = \cdot 298wr^2$; while $R_a' = 1\cdot 5708wr$, and, on substituting, the downward deflection at the supports ($\gamma = 60°$) is given by—

$$y_{60°} = wr^4\left[\frac{\cdot 564}{2\text{EI}} + \frac{\cdot 037}{2\text{CJ}}\right].$$

The values of M_a'', T_a'', and R_a'' for substitution in (27) are, from figs. 5 and 6 :—

$$M_a'' = (M_a + M_b)_{\theta=0,\ \alpha=60°} = (\cdot 588 + \cdot 278)Pr = \cdot 866Pr.$$

$$T_a'' = (T_a + T_b)_{\theta=0,\ \phi=60°} = (\cdot 155 + \cdot 127)Pr = \cdot 282Pr.$$

$$R_a'' = P,$$

and, on making these substitutions,

$$y_{60°} = Pr^3\left[\frac{\cdot 539}{2\text{EI}} + \frac{\cdot 035}{2\text{CJ}}\right].$$

Equating these two expressions for $y_{60°}$ gives

$$P = wr\left[\frac{\cdot 564\text{CJ} + \cdot 037\text{EI}}{\cdot 539\text{CJ} + \cdot 035\text{EI}}\right],$$

and taking EI = 1·24CJ, this makes $P = 1\cdot 05wr$.

The reactions at A and B are then given by

$$R_b = R_a = R_a' - R_a'' = wr\left(\frac{\pi}{2} - 1\cdot 05\right) = \cdot 521wr,$$

while the moments M_a and M_b are given by

$$M_b = M_a = M_a' - M_a'' = wr^2(1 - \cdot 866 \times 1\cdot 05) = \cdot 091wr^2.$$

The torques T_a and T_b are given by—

$$T_b = T_a = T_a' - T_a'' = wr^2\{\cdot 298 - \cdot 281 \times 1\cdot 05\} = \cdot 003wr^2.$$

The state of affairs at any point on the girder is thus given by the relations :—

Between A *and* C—

$$M_\theta = M_a \cos\theta - (R_a r - T_a)\sin\theta = wr^2(\cdot 091 \cos\theta - \cdot 518 \sin\theta).$$

$$T_\theta = (T_a - R_a r)\cos\theta + R_a r - M_a \sin\theta = wr^2(\cdot 521 - \cdot 518 \cos\theta - \cdot 091 \sin\theta).$$

Between C *and the centre* (θ being measured from OA)—

$$M_\theta = M_a \cos\theta - (R_a r - T_a)\sin\theta + Pr\sin(\theta - 60°)$$
$$= wr^2(\cdot 007 \sin\theta - \cdot 819 \cos\theta).$$

$$T_\theta = (T_a - R_a r)\cos\theta - R_a r - M_a \sin\theta - Pr\{1 - \cos(\theta - 60°)\}$$
$$= wr^2(\cdot 007 \cos\theta + \cdot 819 \sin\theta - \cdot 529).$$

E.g., Semicircular Girder with uniform loading and with two piers at 45° *from ends of span.*

In this special case, the end constants and pier reactions are :—

$$P = 1{\cdot}460wr \quad ; \qquad M_a = -{\cdot}031wr^2 ;$$
$$R_a = R_b = {\cdot}111wr \quad ; \qquad T_a = {\cdot}010wr^2 .$$

As before, between A and C—

$$M_\theta = M_a \cos\theta - (R_a r - T_a)\sin\theta,$$
$$T_\theta = (T_a - R_a r)\cos\theta + R_a r - M_a \sin\theta,$$

while between C and the centre—

$$M_\theta = M_a \cos\theta - (R_a r - T_a)\sin\theta + Pr\sin(\theta - 45^\circ),$$
$$T_\theta = (T_a - R_a r)\cos\theta - R_a r - M_a\sin\theta - Pr\{1 - \cos(\theta - 45^\circ)\}$$

(*c*) *Semicircular Girder, built in at the Ends, carrying Uniform Load* w *per foot rise, and having Three Intermediate Supports.*

Let the supports be arranged symmetrically, P_1 and P_2 being the reactions at the outer supports and Q that at the central support. These reactions may be obtained by expressing the facts (1) that the downward deflection at the centre due to the loading is equal to the sum of the upward deflections at the centre due to the forces P_1, P_2, and Q, in their respective positions; and (2) that the downward deflection at P_1 due to the loading is equal to the upward deflection at this point due to forces P_1, P_2, and ϕ; *e.g.*, if, for example, P_1 and P_2 are each at 45° from the ends, we have—

Downward deflection at Q due to loading

$$= wr^4\left\{\frac{{\cdot}7272}{EI} + \frac{{\cdot}053}{CJ}\right\}.$$

Downward deflection at P_1 or P_2 due to loading

$$= wr^4\left\{\frac{{\cdot}3928}{EI} + \frac{{\cdot}0213}{CJ}\right\},$$

these values being obtained from (21′) by substituting the values of θ, viz., 90° and 45°, and of M_a and T_a, from fig. 7.

Again, the upward deflection at Q due to force Q

$$= Qr^3\left[\frac{{\cdot}4674}{2EI} + \frac{{\cdot}0382}{2CJ}\right] \quad \text{from (14) and fig. 5,}$$

and the upward deflection at Q due to the two forces P_1 and $P_2 = P$

$$= 2Pr^3\left[\frac{{\cdot}2110}{2EI} + \frac{{\cdot}0594}{2CJ}\right] \quad \text{from (13) and fig. 5.}$$

Also the upward deflection at P_1 due to force P_1

$$= Pr^3\left[\frac{{\cdot}1865}{2EI} + \frac{{\cdot}0055}{2CJ}\right] \quad \text{from (14) and fig. 5,}$$

while the upward deflection at P_1 due to P_2

$$=Pr^3\left\{\frac{\cdot0845}{2EI}+\frac{\cdot0085}{2CJ}\right\}\quad\text{from (13) and fig. 5,}$$

and the upward deflection at P_1 due to force Q

$$=Qr^3\left\{\frac{\cdot2297}{2EI}+\frac{\cdot015}{2CJ}\right\}\quad\text{from (13) and fig. 5.}$$

Collecting and equating deflections at the same points, gives :—

$$wr(\cdot7272CJ+\cdot053EI)=Q(\cdot4674CJ+\cdot0382EI)+P(\cdot4220CJ+\cdot0594EI),$$
$$wr(\cdot3928CJ+\cdot0213EI)=Q(\cdot2297CJ+\cdot015EI)+P(\cdot2710CJ+\cdot0140EI).$$

If $EI=1\cdot24CJ$, the solution of this gives—

$$Q=\cdot74wr;\quad P=\cdot83wr.$$

From this

$$R_a=R_b=\tfrac{1}{2}\{\pi wr-Q-2P\}$$
$$=\cdot37wr.$$

Also

$$M_a+M_b=2wr^2-2Pr\sin45^\circ-Qr$$
$$=\cdot088wr^2$$
$$\therefore\ M_a=M_b=\cdot044wr^2$$

while T_a (from figs. 5 and 7)

$$=\cdot298wr^2-\cdot114Pr-\cdot182Qr-\cdot081Pr$$
$$=(\cdot298-\cdot297)wr^2$$
$$=\cdot0010\,wr^2.$$

§ 9. Applicability of Formulæ to Sections other than Circular.

Although the formulæ have only been checked by experiments on beams of circular section, they should apply with equal accuracy to any section of which the EI and CJ are known. The former of these products is usually known with some close degree of approximation, for any commercial section. While the value of J may also may also be readily calculated, the value of C is not known with nearly the same degree of accuracy as is that of E. Moreover, the product CJ as used in the simple theory of elastic torsion is only constant for different values of θ, for a circular section. Its value for such sections as are usual in girder work, cannot as yet be predicted with any great pretensions to accuracy. It is hoped to carry out an experimental investigation on this point at an early date.

Owing, however, to the fact that the maximum torque is in general much less than the maximum bending moment, the *resultant* stresses on the girder, at the point where this is most heavily loaded, are only slightly affected by even a considerable variation in the value of CJ, and for all practical purposes the constants given in this paper may be taken as applying to any normal section.

§ 10. CONCLUSIONS.

The results of the investigation render it possible to design a bow-girder with as economical a distribution of material as in the ordinary straight encastré girder, and, if advantage be taken of the quantitative data calculated and plotted in figs. 5 to 9, with little more trouble.

The greatest drawback to the use of the bow-girder for large spans lies in the fact that the distribution of stresses is affected by any uneven settlement of the supports, and that whereas in the straight encastré girder this difficulty may be obviated by building the girder on the cantilever principle with pin-joints at the points of zero bending moment, in the bow-girder such points are also the points at which the twisting moment is approximately greatest, as will appear from a consideration of figs. 8 and 9. Still, as this maximum twisting moment is only about one-ninth of the maximum bending moment, probably the difficulty of designing a joint to take care of this torque would not be insuperable, and, if so, this type of design would possess many advantages.

The great reduction in stresses which is rendered possible by the insertion of one or more intermediate supports forms the most powerful advocate for their use wherever they are not precluded by other considerations.

UNIVERSITY COLLEGE,
DUNDEE.

XXI.—Experiments to show how Failure under Stress occurs in Timber, its Cause, and Comparative Values of the Maximum Stresses induced when Timber is fractured in Various Ways. By **Angus R. Fulton**, B.Sc., A.M.Inst.C.E., Engineering Department, University College, Dundee. *Communicated by* Professor W. PEDDIE. (With Eight Plates and Five Text Illustrations.)

(MS. received July 10, 1911. Read November 13, 1911. Issued separately August 30, 1912.)

INTRODUCTION.

The object of this investigation was not to obtain fresh data on the average strength of timber when subjected to destructive stresses. This has been done in great detail by BAUSCHINGER, LANZA, JOHNSON, and others, and is still being carried on, in America, on a large scale under the Bureau of Forestry. The intention was rather (*a*) to find the effect of the medullary rays when timber was stressed in compression, tension, shear, or by cross-bending; and (*b*) to endeavour to connect up in a satisfactory way the maximum stresses induced in cross-breaking with those obtained by direct compression, tension, or shear. For this purpose, then, it was not necessary that the number of experiments should be excessive, but it was essential that the results obtained should be comparable one with another. To obtain this, a single tree of each variety of wood to be tested was procured, the test pieces were sawn out of the best part of the trunk, carefully stacked, and allowed to season for at least twelve months.

As the timber was stored in a perfectly dry, well-ventilated room, as the specific gravity values were practically constant at the time of carrying out the tests, and as the tests were mainly relative ones, it was not thought necessary to determine the actual moisture conditions.

Four varieties of wood were chosen—Oak, Pitch Pine, Ash, and Box. The two former are representative of the class in which the medullary rays are very pronounced, and the two latter, of those in which they are much less marked.

The Oak specimens were cut from a trunk 21 inches diameter, the Ash 24 inches diameter, and the Box 8 inches diameter; and the place of growth was known only for the Oak, which was Scone Palace grounds.

The test pieces were rectangular in section, with one pair of parallel faces as far as possible tangential to the annual rings, and the other pair consequently parallel to the medullary rays, the length being measured along the axis of the tree. The dimensions of the cross-section were approximately in the ratio of 2 to 1, the deep sides being in a number of cases parallel to the rings, and in an equal number of cases parallel to the medullary rays. Any advantage peculiar to the position of the rings or rays in the test piece would thus be accentuated.

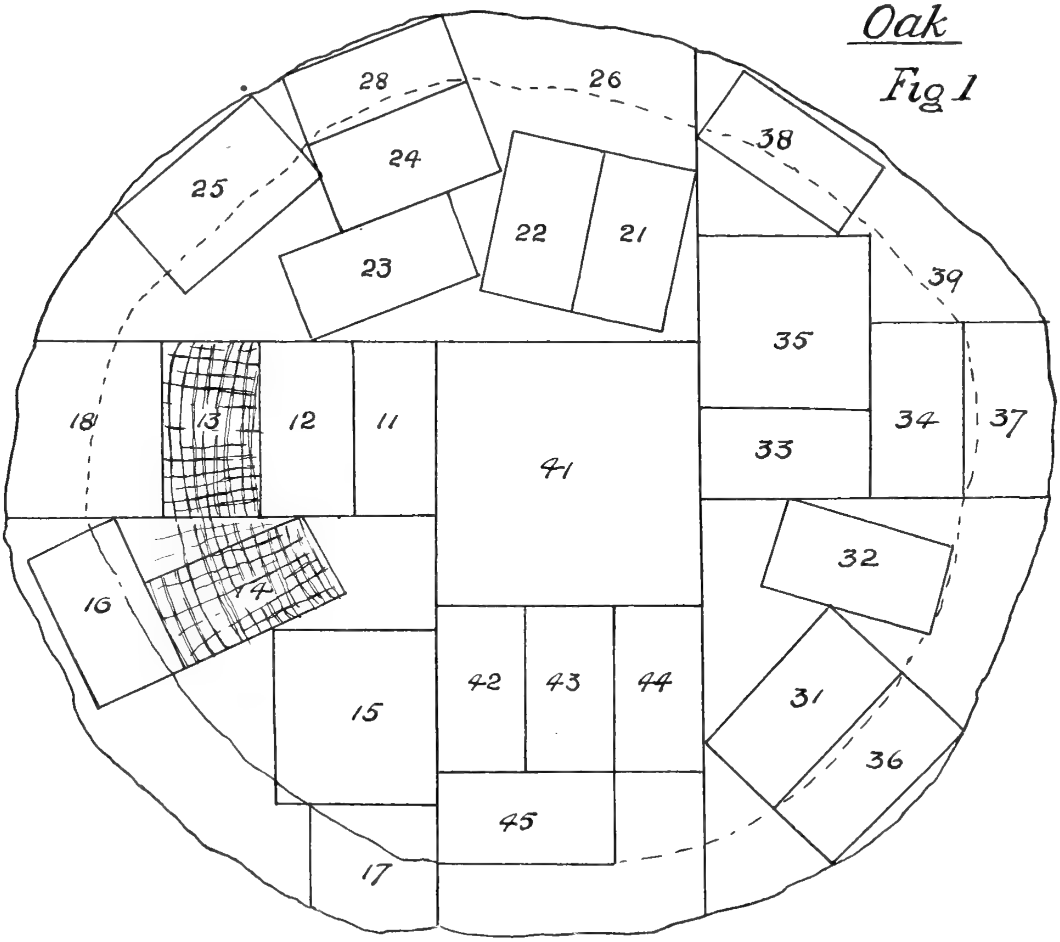


Fig. 1 is a drawing of the cross-section of the Oak tree used, and shows the manner in which the specimens were cut from that section; it is also an example of the method followed in the case of the other woods.

Definition of Stresses.

The following definitions of stresses have been adopted throughout this paper:—

(*a*) A *longitudinal stress* is a stress acting parallel to the axis of the tree.

(*b*) A *radial stress* is a stress acting as nearly as may be parallel to the medullary rays, and therefore perpendicular to the annual rings.

(*c*) A *tangential stress* is a stress acting parallel to the annual rings, and therefore perpendicular to the medullary rays.

Our direct forces will, as far as possible, be such as produce stresses in these directions.

(*d*) In the case of a beam with its axis horizontal and the medullary rays in its cross-section set vertically, we have stresses induced in a longitudinal direction as in (*a*), and a horizontal shear stress which is along the plane of the annual rings. This latter stress will be called a *tangential shear stress.*

(*e*) Similarly, if the beam is laid with the medullary rays horizontal, the horizontal shear stress is along the plane of the medullary rays, and will be called a *radial shear stress.*

Longitudinal Compressive Stress.

(*a*) *Characteristic Failure of Timber.*

If we consider a test piece of timber subjected to a longitudinal compressive stress sufficient to cause rupture, we find that deformation takes place in a direction tangential to the annual rings, and that failure occurs by a local buckling of the fibres over the whole of a plane which is *perpendicular to the annual rings* and inclined to the direction of pressure. This is true for all timbers, true whether the medullary rays are more or less strongly marked, and true whatever the proportions of the cross-sections subjected to this compressive stress.

As already mentioned, the proportions of the cross-sections adopted in these tests were generally in the ratio of 2 to 1. Fig. 2 is a block of Oak cut with broad longitudinal sides tangential, and arranged so as to exhibit one of these sides $\frac{7}{8}$ normal size. It shows this local buckling taking place in two planes more or less equally inclined to the direction of pressure, each fibre being displaced tangentially, but not in a radial direction. Fig. 3 is a block of Ash similarly cut and similarly placed, but here the buckling is shown taking place in a single plane, and this is the more general case. As is always the case, the fibres are displaced tangentially, that is, in the plane of the paper, and the slip extends across the greatest breadth of the test piece. To emphasise this fig. 4 is shown. The broad longitudinal sides of the Ash piece are cut radial, and one is exhibited. With the buckling the fibres have moved tangentially as before, or in a plane perpendicular to the paper, and there is no movement in the radial direction. The same characteristic is illustrated in the case of Boxwood by figs. 5 and 6. There two views of two separate blocks, cut with the broad sides tangential and radial respectively, are shown, and the slip in the tangential direction is evident, with no movement in a radial direction.

(*b*) *Cause of Characteristic Failure.*

The reason why the buckling of the wood fibres invariably takes place in a tangential direction is better seen on examining the section of the timbers under the microscope.

The normal appearance of Oak when examined thus is shown by the micro-photographs figs. 7, 8, 9, and 10. Fig. 7 is a normal radial section showing a side view of a medullary ray seven cells deep. Fig. 8 is a normal transverse section at zone of demarcation between autumn wood of one year and spring wood of the next. Two narrow or secondary medullary rays are shown in plan, and appear as single rows of cells. The more general appearance of the normal transverse section is given in fig. 9, where the magnification is less and a larger portion of the section is seen. The great size of the tracheide compared with that of the wood fibres should be kept in mind for comparison with the section, say, of Boxwood.

But for our purpose possibly the most instructive section is that of fig. 10, in which a normal tangential section is given, showing cross-sections of the cells of the medullary rays, broad and narrow, with wood fibres and parenchyma running longitudinally and sinuously between the groups of ray cells.

If the cross-section of the trunk of a tree is viewed superficially, it might be regarded as made up of a number of thin concentric cylinders continuous throughout the length of the tree and all glued together. Each of these thin cylinders represents an annual ring which is made up of wood fibres principally, the medullary rays dividing it radially, like the joints between the staves of an ordinary barrel. When subjected to longitudinal compressive stress, it would seem as if any buckling that took place in the wood fibres would be in a radial direction.

But, as will readily be seen from fig. 10, the joints, that is the medullary rays, are not continuous throughout the length of the tree, nor even for a very small portion of it. From the radial section of fig. 7 we see that the wood fibres appear perfectly straight and vertical; but from the tangential section, fig. 10, we learn that they have a sinuous displacement in the tangential plane, zigzagging their vertical path round the cells of the medullary rays. This amounts to an "initial set" in a column subjected to end pressure, and failure consequently ensues in the plane containing that initial set.

This is well illustrated in the micro-photographs of wood tested to destruction in this way. Fig. 11 is a general view of a tangential longitudinal section of fractured Oak, and shows that, though failure has occurred to a small degree at the apparently weaker tracheæ, the principal yield has been along a line where the cohesion between the wood fibres and the medullary rays has been the only resistance to the tendency of the fibres to buckle. This is shown to a greater magnification in fig. 12, where the wood fibres are clearly seen leaving the medullary rays.

We would thus conclude that, even though the cohesion between the wood fibres and the medullary rays was equal to the cohesion between two wood fibres radially adjacent, the mere fact of the initial set would be sufficient to start the buckling in a tangential direction.

The micro-photographs figs. 13–18 prove that what has been said of Oak applies equally to the other woods under investigation. Fig. 13 is a normal transverse section of Ash and is comparable to fig. 9 (Oak), but, being to a three times greater magnification, it is evident that, while the medullary rays and wood fibres are not greatly different, the size of the tracheides is only about one-third of that of Oak. Fig. 14 is a corresponding section of Box, and this, being to the same magnification as fig. 13, shows that here the tracheides are greatly diminished in size, and that the wood fibres are smaller and more solid when compared with either Oak or Ash. Fig. 15 is a normal tangential section of Ash, exhibiting the sinuous form of the wood fibres, and becoming, as shown in fig. 16, the source of weakness when subjected to longitudinal stress.

Figs. 17 and 18 are a corresponding pair of tangential sections of Box, and show that, in spite of the greatly multiplied number of tracheides, smaller in diameter of course, it is still the cohesion between the medullary rays and wood fibres that is at fault.

Longitudinal Tensile Stress.

Characteristic Failure and its Cause.

When the longitudinal stress is of a tensile nature the fracture shows certain characteristics. In fig. 19 we have a set of Oak strips $\frac{7}{8}$ natural size, which have been fractured by direct tension. The two upper specimens, one exhibiting its broad side, and the other its narrow side, were cut with their broad sides tangential, while the two lower ones were cut with their broad sides radial. Both (*b*) and (*c*) show a tangential face, and the fracture is a ragged one, tearing through wood fibres and then following the planes of the medullary rays, where evidently it meets with the least resistance. (*a*) and (*d*) are specimens with their radial faces exposed, and show an abrupt break extending more or less straight across this face.

From this it appears that there is little or no slip between the annual rings or wood fibres radially adjacent, but that a considerable slip takes place between the medullary rays and their adjacent fibres.

Figs. 20 and 21 prove that this is not peculiar to the Oak alone. The latter represents an Ash strip, $\frac{4}{5}$ natural size, and shows the slips along the planes of the medullary rays. Although no illustration is given, the radial face had the usual abrupt break. The former represents specimens of Boxwood, where, though the medullary rays are not nearly so prominent, the same kind of fracture occurs. (*a*) and (*b*) of fig. 20 exhibit tangential faces and the slip along the rays, while (*c*) with its radial face shows the tear across.

MICROSCOPIC SECTIONS.

Radial sections of specimens tested in tension do not give us enlightenment, as they exhibit only an abrupt break of the fibres. Tangential sections, however, show the characteristic slip between the cells of the medullary rays and the adjacent tissues, proving the weakness of their adhesion at that part.

Fig. 22 is a tangential section of Oak fractured by longitudinal tension, while fig. 23 is a similar section of Boxwood.

CROSS-BREAKING.

One naturally looks for similar results where similar stresses are induced, as in the case of timber used as beams and tested by means of cross-breaking.

A typical example is that of fig. 25, which shows an Oak beam fractured by this means, the tangential face being exhibited. The beam was laid on a radial face, supported at two ends and loaded in the middle. The ragged break on the tensional side of the beam is similar to what we have already noticed in connection with the direct tension experiments.

The specimen of box seen in fig. 24 also shows the same characteristic, and is even a better example on the tension side of this kind of break than the specimen fractured in direct tension.

The fracture of beams which have been laid on a tangential face, and which are shown exposing a radial face, is sharp, with no evidence of slip taking place by one annual ring sliding past another.

Fig. 26 shows this in the case of Oak, and fig. 27 in that of Ash fractured under similar conditions. In addition, the upper portion shows the bulging out tangentially due to the compression of the applied load and the induced compression along the axis of the beam. This is not usually so pronounced.

The micro-photographs from beams fractured by cross-breaking are similar to those obtained from direct stress experiments. Fig. 29, from a section on the upper or compressive side of a beam, exhibits features similar to those in the first stage of an ordinary compression test.

Fig. 30 shows an enlargement of a portion cut from the lower or tension part of a beam, and since the section is a tangential one, it makes it quite clear that the parting of the tissues follows the groups of ray cells.

Fig. 31 is given for the purpose of showing the effect of end compression on a test piece which contains the centre of the log, and is arranged to exhibit a transverse section. The movement under stress is a tangential one similar to what would be got by a twisting moment combined with an end thrust, one portion of the test piece being rotated past the other, but having the centre of the tree as the common axis of rotation.

One or two more illustrations are here given to show the features of rupture caused by stresses across the grain.

Fig. 28 is that of two blocks of Oak crushed in a tangential direction, the one on the right to a greater degree than the other. The failure has been as in direct compression along a plane making an angle with the direction of stress, but that plane is composed of a series of steps or slips in each case along the lines of the medullary rays. Any severance that takes place along the zones of spring wood is the consequence of this initial slip.

STRENGTHS.

In order to obtain a comparison of the strengths of the timbers when cut with the greater dimensions of the cross-section radial or tangential, experiments were made in the determination of (1) modulus of elasticity, by cross-bending; (2) rupture load by compression; (3) by tension; (4) by cross-breaking.

Modulus of Elasticity by Cross-bending.

1. Beams of Oak, Ash, and Box woods were cut of a length sufficient to allow 3 feet span, the approximate sections being: Oak, 3 inches by $1\frac{1}{2}$ inch; Ash, $3\frac{5}{8}$ inches by $1\frac{5}{8}$ inch; Box, 2 inches by 1 inch to $2\frac{5}{8}$ inches by $1\frac{1}{8}$ inch; and there were as many test pieces as it was possible to cut from the section of a single trunk of each timber.

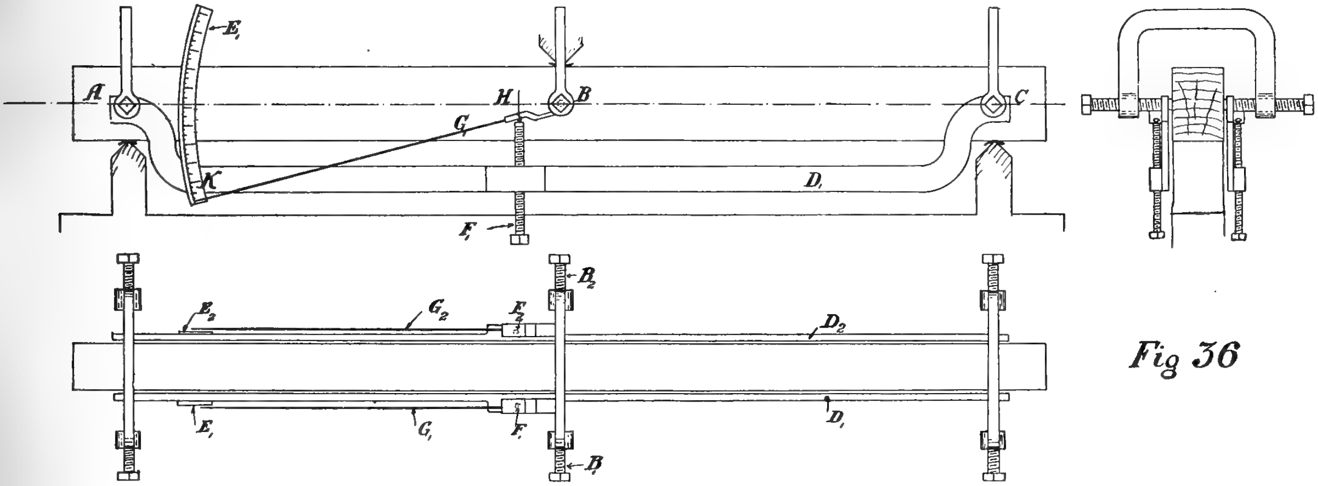


Fig 36

The form of extensometer was that shown in fig. 36, and was devised by the author. To obtain the true deflection, shackles were fixed to the neutral axis of the beam at A, B, C by means of wood screws. The screws at A and C supported the carriers D_1 and D_2, and to them in turn were attached scales E_1 and E_2, and also screws F_1 and F_2, the latter acting as fulcrums for the magnifying levers G_1 and G_2, one being placed at either side of the beam. The screws of the shackle B, which is placed in the centre of the span immediately underneath the centre of the load W, bear on the end of the magnifying lever. Thus any deflection taking place at the centre of the beam B is magnified in the ratio $\frac{HK}{HB}$ (8 in this particular apparatus). The scales E are so graded that the actual deflection is at once read off. With this arrangement any error due to crushing of the timber by the knife-edges is eliminated, the actual deflection of the neutral axis is obtained, and by the use of two scales placed one on either side of the beam, both being read and the mean taken, any inequality of pressure due to want of alignment between timber and testing machine is counteracted.

The deflections were measured with the beam resting first on its radial face and then on its tangential, and the formula by which the modulus was determined was $E=\frac{WL^3}{4bd^3\delta}$.

OAK.

Greatest dimension tangential :—

	No.	S.G.	*A.—Beam resting on Radial Face.*				*B.—Resting on Tangential Face.*			$\frac{E_B}{E_A}$.
			Span.	Breadth.	Depth.	E_A.	Breadth.	Depth.	E_B.	
			″	″	″		″	″		
GROUP I.	11	·74	36	1·56	3	520	3	1·56	523	1·005
	12	·75	„	1·6	3	568	3	1·6	615	1·085
	13	·75	„	1·6	3·03	616	3·03	1·6	650	1·06
	23	·72	„	1·44	3·06	528	3·06	1·44	561	1·065
	31	·72	„	1·62	2·95	585	2·95	1·62	603	1·035
	34	·73	„	1·61	2·97	578	2·97	1·61	596	1·03
									Mean	1·047

Greatest dimension radial :—

			″	″	″		″	″		
GROUP II.	14	·72	36	3	1·6	582	1·6	3	610	1·05
	21	...	„	3·05	1·6	599	1·6	3·05	572	·96
	33	·72	„	3·06	1·6	643	1·6	3·06	637	·99
	33	·72	„	3·06	1·44	583	1·44	3·06	553	·95
									Mean	·99

From Group I. it would appear as though position B possessed greater stiffness compared with A, but Group II. shows a slight advantage in the other direction. A modification, however, ought to be made in B of Group I. and A of Group II. on account of the beams in these cases being comparatively broad and shallow, and therefore possessing a greater degree of stiffness. Allowing for this, in both cases the advantage may be said to lie with the beam resting on its tangential face—to the extent, however, of only 2 or 3 per cent. Other Oak experiments bear this out, though, where knots or decided flaws obviously affect the results, they have been left out.

The following were some of the results obtained with Ash and Box :—

Ash.

Greatest dimension tangential :—

No.	Span.	*A.—Beam on Radial Face.*			*B.—Beam on Tangential Face.*			$\frac{E_B}{E_A}$.
		Breadth.	Depth.	E_A.	Breadth.	Depth.	E_B.	
	″	″	″		″	″		
33	36	1·65	3·625	565	3·625	1·65	628	1·11
31	36	1·65	3·63	736	3·63	1·65	868	1·18
							Mean	1·145
Greatest dimension radial :—								
12	36	3·55	1·87	948	1·87	3·55	894	·945
15	36	3·6	1·65	961	1·65	3·6	842	·875
							Mean	·91
Box.								
Greatest dimension tangential :—								
4	36	1·18	2·08	630	2·08	1·18	915	1·45
11	36	1·07	2·00	725	2·00	1·07	875	1·21
							Mean	1·33
Greatest dimension radial :—								
2	36	2·65	1·16	808	1·16	2·65	604	·75
10	36	2·32	1·14	930	1·14	2·32	782	·84
							Mean	·795

In the Ash and Box experiments, whether $\frac{E_B}{E_A}$ is greater or less than 1 depends mainly on whether the broad face of the beam is vertical or horizontal; but, making allowance for this, there still remains an advantage in stiffness in favour of laying the tangential side horizontal, of about 6 or 7 per cent.

Two conclusions may be drawn from these results :—

(*a*) In each case an advantage, though it may be slight, exists in placing a timber beam on a tangential face, due probably to the medullary rays being now vertical, and therefore not affecting the stiffness.

(*b*) For beams of given proportions of section, say 2 to 1, the effect of placing the beam on a broad or narrow face, and using the ordinary formula to make them comparable, seems to be decidedly in favour of placing them on the broad side. The advantage ranges from 3 per cent. in Oak, 9 per cent. in Ash, to 20 per cent. in Box. Evidently the explanation of this lies in the anti-clastic curvature of the beams. In addition to the bending which takes place in the vertical plane parallel to the axis of the beam, and which is caused by the loading, we have the lateral widening and contracting of the section in compression and tension respectively due to the induced stresses. In deep, narrow beams this process is not greatly interfered with, but in broad, shallow ones there is a constraint due to the method of loading. The more elastic a material is, the less will this constraint be felt. Possibly the presence of very pronounced medullary rays allows the Oak to accommodate itself better than the Ash, and the latter in turn more readily than the Box.

If we assume that all lateral strain is prevented, the apparent increase in value of the modulus of elasticity E, compared with the case where there is no such restraint, is represented by $\frac{\sigma^2}{\sigma^2-1}$, where $\frac{1}{\sigma}=$ Poisson's ratio. If $\frac{1}{\sigma}=\cdot25$ for Ash and $\cdot4$ for Box, then the ratio $\frac{\text{E (flat)}}{\text{E (deep)}}=1\cdot06$ for Ash and $1\cdot2$ for Boxwood. As the author has had no opportunity of measuring Poisson's ratio for these materials, it is impossible to say how far such an assumption is justified.

Compression Tests.

In these tests half the number of specimens were cut with the broad side of the section tangential, and half with that side radial, and each series consisted of varying lengths. The lengths (l) were simple multiples of the narrow dimension (k), and ranged from $l=k$ to $l=13k$.

Fig. 33 shows a set of Oak blocks cut with broad side tangential and exhibiting the radial side, after having been subjected to longitudinal compression. The five shortest blocks, $l=k$ to $l=8k$, show no sign of bending, but have the usual local buckling taking place tangentially, as has been previously noticed. 6 ($l=10k$) and 7 ($l=12k$) have both a compound failure, consisting of the usual local crumpling and of bending in the plane of the paper, which is of course the plane of the least dimension, k.

A similar set of blocks, but cut with the broad side radial and showing the tangential side, is illustrated in fig. 34. Here the compound fracture is slightly shown in the fourth block ($l=6k$), which is much earlier than in the other series. This is to be expected, for the local buckling and the buckling of the test piece as a whole take place in the one plane, that of the paper. Although this appears on shorter lengths than in the other series, there is evidently no great difference in the crushing stress required. The extra inducement to bend only comes into play after the local buckling has taken place and failure has begun. Only in pieces of very short lengths ($l=k$ or $l=2k$) is there any advantage, and then it rests with those cut with the broad side tangential.

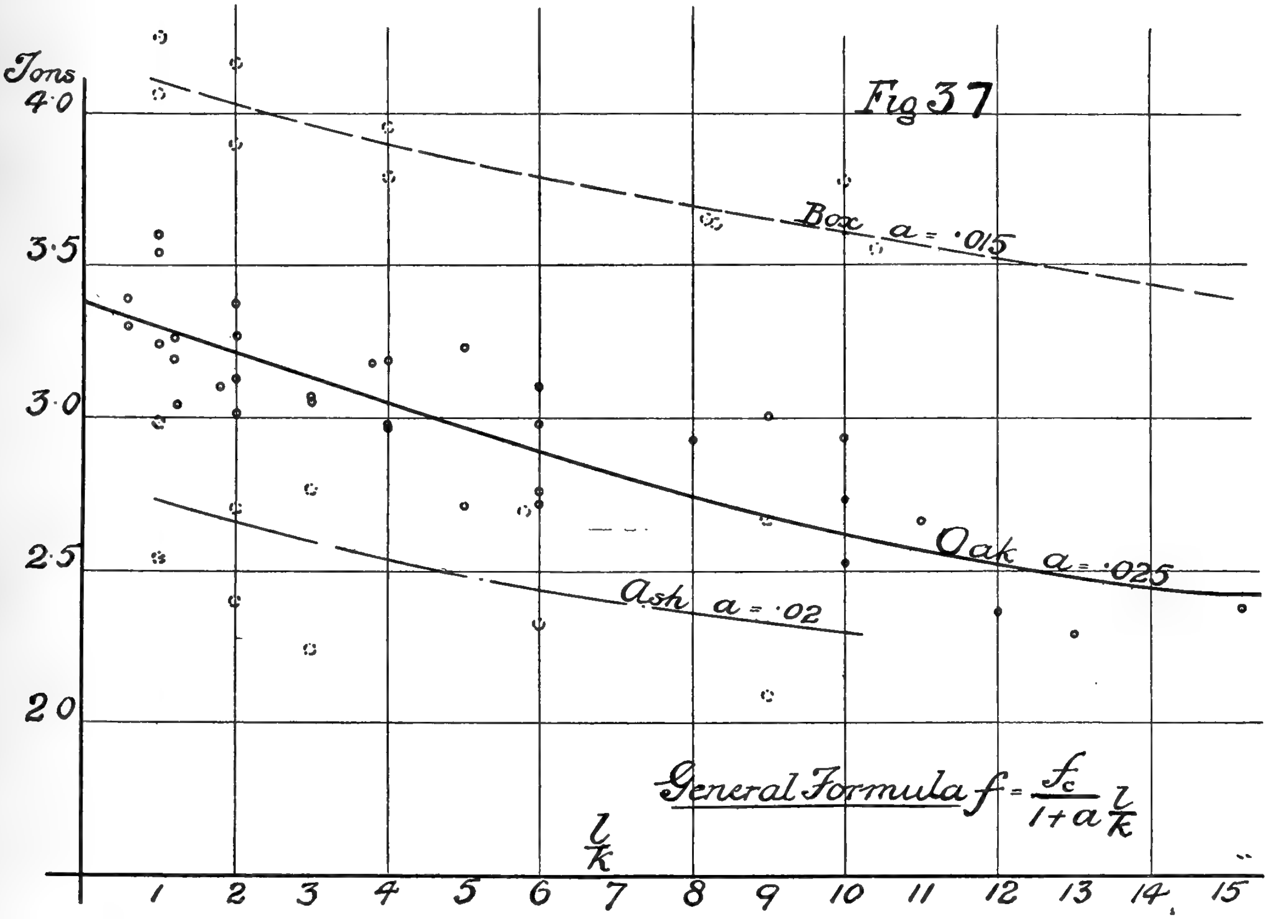
The Ash and Box tests show very similar results, so it is not necessary to illustrate them.

Plotting the results obtained with these timbers, and using the crushing pressure per square inch as ordinates and the ratio $\frac{l}{k}$ as abscissæ, it is found that, within the limits of length investigated and for rectangular sections, the maximum fracture stress per square inch, p, may be represented by $p = \frac{f_c}{1 + a\frac{l}{k}}$ instead of the more common Rankine-Gordon formula, $p = \frac{f_c}{1 + a\frac{l^2}{k^2}}$, where

a = constant depending on material and method of holding test piece.
l = length of test piece.
k = least dimension of cross-section.
f_c = maximum crushing stress per square inch determined from a test piece when $l = k$.

a = ·015 for Boxwood with square ends.
·025 „ Oak „ „ „
·02 „ Ash „ „ „

Fig. 37 shows the results of the tests plotted in this way.



TENSION TESTS.

From the results of the tests for elasticity and in compression it was evident that no great difference of stress would arise in the tension and shearing tests.

The specimens in tension were of rectangular section, 1″ to $1\frac{7}{8}''$ wide by $\frac{1}{4}''$ to $\frac{5}{16}''$ thick, with enlarged ends.

The average results were as follows:—

OAK	broad side radial	7·05 tons per sq. in.	Maximum	7·45 tons.
	,, ,, tangential	6·93 ,, ,,	,,	7·05 ,,
ASH	,, ,, radial	8·81 ,, ,,	,,	9·38 ,,
	,, ,, tangential	8·28 ,, ,,	,,	9·13 ,,
BOXWOOD	,, ,, radial	9·47 ,, ,,	,,	9·71 ,,
	,, ,, tangential	8·8 ,, ,,	,,	10·2 ,,

Here a slight balance is shown in favour of the broad side being radial, though in the Boxwood tests the maximum value was reached by a specimen cut with its broad side tangential. Owing to the careful selection of the timber, the results were very uniform.

SHEARING.

The test pieces here were cylindrical in shape and of $1\frac{1}{4}$ inch diameter. In the case of Oak the shear was measured radially, tangentially, transversely, and obliquely.

	Radial.	Tangential.	Transverse.	Oblique.	
Oak, average .	·48	·6	1·04	·8	tons per sq. in.
Ash . . .	·5	·6	1·03		
Box . . .	·75	·8	1·24		

According to these results, there seems to be a greater resistance to shearing along the rings than to shearing along the lines of the medullary rays, a result which, however, we would naturally expect from the previous experiments.

CROSS-BREAKING.

It has been the practice to measure the stress or strength factor in cross-breaking by the well-known formula,

$$f=\frac{3}{2}\frac{\mathrm{WL}}{bd^2},$$

where W = central breaking load,
L = length of span,
b = breadth, and
d = depth of rectangular section.

This formula is based on the theory of the elastic bending of beams, and gives a value of "f" for the rupture stress which in timber is too great for the ultimate compressive stress, and too small for the ultimate tensile stress of the material. If, however, the value of W inserted in the above formula be the central load at the limit of proportionality of deflection to load, then the stress so calculated agrees fairly well with the crushing strength as got from ordinary longitudinal compression, but has no relation to the tensile strength. This is due to the fact that in timber the elastic limit is about ·6 of the breaking load, and also that the ultimate compressive strength is approximately ·6 of the calculated strength factor. There is thus no direct connection. But, on the assumption that the limit of elasticity varies directly as the breaking load and therefore as the modulus of rupture, the value of the latter is usually considered as a good indication of the compressive strength of the timber.

In the tests for elasticity we have seen that the modulus varies with the position of the section, being greater when resting on the broad side than when on the narrow side. We would expect, therefore, that the stress at the point of ultimate fracture would show a corresponding difference. But the tests hardly bear this out. Some of the results have been grouped in pairs, and comparisons are made between their moduli of elasticity and of rupture under similar and dissimilar conditions, but these ratios are not constant. E_H and E_V are Young's modulus with broad side horizontal and vertical respectively, and f_H and f_V are the calculated extreme fibre stresses obtained under similar conditions.

Ash.

Test $\frac{31}{12}$ } Broad side tangential ,, ,, ,, ,,	$\frac{E_V}{E_V} = \cdot 82$	$\frac{E_H}{E_H} = \cdot 915$	$\frac{E_H}{E_V} = \cdot 97$	$\frac{f_H}{f_V} = 1\cdot 15$
,, $\frac{33}{15}$ } ,, ,, radial ,, ,, ,, ,,	,, $= \cdot 67$	,, $= \cdot 65$	,, $= \cdot 745$	,, $= 1$
,, $\frac{31}{33}$ } ,, ,, tangential ,, ,, ,, radial	,, $= 1\cdot 3$	,, $= 1\cdot 38$		$\frac{f_H}{f_H} = 1\cdot 15$
,, $\frac{12}{15}$ } ,, ,, tangential ,, ,, ,, radial	,, $= 1\cdot 07$	,, $= \cdot 98$		$\frac{f_V}{f_V} = 1$

Boxwood.

Test $\frac{4}{10}$ } Broad side tangential ,, ,, ,, radial	$\frac{E_V}{E_V} = \cdot 8$	$\frac{E_H}{E_H} = \cdot 965$		$\frac{f_V}{f_V} = 1\cdot 09$
,, $\frac{11}{10}$ } ,, ,, tangential ,, ,, ,, radial	,, $= \cdot 925$	,, $= \cdot 885$		,, $= 1\cdot 33$

A high Young's modulus showing a high degree of stiffness is quite compatible with a comparatively low ultimate strength, as the presence of any flaw, though not evident in the elastic stage, will be shown by a low breaking load. Thus beams which show the lower modulus of elasticity of the pair may show the higher strength factor. Before proceeding, then, to determine extreme fibre stresses by the ordinary formula, an attempt has been made by modifying it to connect up the stresses induced at the point of ultimate fracture in cross-breaking with the ultimate stresses in direct compression, tension, and shear.

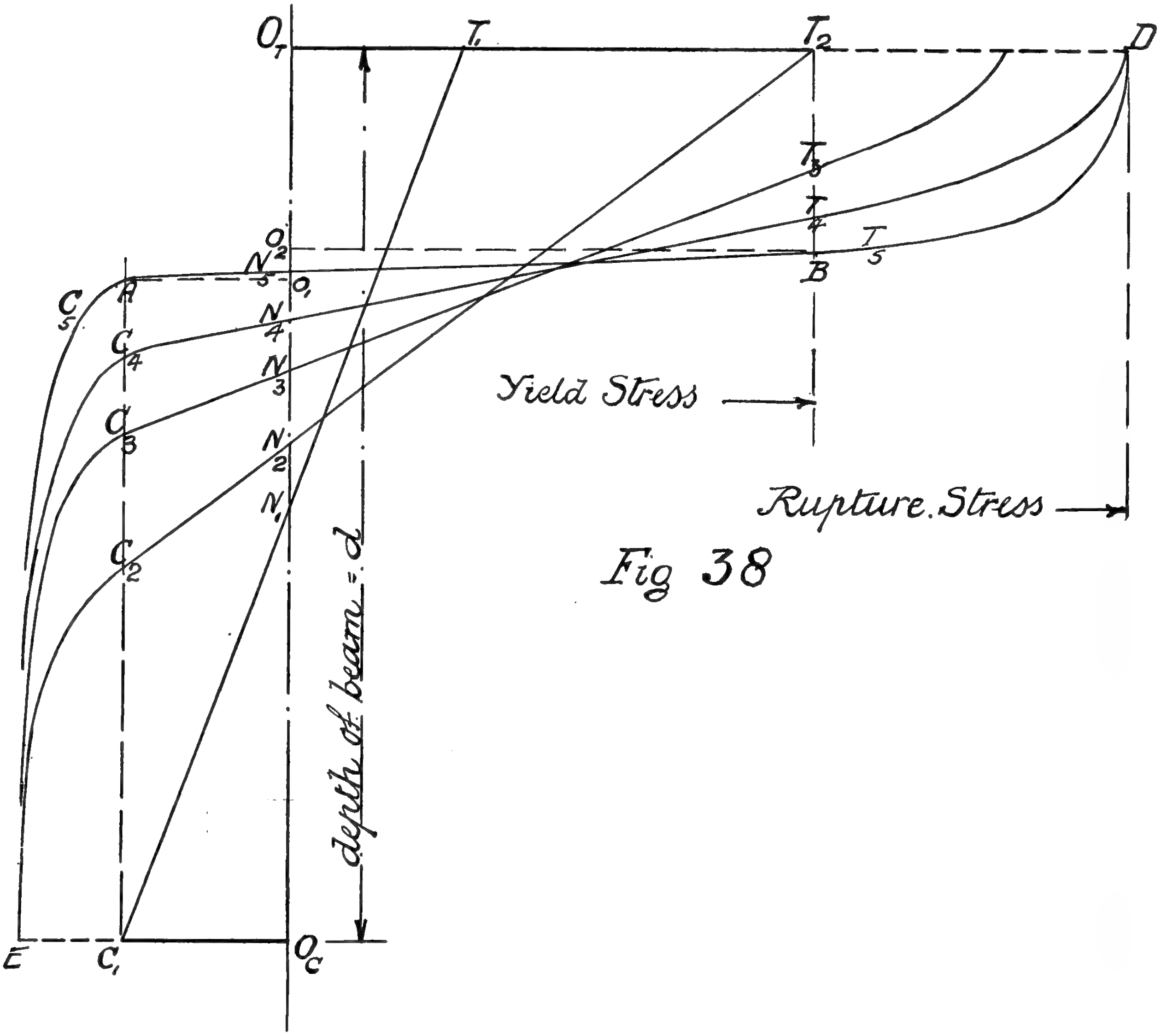


Fig 38

The probable development of the stress diagram of a beam of rectangular section, supported at two ends and loaded in the middle, is shown in fig. 38 for the typical case of an Ash beam. $C_1N_1T_1$ is the stress diagram up to the elastic yield-point C_1 of the extreme fibres on the compression side. During the second period elastic yield continues on the tension side until the extreme fibres on that side also reach the elastic limit T_2. Meanwhile, since the compression strain of the extreme fibres on the other side has been mostly plastic, the compression stress has not increased proportionately to the strain, and on reaching the fracture value E no further increase of stress takes place in the extreme fibres, any further increment of load being met by the adjacent internal fibres becoming stressed in turn beyond the elastic limit to the fracture point. Since the total stress area across the section remains zero, there must follow a deviation of the neutral axis towards the tension side, and an increase of the compression area to keep pace with the tension area, and $EC_2N_2T_2$ represents the new diagram.

From period 2 to 4, with increase of load, the extreme tension fibres are being stretched plastically till they reach fracture point D with a stress diagram EC_4N_4D. Then, as on the compression side, the stress is transmitted to the internal fibres by cohesion until they too reach their fracture point, and this further stage would be represented by EC_5N_5D. The limits that can be set to this process are (*a*) when the tension and compression stress areas assume the rectangular form, and are equal to each other, the ordinates in each case being equal to the ultimate breaking stresses of the material in direct tension and compression respectively, and (*b*) when the cohesion between adjacent fibres measured from the neutral axis outwards is not sufficient to withstand the shear induced by the resisting moment of the beam, which is at a maximum along the neutral axis of the beam.

The first alternative occurs only when the induced shear has not risen to the shear fracture value of the material, before the compression and tension stress areas assume approximately the rectangular form; the second, when the induced shear reaches the value of the shearing strength, even though the maximum compressive and tensile strengths may not be reached.

MAXIMUM FIBRE STRESS.

Let $EC_5N_5T_5D$ represent the stress diagram at instant of fracture.

$AO_1 = C_1O_C =$ elastic limit in compression $= K_c$ ultimate compressive stress.
$BO_2 = T_2O_T =$,, ,, tension $= K_t$,, tensile ,,
$O_1O_2 =$ fibres still being stressed elastically.
$O_2O_T =$ tension fibres stressed plastically.
$O_1O_C =$ compression fibres stressed plastically.
BD and AE are assumed to be parabolic curves.
Tension area $O_TN_5BD =$ compression area O_CN_5AE.

The number of fibres which are stressed elastically may be reckoned so small that AB may be assumed to coincide with the final neutral axis, N_5.

Let $b =$ breadth of beam and $d =$ depth; then

$$\begin{aligned}\text{Tension area} &= b \times O_TN_5\{\text{elastic stress} + \tfrac{2}{3}(\text{fracture stress} - \text{elastic stress})\}\\ &= b \times O_TN_5\{K_t \text{ fracture stress} + \tfrac{2}{3} \times (1 - K_t)\text{ fracture stress}\}\\ &= b\,.\,O_TN_5\,.\,\frac{2+K_t}{3}\text{ ultimate tensile or fibre stress} = b\,.\,O_TN_5\,.\,\frac{2+K_t}{3}t.\end{aligned}$$

The neutral axis, if the extreme limit of a rectangular area of stress was reached, would divide the beam inversely as the maximum stresses, *i.e.* $\frac{O_TN_5}{O_CN_5}=\frac{c}{T}$ and $\frac{O_TN_5}{d}=\frac{C}{T+C}$; therefore $O_TN_5=d\frac{C}{T+C}$.

With the stress areas assumed, the position of the neutral axis and the distance between the centres of gravity of the two component stress diagrams will not differ appreciably from that got with a purely rectangular stress diagram.

Therefore,

$$\text{Tension area}=bd\frac{C}{T+C}\times\frac{2+K_t}{3}t,$$

and similarly

$$\text{Compression area}=bd\frac{T}{T+C}\times\frac{2+K_c}{3}c.$$

The moment of the internal stresses resisting the external bending moment at the instant of fracture will be :

$$\text{Tension stress area}\times\frac{d}{2}=\text{compression stress area}\times\frac{d}{2}=M,$$

$$\therefore\quad b\times d\times\frac{C}{T+C}\times\frac{2+K_t}{3}t\times\frac{d}{2}=b\times d\times\frac{T}{T+C}\times\frac{2+K_c}{3}c\times\frac{d}{2}=M,$$

where t and c are the extreme fibre stresses. For timber, $K_t=K_c=\cdot625$ approx. Therefore

$$t=\frac{2\cdot3M}{bd^2}\cdot\frac{T+C}{C}\quad\text{and}\quad c=\frac{2\cdot3M}{bd^2}\cdot\frac{T+C}{T}\qquad\ldots\qquad(1).$$

Now, extreme direct stresses for

	OAK.	ASH.	BOXWOOD.
T=	7·45	9·38	10·2
C=	3·6	3·0	4·25

∴	OAK	$t=\frac{WL}{4}\cdot\frac{2\cdot3}{bd^2}\cdot\frac{11\cdot05}{3\cdot6}$	$=1\cdot75\frac{WL}{bd^2}$	$c=\frac{WL}{4}\cdot\frac{2\cdot3}{bd^2}\cdot\frac{11\cdot05}{7\cdot45}$	$=\cdot845\frac{WL}{bd^2}$
∴	ASH	$t=$,, $\cdot\frac{12\cdot38}{3}$	$=2\cdot35$,,	$c=$,, $\cdot\frac{12\cdot38}{9\cdot38}$	$=\cdot75$,,
∴	BOX	$t=$,, $\cdot\frac{14\cdot45}{4\cdot25}$	$=1\cdot94$,,	$c=$,, $\cdot\frac{14\cdot45}{10\cdot2}$	$=\cdot82$,,

MAXIMUM SHEAR STRESS.

To discover the maximum shear stress, let t and $(t+\delta t)$ be the extreme fibre stresses on two transverse sections of the beam at a distance δx apart measured along the axis of the beam. Then

$$t=\frac{T+C}{C}\cdot\frac{M}{bd^2}\cdot2\cdot3\quad\text{and}\quad t+\delta t=\frac{T+C}{C}\cdot\frac{M+\delta M}{bd^2}\cdot2\cdot3\,;$$

therefore

$$\delta t=\frac{T+C}{C}\cdot\frac{2\cdot3}{bd^2}\cdot\delta M\ \text{per}\ \delta x\ \text{length},$$

or

$$\frac{\delta t}{\delta x}=\frac{\delta \mathrm{M}}{\delta x}\cdot\frac{2{\cdot}3}{bd^2}\cdot\frac{\mathrm{T+C}}{\mathrm{C}}=\mathrm{F}\times\frac{2{\cdot}3}{bd^2}\cdot\frac{\mathrm{T+C}}{\mathrm{C}},$$

where $\mathrm{F}=\frac{\delta \mathrm{M}}{\delta x}$ = shearing force on that section of the beam.

Total difference of tension or longitudinal shear at neutral axis per unit of breadth $=\Sigma\frac{\delta t}{\delta x}$ from extreme fibre to neutral axis = S = shearing stress per square inch. Therefore, if fibre stress diagram is rectangular in form,

$$\mathrm{S}=\Sigma\,.\,\frac{\delta t}{\delta x}=\mathrm{F}\,.\,\frac{2{\cdot}3}{bd^2}\cdot\frac{\mathrm{T+C}}{\mathrm{C}}\cdot\left(\frac{\mathrm{C}}{\mathrm{T+C}}\cdot d\right)=\frac{\mathrm{F}\times 2{\cdot}3}{bd}\,.$$

But the area of stress diagram has been assumed to be $\frac{2+\mathrm{K}_t}{3}$ times that of rectangular form, where $\mathrm{K}_t={\cdot}625$;
therefore

$$\mathrm{S}=\frac{7}{8}\times\frac{2{\cdot}3}{bd}\cdot\mathrm{F}=\frac{2\mathrm{F}}{bd}=\frac{2\frac{\mathrm{W}}{2}}{bd}=\frac{\mathrm{W}}{bd}\quad .\quad .\quad .\quad .\quad .\quad (2).$$

To determine the condition that fracture may equally occur either by tearing or crushing or shearing,

$$t=k\frac{\mathrm{L}}{d}\cdot\frac{\mathrm{W}}{bd}=k\,.\,\frac{\mathrm{L}}{d}\,.\,\mathrm{S}$$

by equations (1) and (2), where k is a constant. If S and t be known, then $\frac{\mathrm{L}}{d}$ can be determined, and may be called the critical ratio. With a ratio of length to depth less than this, the presumption is that the fracture will take place by shear; with a ratio greater than this, that the fracture will be caused by tearing or crushing, beginning at the extreme fibres.

The critical ratios, assuming the ultimate direct stresses for t and S, are :—

Oak.	Ash.	Boxwood.
$\frac{\mathrm{L}}{d}=\frac{t}{\mathrm{S}k}=\frac{7{\cdot}45}{{\cdot}6\times 1{\cdot}75}=7$	$\frac{9{\cdot}38}{{\cdot}9\times 2{\cdot}35}=4{\cdot}4$ to $\frac{9{\cdot}38}{{\cdot}6\times 2{\cdot}35}=6{\cdot}6$	$\frac{10{\cdot}2}{1{\cdot}26\times 1{\cdot}94}=4{\cdot}15$ to $\frac{10{\cdot}2}{{\cdot}8\times 1{\cdot}94}=6{\cdot}15$

In the following tables of the results of experiments, the values of t, c, and S have been worked out from the formulæ (1) and (2), and give a better idea of the relative stresses.

OAK.

Spec. No.	Span.	*b*.	*d*.	$\frac{L}{d}$.	Breaking Load in Tons.	$t=\frac{1·75WL}{bd^2}$. Tons per sq. in.	$c=\frac{·845WL}{bd^2}$. Tons per sq. in.	Elastic Formula, $t=c=1·5\frac{WL}{bd^2}$	$S=\frac{W}{bd}$. Tons per sq. in.	Direction of Horizontal Shear.
116	6″	1·6″	3″	2	3·38	2·46	1·18	2·12	·70	Radial.
114	6	1·6	1·95	3·07	3·15	5·45	2·63	4·68	1·01	
2224	4·8	1·2	1·6	3	1·82	4·95	2·39	4·24	·94	
1431	5	·5	1·58	3·16	1·02	7·15	3·45	6·13	1·29	„
1411	6	1·62	1·62	3·75	2·08	5·28	2·54	4·53	·80	
1432	6	·5	1·58	3·78	·96	8·1	3·9	6·93	1·22	„
2225	6·4	1·2	1·6	4·0	1·36	4·98	2·4	4·21	·71	
115	12	1·6	3	4·0	3·03	4·42	2·13	3·79	·63	„
342	12	1·6	2·97	4·03	3·7	3·08	1·49	2·64	·78	
1413	7	1·62	1·62	4·35	2·14	6·3	3·04	5·40	·83	„
1433	7	·5	1·58	4·42	·76	7·45	3·6	6·39	·96	
2226	8	1·2	1·6	5·0	1·34	6·1	2·94	5·23	·70	„
1434	8	·5	1·58	5·08	·67	7·55	3·65	6·47	·84	
1435	9	·5	1·58	5·72	·70	8·85	4·26	7·59	·88	„
1222	4·8	1·57	·82	5·84	1·05	8·25	3·98	7·07	·81	
2211	9·6	·8	1·57	6·12	·84	7·2	3·47	6·17	·67	„
113	6	1·6	·95	6·3	1·03	7·45	3·6	6·39	·67	
112	12	1·6	1·95	6·54	1·97	6·8	3·28	5·83	·63	„
2214	11·2	·8	1·57	7·14	·67	6·75	3·25	5·79	·53	
1411	12	1·62	1·62	7·4	1·15	5·85	2·82	5·01	·45	„
111	12	1·6	·95	12·6	·48	7·00	3·37	6·00	·32	„
2221	3·6	1·6	1·2	3·0	1·85	5·08	2·45	4·36	·96	Tangential.
1231	5	1·0	1·6	3·15	1·74	5·95	2·87	5·10	1·09	
1232	6	1·0	1·6	3·75	1·67	6·85	3·3	5·87	1·05	
1412	6	1·62	1·62	3·75	2·43	6·15	2·96	5·27	·94	„
332	12	1·45	3·1	3·86	3·98	6·0	2·9	5·15	·88	
1233	7	1·0	1·6	4·4	1 65	7·9	3·81	6·78	1·03	„
2222	4·8	1·6	1·2	4·0	1·75	6·38	3·08	5·47	·91	
1414	7	1·62	1·62	4·35	2·11	6·5	3·14	5·57	·80	„
2223	6	1·6	1·2	5·0	1·75	7·95	3·84	6·81	·91	
1234	8	1·0	1·6	5·0	1·26	6·92	3·35	5·93	·78	„
2212	4·8	1·57	·8	6·0	1·05	8·75	4·22	7·50	·83	
1221	9·6	·82	1·57	6 12	·81	6·7	3·24	5·74	·62	„
2213	5·6	1·57	·8	7	·84	8·05	3·88	7·90	·66	
1224	11 2	·82	1·57	7·14	·75	7·25	3·5	6·21	·58	„
1412	12	1·62	1·62	7·4	1·45	7·15	3·45	6·13	·55	„

ASH.

Spec. No.	Span.	b.	d.	$\frac{L}{d}$.	Breaking Load in Tons.	$t=\frac{2·35WL}{bd^2}$. Tons per sq. in.	$c=\frac{·75WL}{bd^2}$. Tons per sq. in.	Elastic Formula, $t=c=1·5\frac{WL}{bd^2}$	$S=\frac{W}{bd}$. Tons per sq. in.	Horizontal Shear.
121	18"	1"·85	3"·45	5·2	4·7	9·05	2·88	5·76	·731	Radial.
431	8	3·5	1·32	6	3·11	9·6	3·06	6·12	·67	,,
432	9	3·5	1·32	6·8	3·03	10·5	3·35	6·70	·66	,,
211	14	3·62	1·65	8·5	2·83	9·5	3·03	6·06	·47	,,
122	36	1·87	3·55	10·1	2·35	8·45	2·7	5·40	·36	,,
531	36	1·77	3·52	10·2	2·18	8·45	2·7	5·40	·35	,,
212	18	3·62	1·65	10·9	2·3	9·7	3·09	6·18	·38	,,
41	36	1·6	3·2	11·3	1·59	8·25	2·63	5·26	·31	,,
33	36	3·62	1·65	21·8	·98	8·45	2·7	5·4	·16	,,
123	9	3·45	1·85	4·85	5·2	9·3	2·96	5·92	·83	Tangential.
433	21	1·32	3·5	6	2·92	8·9	2·84	5·68	·63	
532	14	3·52	1·77	7·9	3·25	9·7	3·09	6·18	·52	,,
533	18	3·52	1·77	10·1	2·06	7·9	2·52	5·04	·33	,,
213	36	1·65	3·62	9·95	2·22	8·7	2·78	5·56	·37	,,
434	36	1·32	3·5	10·3	1·77	9·25	2·95	5·70	·38	,,
15	36	1·65	3·6	10	2·13	8·35	2·66	5·32	·36	,,
31	36	3·63	1·65	21·8	1·13	9·7	3·09	6·18	·19	,,

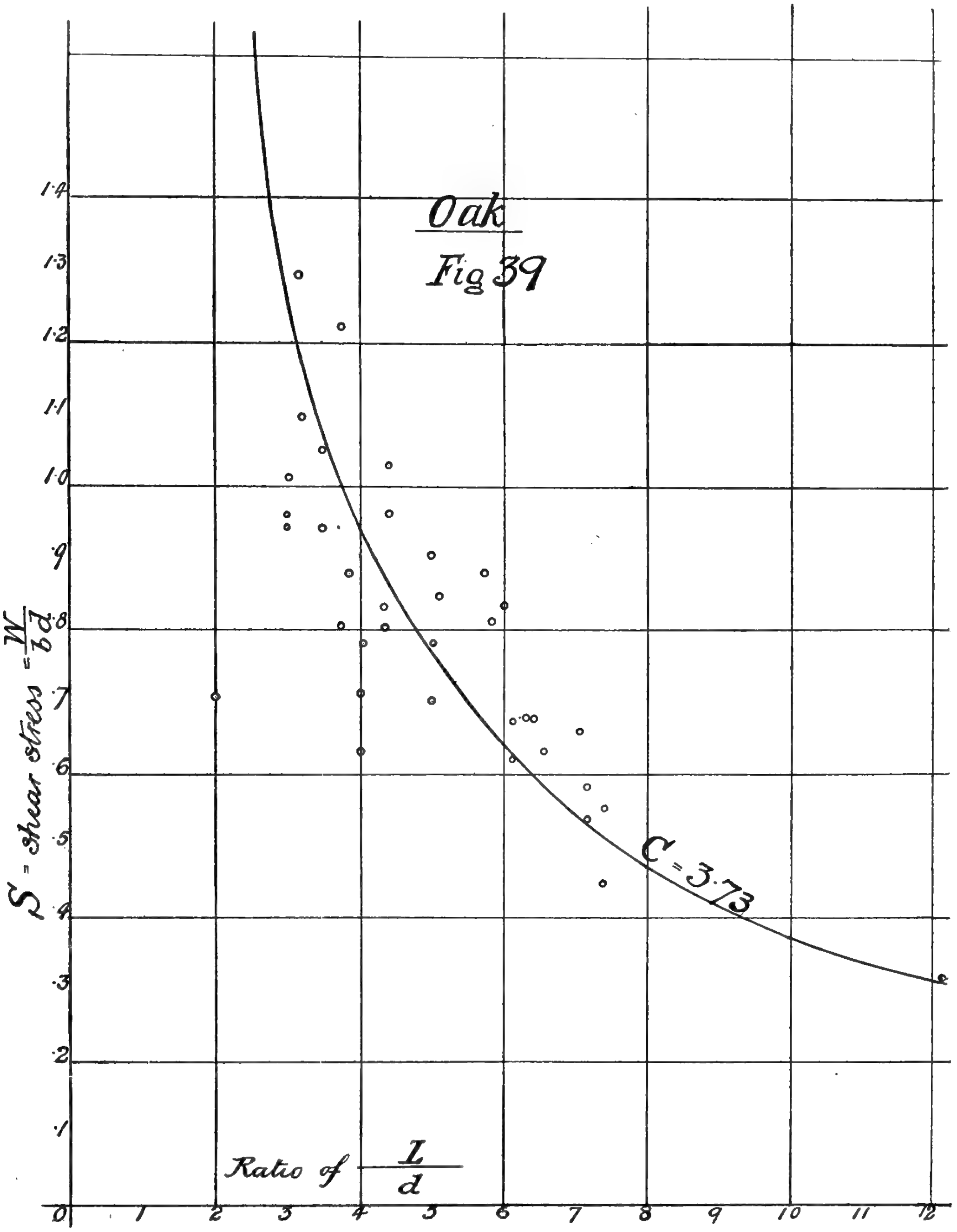
BOXWOOD.

Spec. No.	Span.	b.	d.	$\frac{L}{d}$.	Breaking Load in Tons.	$t=\frac{1·94WL}{bd^2}$. Tons.	$c=\frac{·82WL}{bd^2}$. Tons.	Elastic Formula, $t=c=1·5\frac{WL}{bd^2}$	$S=\frac{W}{bd}$. Tons.	Horizontal Shear.
71	5"·6	1"·7	1"·4	4	2·66	8·7	3·67	6·74	1·12	Radial.
111	8	1·05	2	4	1·98	7·3	3·08	5·67	·94	,,
112	12	1·05	2	6	1·49	8·25	3·48	6·40	·71	,,
72	8·4	1·7	1·4	6	1·95	9·55	4·04	7·40	·82	,,
73	14	2	1·4	10	·78	5·5	2·32	4·25	·28	,,
113	20	1·05	2	10	1·15	10·6	4·48	8·23	·55	,,
4	36	1·18	2·08	17·3	·63	8·6	3·64	6·68	·26	,,
114	4	2	1·05	3·8	3·06	10·7	4·52	8·29	1·46	Tangential.
74	6·8	1·4	1·7	4	2·86	9·35	3·95	7·25	1·2	
115	6	2	1·05	5·7	2·26	11·9	5·05	9·28	1·07	,,
75	10·2	1·4	1·7	6	1·03	5·05	2·14	3·93	·43	,,
76	20	1·4	2·0	10	1·55	10·4	4·4	8·08	·55	,,
10	36	1·14	2·32	15·5	·7	8·0	3·37	6·18	·26	,,

Taking the average values in each set of tests, we have :—

When Horizontal Shear is	OAK.	ASH.	BOXWOOD.
Tangential Radial	$t=6·88$ $t=6·25$	9·0 9·1	9·2 tons 8·4 ,,
Tangential Radial	$s=$ ·84 $s=$ ·78	·45 ·45	·83 tons ·67 ,,

This goes to show that a beam is rather stronger when laid with the medullary rays in a vertical plane and its annual rings as nearly as possible horizontal. This is in keeping with the results arrived at in ordinary shear, which showed that the timber was better able to resist tangential shear than horizontal; but the difference, especially in the case of Ash, is not a very important one.



The values of the tensile and compressive stresses, as given in the above tables, show that the assumptions upon which the formula is based are approximately correct. This is illustrated if the shear values $s=\frac{W}{bd}$ are plotted on a diagram as ordinates with the ratios of $\frac{L}{d}$ as abscissæ, as has been done in fig. 39. A fair curve to pass through the mean of these points is a hyperbola with a constant which, in the case of Oak, is equal to 3·73.

Thus

$$\frac{W}{bd}\cdot\frac{L}{d}=C=3{\cdot}73=\frac{t\text{ (maximum tensile stress)}}{k\text{ (constant)}}$$

If the average value of t is inserted here, say 6·53 tons, then

$$k=\frac{6{\cdot}53}{3{\cdot}73}=1{\cdot}75,$$

which was the value of the calculated constant on the assumption of an approximately rectangular stress diagram.

It is difficult to account for the very high values which are apparently reached in some cases by the shear stresses, though the average values are in practical agreement with those in direct shear. The cases in which this excessive calculated value is reached occur only when the span is very short relative to the depth, and where, consequently, the central load is not far removed from the line of the reaction. The material is thus subjected to a compressive bearing stress which tends to increase the value of the resistance of the material to horizontal shear. As the load becomes more remote from the reaction, this effect grows less, and is not observable at that ratio of length of span to depth of beam at which the material will give either by tension, compression, or shear. That there is some raising of the shear value is evidenced by shearing taking place habitually in beams at what may be called the normal shearing value when $\frac{L}{d}$ is near the critical ratio, as well as at the more inflated value when $\frac{L}{d}$ is very small. Fig. 32 shows some typical shearing fractures of Oak, but these fractures never occur above the critical ratio. With horizontal shear tangential, 4 was the highest value of $\frac{L}{d}$ attained when shear was the direct cause of failure, and with horizontal shear radial, 5. The only condition under which so high a value of $\frac{L}{d}$ as 10 could be reached in a beam fractured by horizontal shear would be where a shake, situated near the neutral axis, already existed in the timber, which would, of course, offer little resistance to shear.

CONCLUSIONS.

1. The initial cause of fracture in timbers lies in the medullary rays.
2. Rectangular beams when laid on a tangential face are stiffer and have a higher fracture value than when on a radial face.

3. Rectangular beams of unequal sides are stiffer but not materially stronger when laid on the broad side of the section.

4. When at the fracture point a rectangular stress diagram very slightly modified accurately represents the distribution of stress in a timber beam.

5. For timber struts where the ratio of length to smaller dimension of cross-section does not exceed 12 to 15, a modification of the usual column formula is necessary.

6. Fracture by shearing does not take place in timber beams of the commoner woods supported at two ends and loaded in the middle where the ratio of span to depth of beam exceeds, say, 7.

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EXPLANATION OF PLATES.

Plate I.

Fig. 2. A block of Oak cut with the broad longitudinal sides *tangential*, and arranged so as to exhibit one of these sides. × $\frac{7}{8}$ n.s. The fibres are displaced tangentially, local buckling taking place in two planes, more or less equally inclined to the direction of pressure.

Fig. 3. A block of Ash cut with the broad longitudinal sides *tangential*, and arranged so as to exhibit one of these sides. × $\frac{7}{8}$ n.s. It has been fractured by crushing in a longitudinal direction, and the buckling has taken place in a single plane. This is the general case.

Fig. 4. A block of Ash with the broad longitudinal sides *radial*, and arranged so as to exhibit one of these sides. × $\frac{7}{8}$ n.s. The illustration shows that there is no movement in a radial direction.

Fig. 5. A block of Boxwood cut with its broad longitudinal sides *tangential*, and arranged to show one of these sides. × $\frac{7}{8}$ n.s.

Fig. 6. A block of Boxwood cut with its broad longitudinal sides *radial*, and arranged to show one of these sides. × $\frac{7}{8}$ n.s. The stress is longitudinal compression and the displacement is tangential, irrespective of the proportions of the cross-section.

Plate II.

Fig. 7. Oak wood. A normal radial section, × 176 diams., showing a medullary ray (*m*) crossing wood-fibres (*f*), wood-parenchyma (*p*), etc.

Fig. 8. Oak wood. A normal transverse section at the zone of demarcation between the autumn wood of one year and the spring wood of the next, × 240 diams., showing two narrow medullary rays (*m*), wood-fibres (*f*), etc.

Fig. 9. Oak wood. A normal transverse section at the line of demarcation between two annual zones of growth. × 88 diams. One large tracheide (*t*) and a portion of another are shown. The size of this tracheide should be compared with that of Box.

Fig. 10. Oak wood. A normal tangential section, × 240 diams., showing a portion of a broad medullary ray (M), narrow rays (*m*), wood-fibres (*f*), wood-parenchyma (*p*), etc.

Fig. 11. Oak wood. A general view of a tangential section of fractured wood, × 20 diams., showing that the fracture takes place more readily at the medullary rays (*m*) than at the apparently weaker tracheæ (*t*).

Fig. 12. Oak wood. A tangential section from a partially crushed block, × 176 diams., showing that the fracture is caused by the wood-fibres separating from the medullary rays (*m*).

Plate III.

Fig. 13. Ash. A normal transverse section, × 240 diams. It shows portions of tracheæ (*t*), medullary rays (*m*), wood-fibres (*f*), etc. Tracheides shown only about one-third the size of those of Oak.

Fig. 14. Box. A normal transverse section, × 240 diams. It shows tracheæ (*t*), medullary rays (*m*), wood-fibres (*f*), etc. The relative size of the tracheæ in these three different woods may now be compared.

Fig. 15. Ash. A normal tangential section, × 240 diams., showing medullary rays (*m*) and wood-fibres (*f*). The sinuous path of the wood-fibres making their way past the medullary rays is well shown.

Fig. 16. Ash. A tangential section, × 176 diams., of a fractured specimen. It shows early stage in the crumpling of the fibres and their splitting from the medullary rays.

Fig. 17. Box. A normal tangential section, × 240 diams. It shows tracheæ (*t*), medullary rays (*m*), wood-fibres (*f*), etc. Most of the medullary ray cells are filled with starch.

Fig. 18. Box. A tangential section, × 176 diams., of specimen that has been compressed. It also shows crumpling of the fibres and their splitting from the medullary rays.

Plate IV.

Fig. 19. Oak. A set of strips, × $\frac{7}{8}$ n.s., that have been fractured by tension. (*a*) exhibiting its narrow side, and (*b*) exhibiting its broad side, were both cut with their broad sides tangential; (*c*) and (*d*), similarly shown, were cut with their broad sides radial. (*b*) and (*c*) therefore show a tangential face, and the fracture is a ragged one. In (*a*) and (*d*), where a radial face is exposed, there is an abrupt break extending more or less straight across the face. This is due to little or no slip taking place between the annual rings or wood-fibres radially adjacent, but a considerable slip takes place between the medullary rays and the adjacent fibres.

Fig. 20. Box. Three strips, × $\frac{19}{20}$ n.s., that have been fractured by tension. (*a*) and (*b*) exhibit tangential, and (*c*) radial, faces. The fracture runs through the wood to a considerable extent tangentially, but radially it is very abrupt.

Plate V.

Fig. 21. Ash. One strip, × $\frac{4}{5}$ n.s., fractured by tension. It has been cut with broad sides tangential, and exhibits one of these sides showing usual ragged break.

Fig. 22. Oak. A tangential section, × 76 diams., from a beam fractured by cross-breaking, on the tension side. It shows the separation of tissues takes place most readily between medullary rays and adjacent tissues.

Fig. 23. Box. A tangential section, × 176 diams., from a strip broken by tension.

Fig. 24. Box. A tangential face of beam, × $\frac{7}{8}$ n.s.

Plate VI.

Fig. 25. Oak. A tangential face, × $\frac{7}{8}$ n.s., of a beam fractured by cross-breaking. The ragged break on tensional part similar to that obtained in direct tension.

Fig. 26. Oak. Radial face of beam fractured by cross-breaking, and showing abrupt break, × $\frac{7}{8}$ n.s.

Fig. 27. Ash. A beam cut with the broad sides radial, and arranged to show one of these sides, × $\frac{17}{20}$ n.s., after cross-breaking. Note the bulging on the upper side due to compression.

Fig. 28. Oak. Transverse sections of two blocks cut with the broad longitudinal sides tangential, × $\frac{7}{8}$ n.s., and subjected to a *tangential* stress which is less in (*a*) than in (*b*).

Plate VII.

Fig. 29. Oak. A tangential section from the compressed side of a beam, × 176 diams., showing crumpling of the tissues. The direction of the induced compression C is shown by the arrow-heads.

Fig. 30. Oak. A tangential section from the fractured lower portion of a beam, × 176 diams.

Fig. 31. Oak. A transverse section of log, × $\frac{7}{8}$ n.s., which has been fractured by longitudinal compression. The slip is essentially a tangential one. *Note.*—This specimen contains the centre of tree.

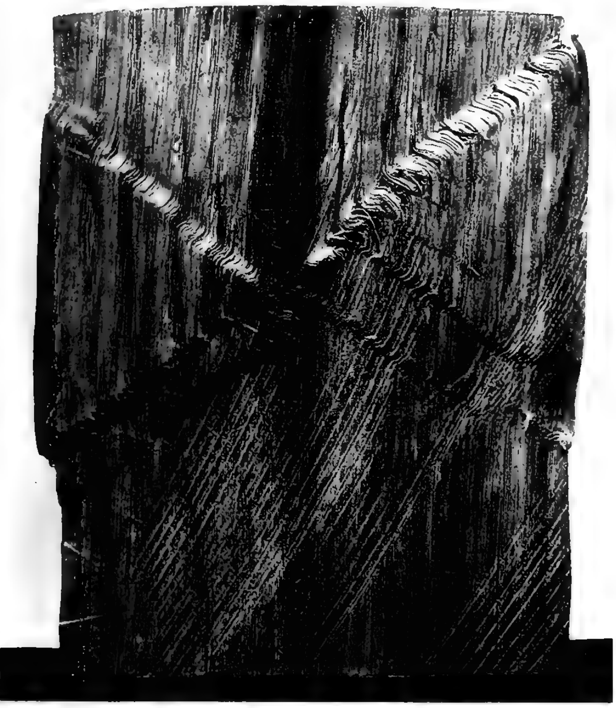
Fig. 32. Oak. A set of beams which have been laid on their tangential face and fractured by cross-breaking. The radial faces are exhibited × $\frac{1}{3}$ n.s. *Note.*—The line of shear is always nearer the tension side. Ratios of $\frac{L}{d}$ less than 4.

Plate VIII.

Fig. 33. Oak. Seven specimens fractured by longitudinal compression, × $\frac{1}{3}$ n.s. K = narrow dimension, and is *radial.* Local buckling takes place until $l = 8k$, and is tangential. Above this it is a compound of bending and local crumpling in oblique plane.

Fig. 34. Oak. Seven specimens fractured by longitudinal compression, × $\frac{1}{3}$ n.s. K = narrow dimension, and is *tangential.* Local buckling occurs until $l = 6k$ and is tangential. Above this it is a compound of bending and buckling in a vertical plane.

FULTON: EXPERIMENTS ON TIMBER.—PLATE I.



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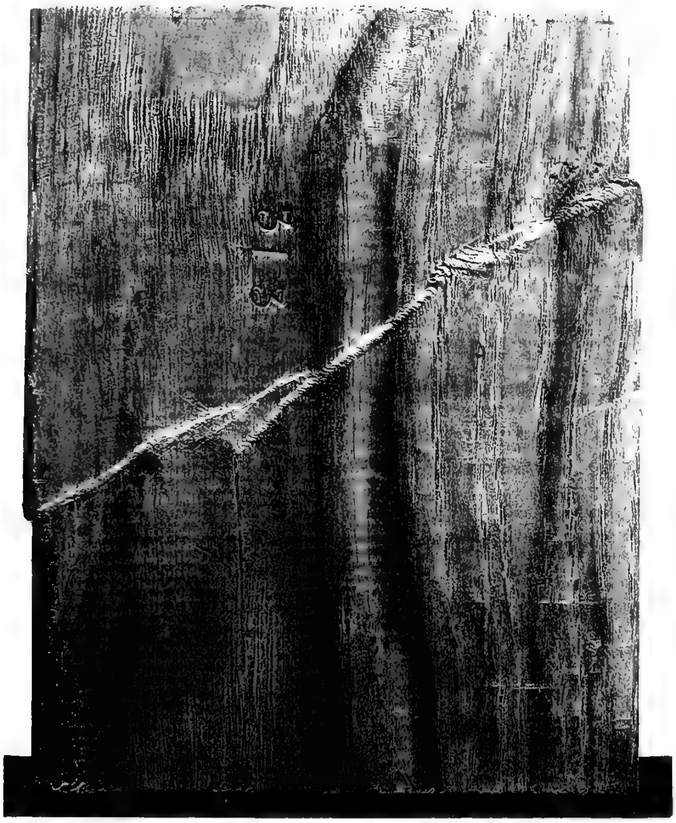

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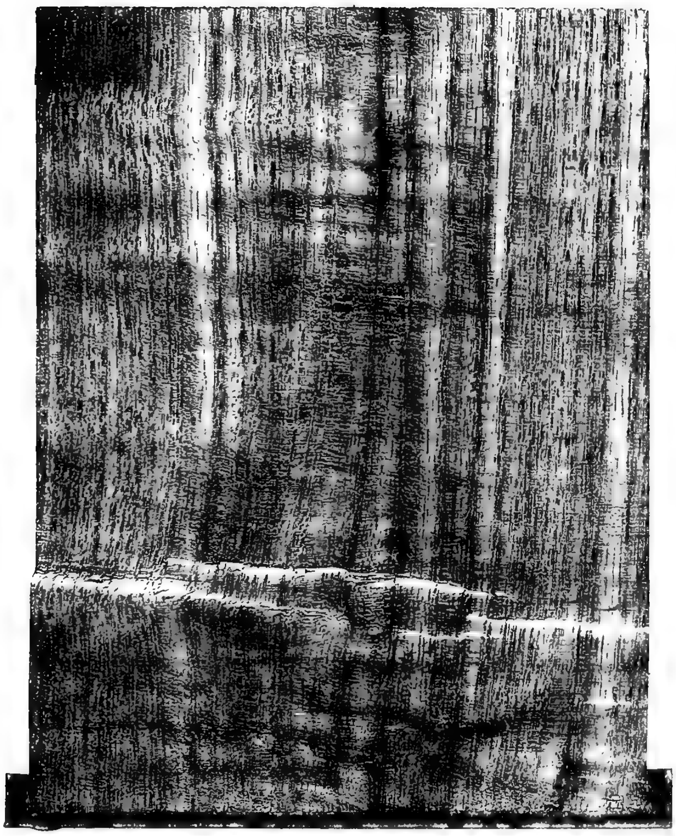

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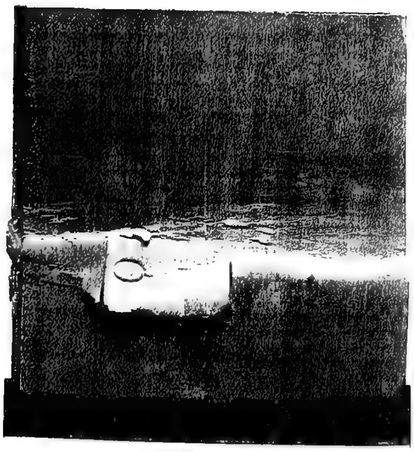

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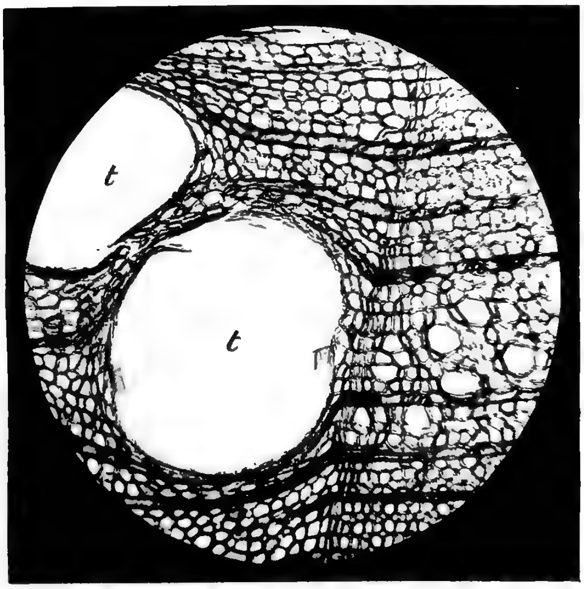
FULTON: EXPERIMENTS ON TIMBER.—PLATE II.



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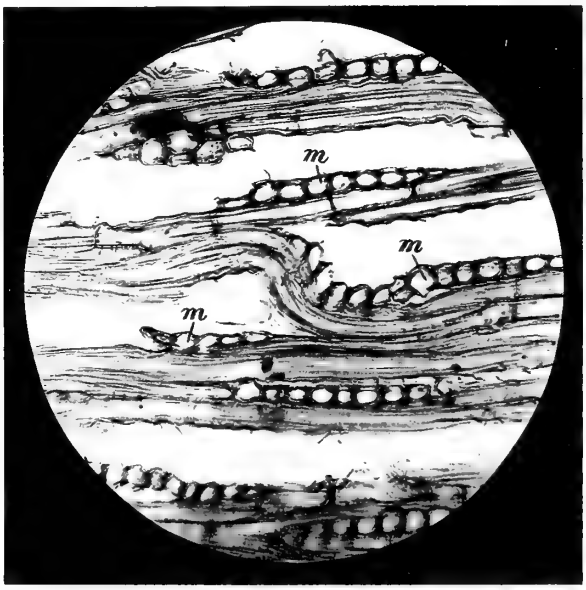

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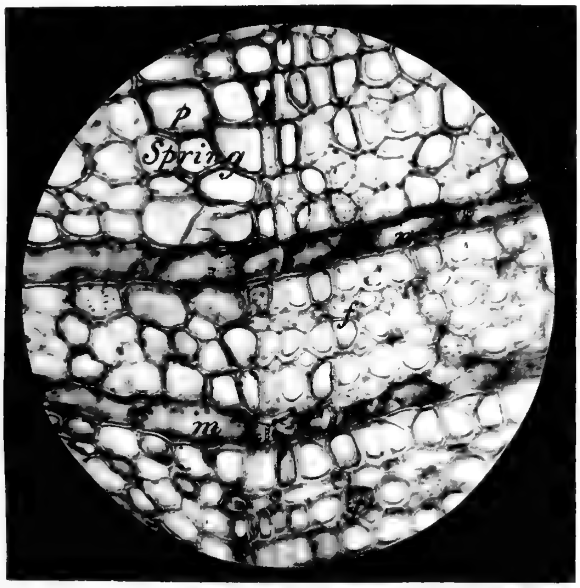

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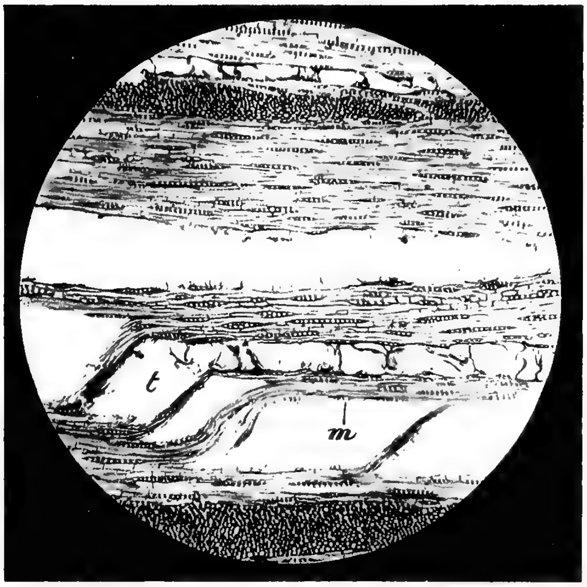

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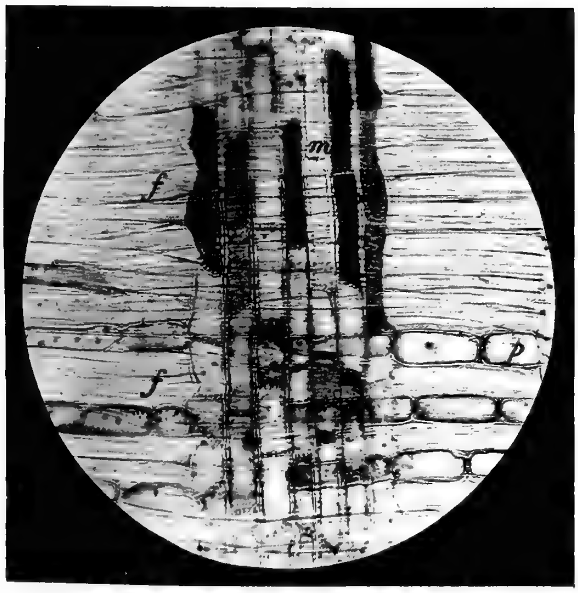

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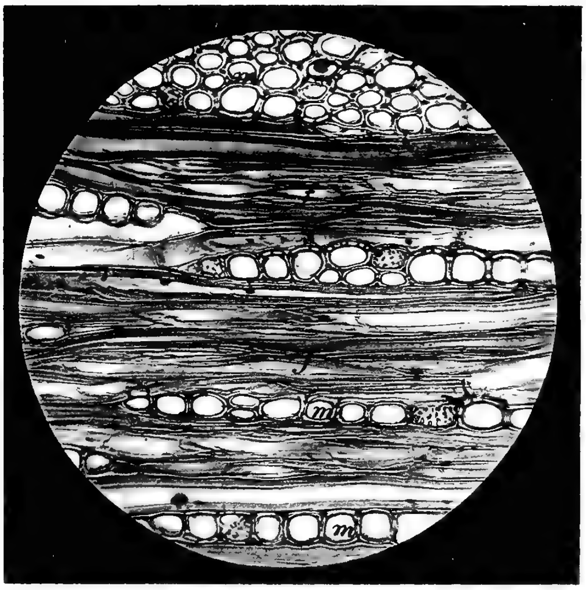

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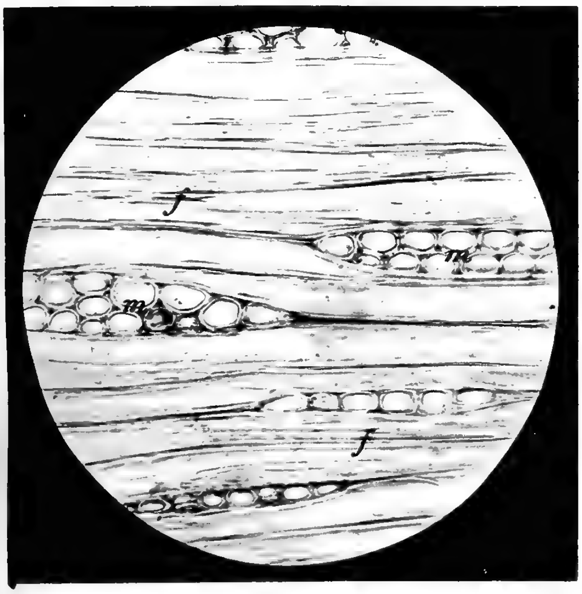
FULTON: EXPERIMENTS ON TIMBER.—PLATE III.



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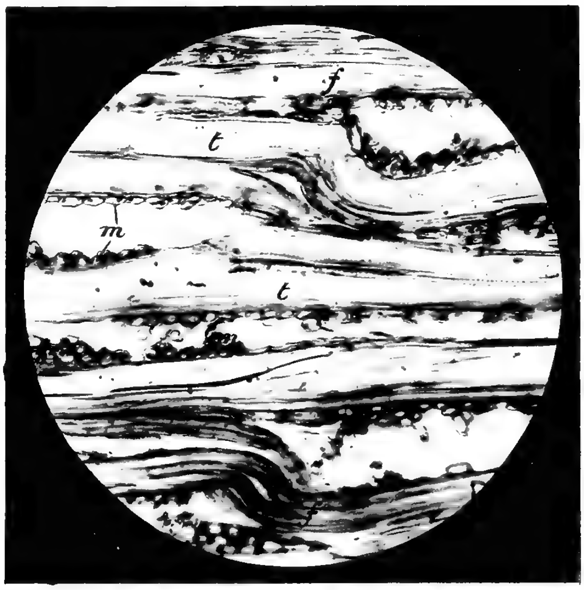

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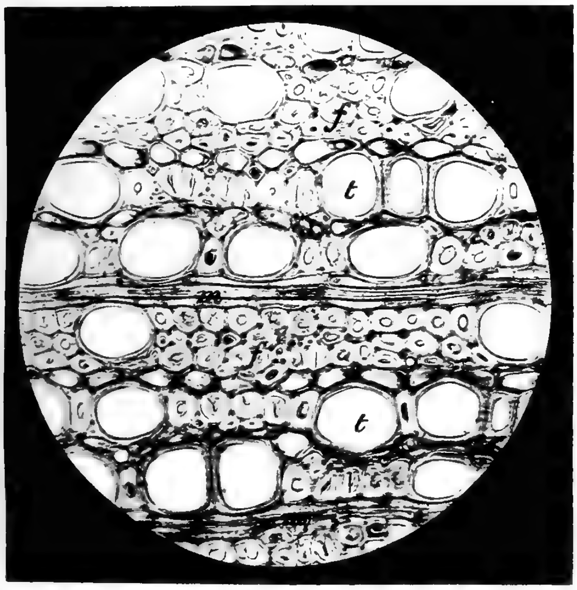

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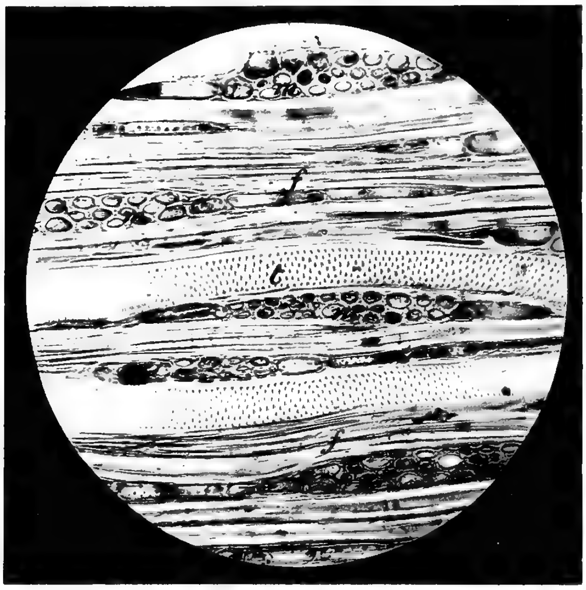

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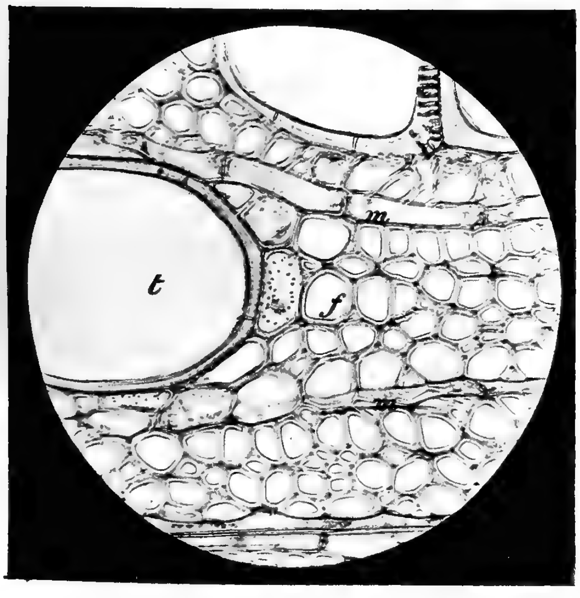

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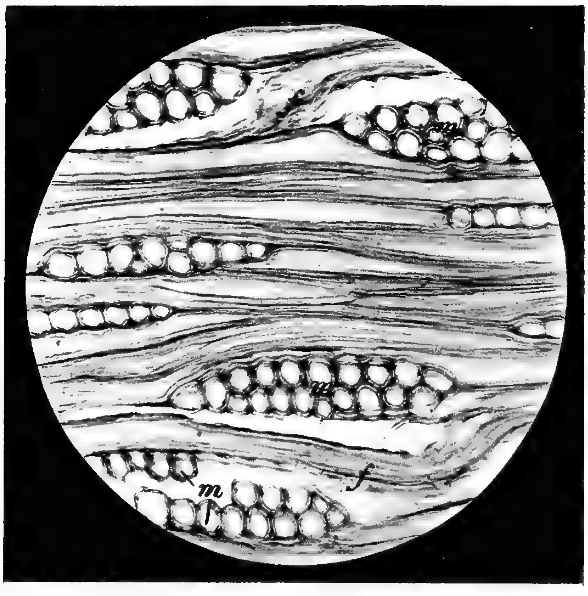

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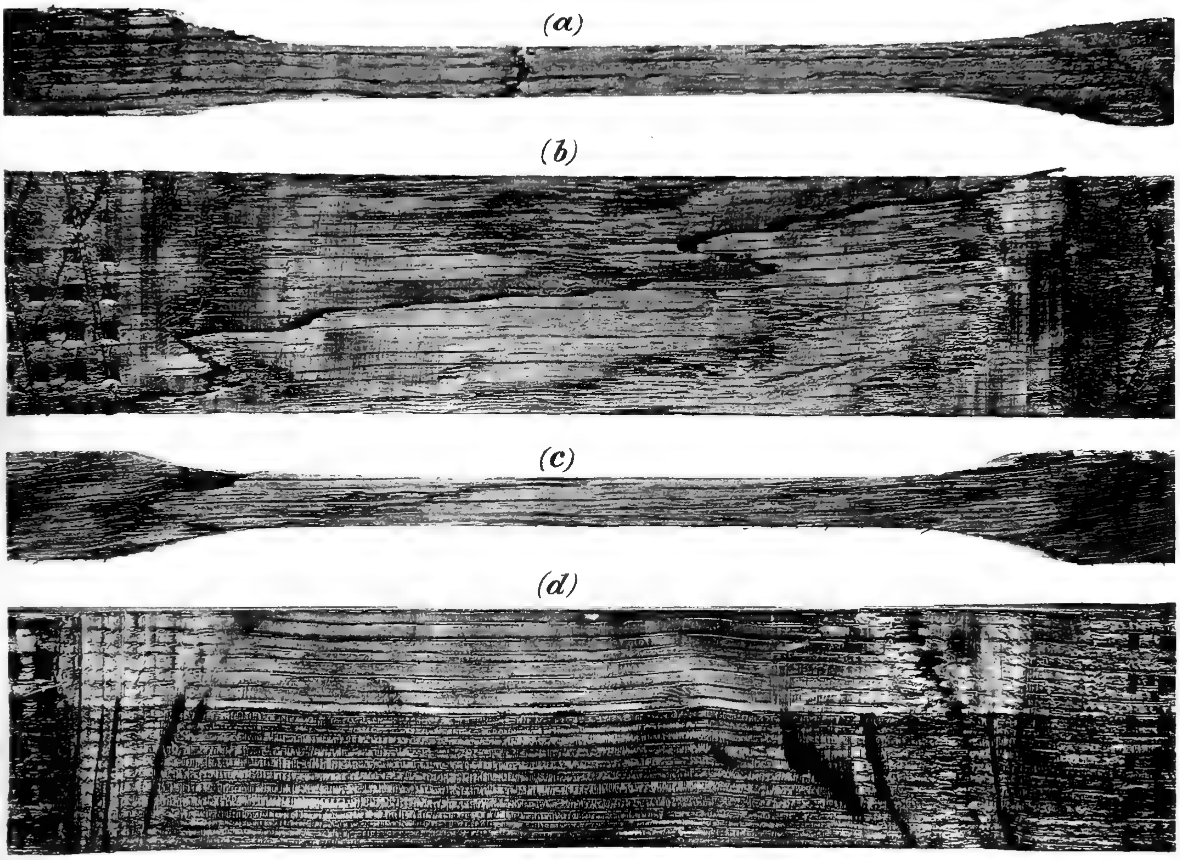
FULTON: EXPERIMENTS ON TIMBER.—PLATE IV.



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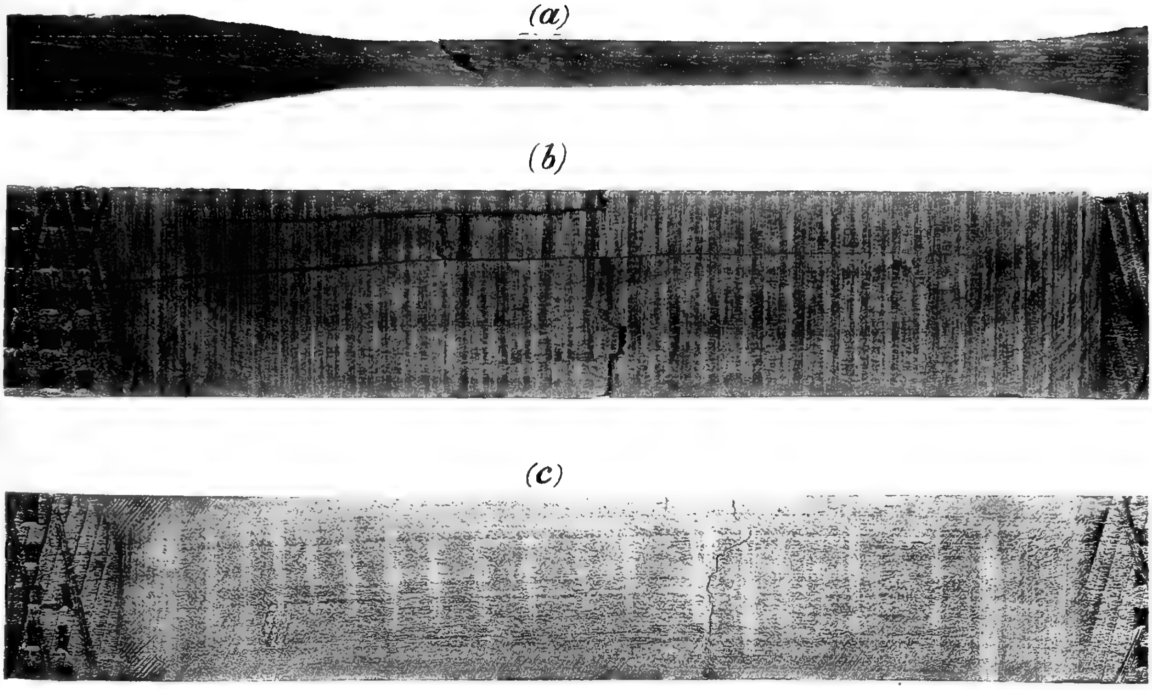

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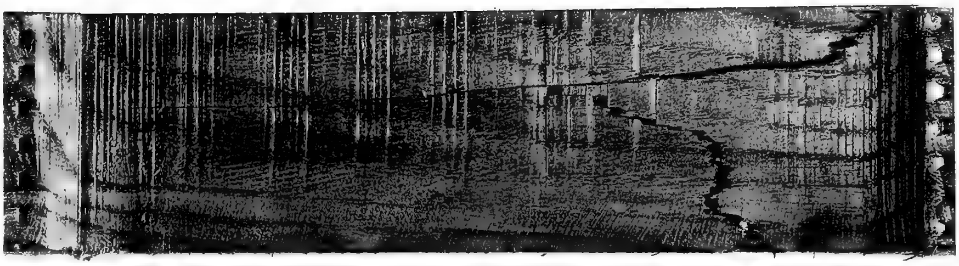
FULTON: EXPERIMENTS ON TIMBER.—PLATE V.



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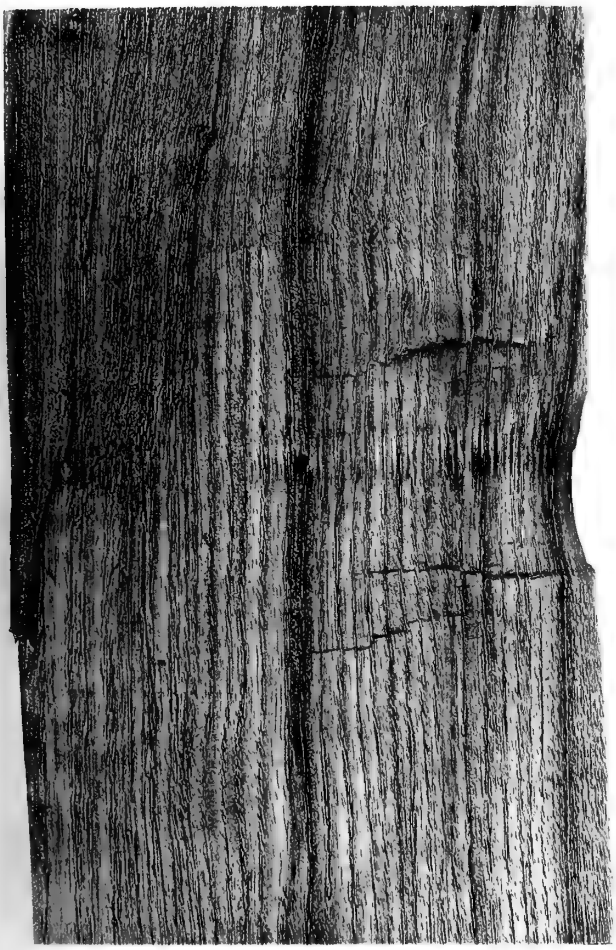
FULTON: EXPERIMENTS ON TIMBER.—PLATE VI.



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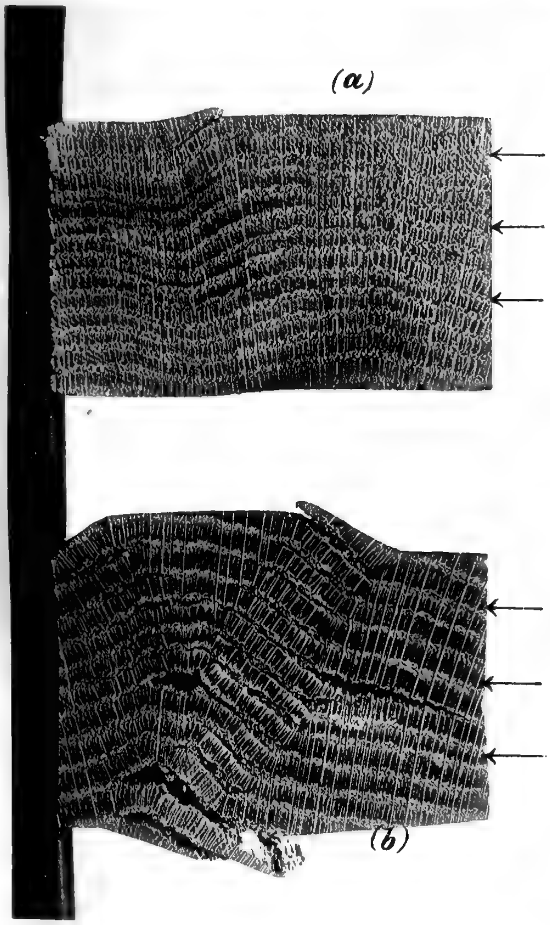

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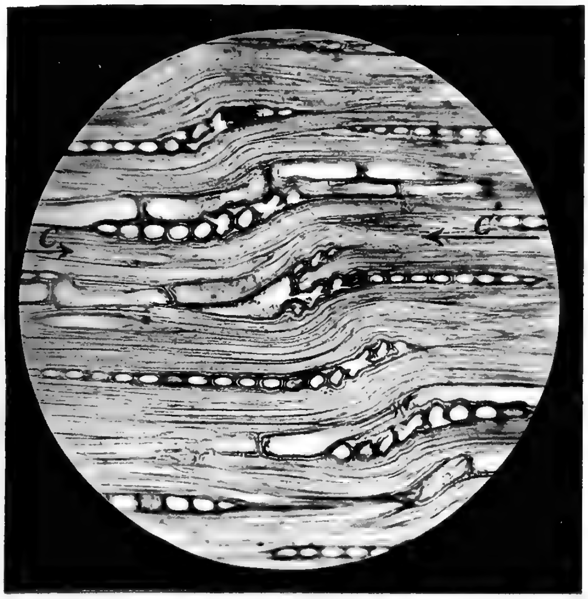
FULTON: EXPERIMENTS ON TIMBER.—PLATE VII.



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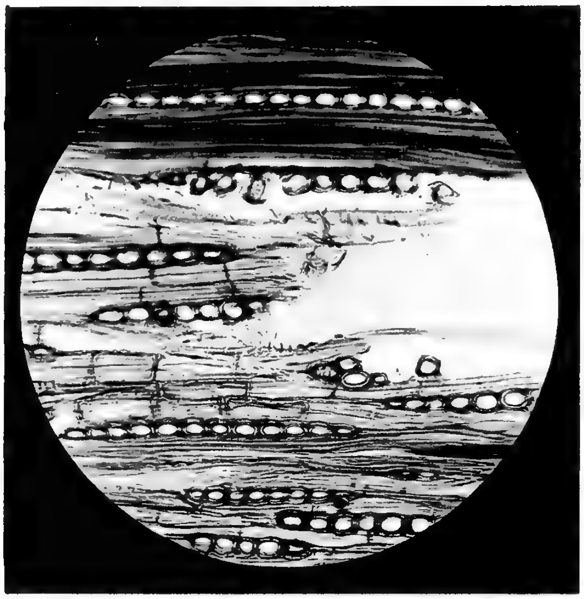

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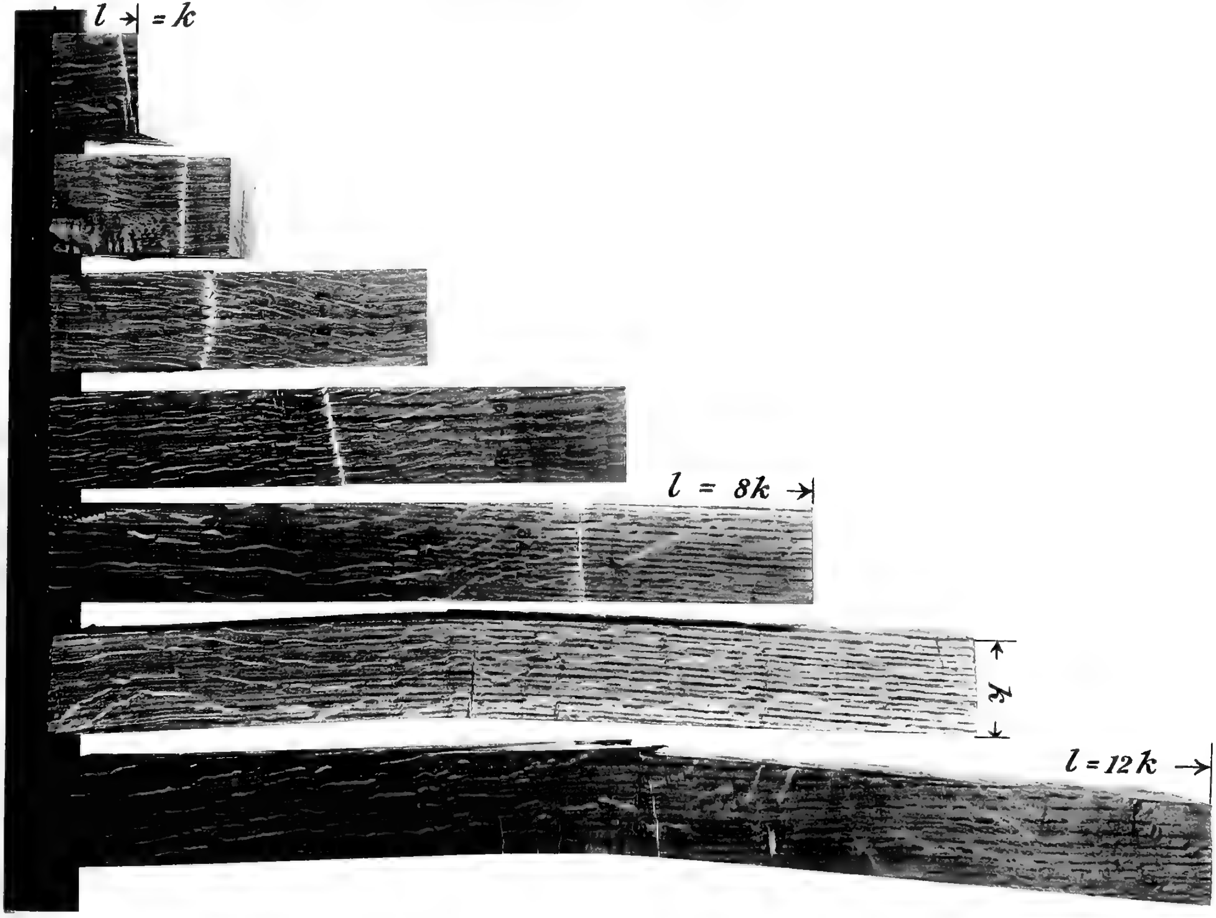
FULTON: EXPERIMENTS ON TIMBER.—PLATE VIII.



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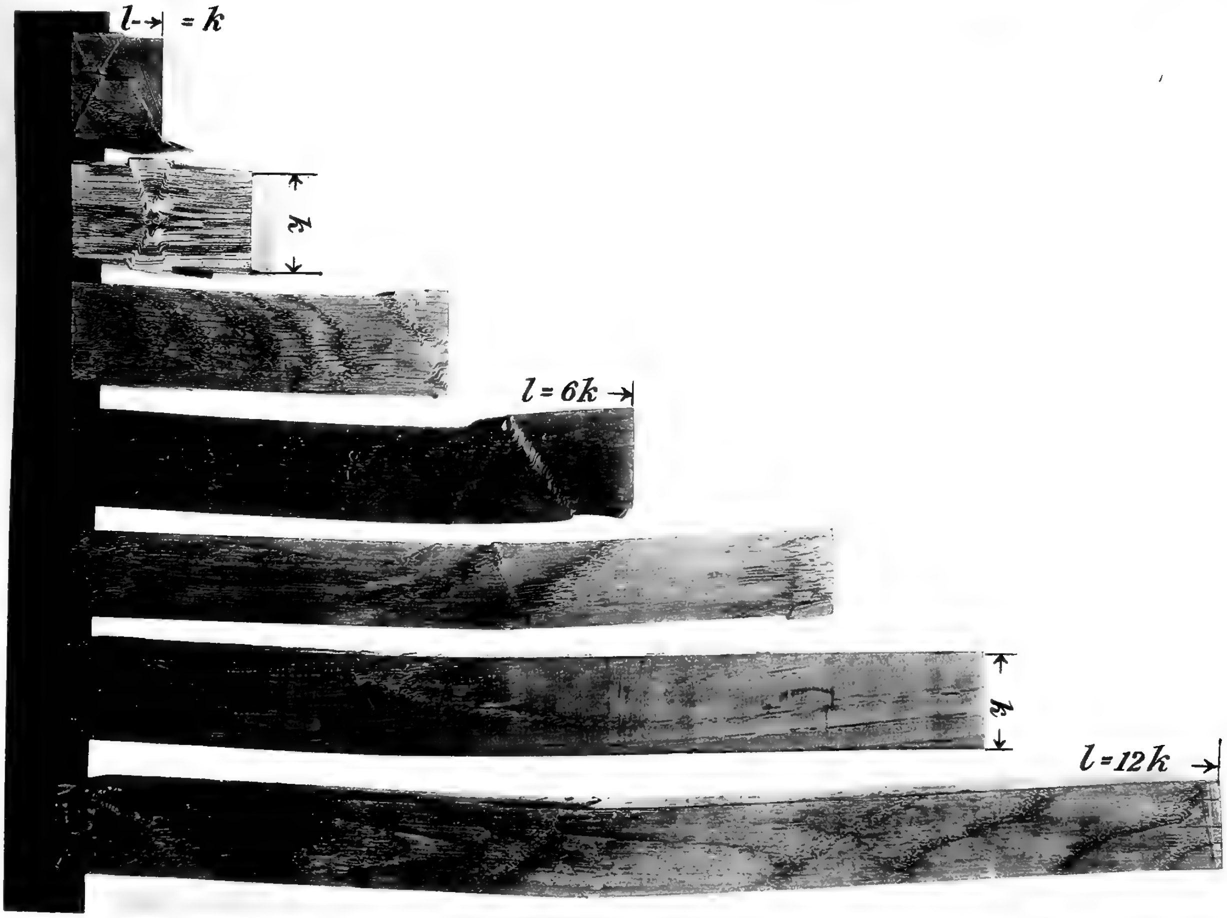

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XXII.—The Cestoda of the Scottish National Antarctic Expedition. By John Rennie, D.Sc., and Alexander Reid, M.A., University of Aberdeen. (With Two Plates.)

(MS. received May 6, 1912. Read June 17, 1912 Issued separately September 6, 1912.)

The Cestode material obtained by the *Scotia* Expedition consisted of eight adult and three larvæ or immature forms. Of these, one (*Anchistrocephalus microcephalus*, Rud.) is not Antarctic, having been obtained from the Sunfish (*Orthagoriscus mola*), at Station 107, in 39° 12′ S., 53° 44′ W., on January 1, 1903.

Of the others, only two appear to have been previously described, viz. *Dibothriocephalus antarcticus*, Baird, and *Dibothriocephalus wilsoni*, Shipley. The hosts from which the Cestoda of the Antarctic and sub-Antarctic regions were obtained are, with the exception of the Bonito,* from which a larval *Tetrarhynchus* was obtained, Seals and Penguins. In view of this fact, the number of forms obtained may be regarded as relatively large. A study of the species on record from Arctic Pinnipedia suggests the interesting fact that the two Cestode faunas are quite distinct. Eight species of *Dibothriocephalus* are on record from Pinnipedia of the Arctic regions, none of which have so far been obtained in the Antarctic. The adult forms found, however, with one exception all belong to this genus.

A noteworthy feature is the relatively large proportion of very small and delicate species of Cestoda occurring in the Pinnipedia of the Antarctic. Indeed, none of the forms obtained can be described as large; the maximum size is that of *D. pygoscelis*, viz. 29 cm.

Shipley has suggested with regard to the Cestoda of Ross's Seal that, in view of the feebleness and variability of its dentition, it probably feeds on soft substances, and expresses the opinion that the plerocercoid stage probably occurs in the tissues of Cephalopods. Jellyfish are also mentioned, and these form part of the food of this Seal.

With regard to Seal Cestodes in general, we note that although the parasites are small the infection is generally heavy, and from this it may be argued as probable that the intermediate hosts become infected without much difficulty. The embryos are extraordinarily minute, and if dissipated in the waters would probably infect drifting organisms, *e.g.* Jellyfish or Ctenophora, more readily than others, *e.g.* Fishes. On the other hand, Crustacea and similar organisms of scavenging habits, feeding on the fæces of the Seals, have an even better chance of being infected, and these may provide the intermediate host. Beyond this it is scarcely profitable to speculate further.

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* This fish (*Thynnus pelamys* Linn.) it appears was found at Station 31—some distance south of the Cape Verde Islands—on 4th December 1902, and its parasite therefore cannot be described as Antarctic or sub-Antarctic.

Description of Species.

Ariola (1) divides the family Bothriocephalidæ as under :—

Sub-families :

Diplogoninæ. Two sets of gonads to each segment.

Mesogoninæ. A single set of gonads; genital apertures on surface. All the Bothriocephalidæ found, with one exception, belong to this group.

Pleurogoninæ. Marginal genital apertures.

One of the species found, *Anchistrocephalus microcephalus*, Rud., belongs to this group.

Order PSEUDOPHYLLIDEA, Carus.

Family DIBOTHRIOCEPHALIDÆ, Lühe.

Sub-family MESOGONINÆ (Ariola).

Genus *Dibothriocephalus* (Lühe).

Dibothriocephalus scoticus, n. sp. (Pl. I. figs. 1 and 2.)

This form occurred in the intestine of a Sea-leopard (*Stenorhynchus leptonyx*).

The maximum dimensions are: strobila, length 13·3 cm., breadth 6·8 mm.; scolex, 2·5 mm. by 1·5 mm. The scolex when fully extended shows a pair of dorso-ventral suckers widely gaping posteriorly and tapering towards the tip, which is rather sharply conical. The sucker lips are rather thin, almost weak.

No distinct neck is present. The proglottides are fairly broad, with well-marked backwardly directed flanged margins. Anteriorly they are roughly rectangular, much shorter than broad; in the mature parts of the strobila they become relatively longer.

The cuticle is rather thin, and beneath it an extremely fine circular layer of muscle can be made out with difficulty. Next this is a longitudinal layer, also slightly developed. This longitudinal layer lies between the narrowed ends of the cellular subcuticula, whose elements form a clearly defined band. Following on this is the layer of the yolk follicles, which, in the mature segments, except at the level of the uterus and cirrus sac, forms a practically continuous band. Within this occur two muscle layers, a well-defined longitudinal layer outermost; while, within, a thin circular band separates the peripheral area from the central.

The longitudinal nerve cords are placed about one-fourth of the transverse diameter from the margin.

In the mature segments there are about nine testes follicles external and about six internal to the nerve cord on each side.

Central longitudinal excretory canals were not observed, but there are numerous small peripheral canals in the subcuticula just external to the yolk follicles.

The yolk cells are extremely variable in form and size, and may be described as amœboid in appearance. The largest measure ·017 mm.; the smallest noted, ·012 mm. There is a well-marked yolk reservoir of pear shape between the two lobes of the ovary.

The ovary in transverse section appears as an elongated band, becoming shorter and thicker in its more anterior parts. The larger cells measure ·014 mm. in diameter.

The uterus consists of a winding tube of about four loops, the limbs of which in transverse section are seen to wind both dorsally and ventrally. There is a large dilated space just at the opening. On external view, the uterus in mature segments appears clustered in a rounded mass posteriorly, the winding portion being distinct only in its more anterior region. The shelled ova vary in size; the smallest measure ·070 × ·043 mm., and the largest ·082 × ·048 mm. They are operculate.

The testis is very large, consisting of numerous follicles occupying the greater part of the medullary region. The follicles are more or less spherical in form, and lie in close-set rows extending across the whole width of the proglottis, being separated from each other by the dorso-ventral muscles, which are correspondingly numerous. A common size of a follicle in a mature proglottis is ·069 to ·087 mm. in maximum diameter.

The cirrus sac is thick-walled, and oval in transverse section, presenting no distinctive peculiarities.

From the foregoing description, it appears that this species has not been previously observed. From the same host, von Linstow (3) has described *D. quadratus*, and with his account a careful comparison has been made. The scolex in the two species is very similar in general form. In *D. quadratus* it measures 1·3 mm. by ·71 mm., or about half the dimensions of the present species. The strobila is 22·5 cm. long, and 3·5 mm. broad at its widest part; the proportions of the present species are, it will be observed, altogether different. The longitudinal dimension of the ova given by von Linstow is ·055 mm., which is considerably less than the smallest measurement observed in *D. scoticus.* The shelled ova are in *D. quadratus* described as non-operculate; in the present species they are clearly operculate. Further, the appearance of the yolk follicles is quite different in the two species.

A comparison has also been made with other *Dibothriocephalus* species recorded in Pinnipedia, with like negative results.

In honour of the Scottish Expedition, we have named this new species *Dibothriocephalus scoticus.*

Dibothriocephalus coatsi, n. sp. (Pl. I. figs. 5 and 6.)

In *Stenorhynchus leptonyx* there occurred along with *Bothriocephalus scoticus* a number of specimens of a small, hitherto unrecorded Cestode.

The total length of strobila of the examples found is from 42 to 80 mm. In a specimen of 42 mm. the width at the broadest part, which is 23 mm. from the anterior end, is 1·8 mm.

The scolex is of distinctive appearance, being long, blunt, and of almost uniform width, measuring 2 mm. by ·75 mm. in extent. There is a pair of shallow, widely gaping suckers, dorso-ventrally placed, extending the whole length, and open at both ends (fig. 5).

The mature segments are rectangular in form, with slightly undulating margin. In the specimen 42 mm. long, the largest, which were terminal, measured ·61 mm. long by 1·04 mm. broad. They are also relatively thick, measuring in section ·61 mm. dorso-ventrally.

The cuticula and sub-cuticula are of typical appearance. Beneath the sub-cuticula are the yolk follicles. These are very numerous, and in many sections, *e.g.* those at the level of the ovary, they form a practically continuous band. The individual yolk cells, which vary in form, measure on an average about ·014 mm. by ·017 mm.

The shape of the ovary presents no unusual features. In a section at the level of its junction with the yolk ducts it has the form of a transverse band. Posteriorly to this it appears as a pair of detached, more or less rounded, and thicker masses. The ovarian cells measure ·017 mm. by ·01 mm.

The uterus consists of a few close coils which wind dorso-ventrally, so that in section it usually has the appearance of an almost complete circle. The shelled ova measure ·052 mm. by ·041 mm.

The testis follicles, which occupy the greater part of the central area of the proglottis, measure in their greatest dimensions ·034 mm. by ·052 mm.

There is a well-developed inner layer of longitudinal muscles; the dorso-ventral muscles are also well marked.

The longitudinal nerve cords are extremely ill-defined and weak, although relatively large. They are placed slightly less than one-fourth of the width of the proglottis from the margin, and are slightly nearer to the ventral than the dorsal surface.

The central longitudinal excretory canals can be made out only in places. They are placed at the extreme lateral margin of the central layer, next to the longitudinal muscles, but, as they frequently cannot be traced in serial sections, they probably anastomose a good deal. Peripheral canals are present just exterior to the yolk follicles. These are most clearly visible at the lateral margins, where two or three frequently occur close together.

This form differs in most particulars from all the hitherto described species of the group to which it belongs, and we have therefore classed it as new, naming it *Dibothriocephalus coatsi.* It is an interesting fact that two new species should have been obtained from *Stenorhynchus* by the Scottish Expedition, and that *D. quadratus*, the only form hitherto described from this host, should not have been found.

Dibothriocephalus antarcticus.

Bothriocephalus antarcticus, Baird, 1853.

About a dozen or more examples of this species were obtained from the stomach of a Ross's Seal, *Ommatophoca rossi.* These were all smaller than Baird's specimens, which were about 9 inches long. The *Scotia* examples range from 132 to 29 mm., but most measure about 100 mm. Baird's (2) description is rather brief and confined to externals, but from this, together with his excellent figure, there is no mistaking the identity of the *Scotia* specimens with his type.

This species was also found by the *Discovery* Expedition, and the specimens are described by Shipley, to whose account reference is made below.

Dibothriocephalus antarcticus, Baird (2), is a slender-bodied worm, with a conical scolex and with fairly sharp tapering point. The two suckers are long and comparatively deep. According to Baird, there are "two small rounded projecting lobes" at their posterior margins, but these in the *Scotia* examples are only occasionally present, and appear to be dependent upon the state of contraction of the animal. There is no neck; the anterior part of the body for some distance behind the scolex is rounded, resembling an annelid in form; in the more posterior part the form is thick and flattened, being here elliptical in section. The colour is reddish yellow. The segments, even in the mature part of the animal, are very short; they are deeply constricted off from each other, and as the free margins are directed backward the segments appear to overlap more than they actually do. The only dimensions given by Baird are: "length, about nine inches; greatest breadth of body, about three lines," and although the *Scotia* examples are very much smaller, the proportions agree well. The *Discovery* specimens come much nearer in length to the *Scotia* examples, although there is a very distinct discrepancy as regards width. Shipley reports that most of the *Discovery* examples "were just under 10 cm.," and that "the greatest breadth is 7 mm. in the largest specimen." The longest *Scotia* worm is 13·2 cm., and its greatest breadth is 4·5 mm.; most of the specimens are about 4 mm. in width. Again, as regards scolex dimensions, Shipley gives "3 mm. in length and 3 mm. in breadth posteriorly." In none of the *Scotia* specimens is the greatest breadth equal to the length of the head; they measure from 3 to 3·5 mm. long by 2 mm. wide. The actual differences here, however, are slight.

A general account of the anatomy is given by Shipley (4). He mentions that, besides the two longitudinal canals of the excretory system, "there are also small canals which lie close under the surface at the edges of the proglottides, usually two at each side, but they also break up from time to time into twisting branchlets." These canals appear to be very numerous; from 42 to 45 may be present in a section, while at each lateral margin a group of four can usually be made out.

The testes which occupy the central layer lie mostly towards the dorsal surface. There are from 18 to 20 follicles in a transverse section.

Dibothriocephalus wilsoni, Shipley. (Pl. I. fig. 4.)

This small tapeworm, which SHIPLEY (4) has already referred to as "very attractive" in appearance, was also found by the *Scotia* investigators, although not in the same host. These were obtained in the intestine of Weddell's Seal along with numbers of *Bothriocephalus mobilis*, n. sp. The *Discovery* specimens occurred in Ross's Seal (*Ommatophoca rossi*).

It is a small, semi-translucent, delicate-looking Cestode, not undeserving of SHIPLEY's epithet. The scolex is short and conical in the contracted state, as appears in SHIPLEY's figure. In more extended specimens, however, it is more rounded at the free end, as well as longer. An interesting point is the early appearance of mature segments; the first of these may be but the fifth behind the head. SHIPLEY's dimensions for this species are: length, 4 to 5·5 mm.; greatest breadth, 1 mm.; 9 to 13 proglottides; scolex, ·5 mm. Some of the *Scotia* specimens are quite 10 mm. in length, and have 18 segments; one which measured less than 4 mm. contained 8 segments, none of which were mature, but in 5 of which the outline of the developing uterus and other sex ducts could be traced in a surface view.

The only other point made out with regard to which SHIPLEY's account may be supplemented refers to the dimensions of the ova. His figures are ·042 by ·035 mm., and these he gives as about the average. We find the ova do vary in size, and while we have not struck an average figure, we think that on the whole the dimensions we have to quote are fairly common and typical. These are ·069 by ·037 mm.

The general appearance of this Cestode is given in fig. 4.

Dibothriocephalus mobilis, n. sp. (Pl. II. figs. 7 to 10.)

This is an extremely pretty little Cestode, highly translucent, which was found in the intestine of Weddell's Seal, where it occurred in considerable numbers. It measures from 12 to 20 mm. in length, and is about 2 mm. at its widest part. The scolex is broad at its free end, narrowing towards its junction with the strobila. It measures ·5 mm. in diameter. The suckers are lateral in position, deep and widely gaping the whole length of the scolex, and having extremely mobile lips. They are capable of extension backward, showing in such a case large posteriorly directed flaps. Owing to the extreme mobility of the scolex, it is rather variable in form, although its general appearance remains characteristic (figs. 7 and 8).

No neck is present. The segments are rectangular, at first narrow, being about twice as broad as long, lastly becoming practically square at the posterior end. The number varies from about 16 to 25; they are mature about the 7th or 8th segment. On a surface view the genital pores are seen to lie together close to the anterior border of the proglottis.

The uterine pores are placed for the most part alternately right and left of the middle line in successive segments. The uterus in the immature segments shows three loops to each side; in the mature parts it appears as a rounded mass filled with the shelled ova. The yolk follicles are exceedingly numerous in the mature segments, lying closely over the whole of the inner part of the peripheral layer and visible externally. They form morula-like masses, more or less irregular in shape. In section they are mainly circular, and measure ·052 mm. in diameter. The individual yolk cells are large, measuring when fully grown about ·016 mm.

The ovary consists of a pair of flattened circular masses, which in their maximum development measure ·174 mm. in diameter, connected by a narrow band in the middle. The shelled ova measure ·051 mm. × ·034 mm. They are not operculate.

The testes follicles, which occupy the central area, occur in the planes between those occupied by the yolk follicles. Where the yolk follicles occur the central area is narrowed, and only the extreme ends of the individual testes appear here. The individual cells of the testes are extremely small. The cirrus sac is highly muscular, circular in form ; the short protrusible penis is relatively thick.

The cuticle is remarkably thick, measuring ·014 mm. ; the sub-cuticle consists of fairly large cells of irregular shape, amongst which the small excretory canals occur. These are fairly numerous, viz. between 30 and 40. The rest of the body consists largely of a thin and loosely packed parenchyma.

This form is clearly differentiated from all the other small Bothriocephalids in the laterally placed suckers and distinctive form of the scolex, size and general shape of the proglottides, nature of the yolk follicles, and characteristics of the ova.

We propose for it the name of *Dibothriocephalus mobilis.*

Dibothriocephalus pygoscelis, n. sp. (Pl. II. figs. 11 and 12.)

A small quantity of Cestode material, undated, and labelled, " Adult tapeworms from some species of *Pygoscelis*, probably *P. antarctica* or *P. adelia* ; possibly, though not likely, *P. papua*," was found to consist of a number of extremely brittle fragments of a *Dibothriocephalus*.* Only one or two head pieces could be found, the larger of which measured 29 cm. Fragments up to 21 cm. in length occur in the collection.

The scolex measures 1·8 mm. in length, is of almost uniform breadth, slightly broader at the posterior border, where it measures ·7 mm. in diameter. The suckers are long and shallow, forming a pair of dorso-ventral grooves, extending nearly the whole length of the scolex.

There is a short neck ; the anterior proglottides are markedly flanged, and at least four times as broad as long. In the broadest part of the worm they reach 9 mm. in breadth and about 1·5 mm. in width. The common genital pore can be seen upon the ventral surface as a rather broad crescentic slit, a little way behind the anterior border, while the uterine pore is placed slightly behind in the middle line.

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* This was found by Dr Pirie lying on the snow near the beach at Scotia Bay, South Orkneys, where a number of penguins had been congregated—chiefly *P. antarctica* and *P. adelia*,—January 11, 1904. See *Zoological Log*, p. 95, including footnote.

The following additional points have been made out.

The cuticula and sub-cuticula are well developed. Peripheral excretory canals are numerous. The yolk follicles are very numerous and large. In longitudinal section they appear as closely arranged, long, narrow bands, sometimes spindle-shaped, extending from the sub-cuticula to the longitudinal muscle layer, which is well marked.

The uterus has four or more turns, winding dorsally and ventrally in a spiral manner (fig. 12). The shelled ova vary in size. A common dimension is: length ·073 mm., breadth ·051 mm. But there is a small proportion of long and narrow eggs measuring ·100 mm. by ·041 mm. The eggs are operculate.

The species appears to be unrecorded previously. No *Dibothriocephalus* species have hitherto been described from either Arctic or Antarctic birds. It resembles generally the scolex of *D. quadratus* in form and dimensions, but the proglottides are smaller and the ova dimensions are dissimilar; it resembles *D. cordatus* in the dimensions of the eggs, but disagrees in other features. *D. lanceolatus* is a much smaller form. In general features *D. pygoscelis* resembles *D. romeri*, but is on the whole larger, and again the egg dimensions are greater. In particular, the specially large size of the shelled ova and form of the scolex differentiate it from all other described Arctic or Antarctic species occurring in either birds or Pinnipedia.

We propose to name it *Dibothriocephalus pygoscelis*.

Sub-family PLEUROGONINÆ (Ariola).

Genus *Anchistrocephalus*, Monticelli, 1890.

SYNONYMS.

Tænia, Auctorum.
Bothriocephalus, Rudolphi, 1808.
Dibothrium, Diesing, 1850.
Polyonchobothrium, Diesing, 1850.
Anchistrocephalus, Monticelli, 1890.

Anchistrocephalus microcephalus (Rud.), 1819. (Pl. I. fig. 3.)

This tapeworm was found in very large numbers in the intestine of the Sunfish, *Orthagoriscus mola*, in a mass weighing several pounds, and almost completely blocking the intestine. *O. mola* was captured at Station 107.

It was first described by RUDOLPHI, in 1810, and its occurrence has since been noted and its anatomy described by other investigators. It is a readily recognisable species, and does not appear to have been recorded in any host other than the Sunfish. The scolex has a pair of rather deep, open, thick-margined, square-looking suckers topped by a hemispherical rostellum, the base of which is encircled by several close-set rows of small hooks (fig. 3 (*a*)).

The genital pores are marginal in position (fig. 3 (*b*)).

The appearance of the scolex varies with the state of contraction, and the rostellum may be retracted so as to be concealed below the anterior margins of the suckers, and thus appear to be absent. Similarly, the anterior proglottides, which in the extended condition are rather long, with thick, overlapping posterior margins (described by ARIOLA as "campanulate"), in the contracted condition become rectangular, short, and relatively very broad. The maximum size occurring in the *Scotia* specimens is 40 cm. by 5·5 mm., which is considerably less than that given by ARIOLA, viz. 66 cm. by 7·5 mm. This, which appears surprising in view of the large number of examples in the collections, is probably due to breakages. The specimens occurred very closely matted together, and there are numerous fragments without scolices. ARIOLA (1) has given a summary of the chief features of this species.

The following additional points have been made out in transverse sections.

The longitudinal nerve cords, which are large and well defined, are situated about one-fifth of the transverse diameter from the margin, external to the longitudinal excretory canals.

The central excretory canals are six in number, three each, right and left of the middle line.

Order CYCLOPHYLLIDEA, van Ben.

Family TÆNIIDÆ, Ludw.

Hymenolepis, sp. (?).

The Cestode here described was found in the intestine of the Ringed Penguin, *Pygoscelis antarctica*—locality, South Orkneys. It occurred in groups of from four to twelve, having their heads within a small swelling upon the intestine of about the size of a pea. The swelling, which had brownish granular contents, projected upon the outer side of the intestine. The heads appeared, as far as could be made out, to lie freely in the cavity formed by the swelling or cyst. This opened to the intestinal cavity by a very narrow aperture through which the closely grouped necks of the worms passed.

The "heads" are of very irregular and variable form. This anterior region is best described as a "pseudo-scolex." The "neck" is very long, and in most cases is at one part enlarged in a long oval form. The segmented portion is nearly cylindrical—not flattened—and, apart from colour, has quite an annelid appearance. The following measurements were made :—

Length of "neck," 6–12 mm.
Width of "neck" at broadest part, ·93 mm. to 1·13 mm.
Length of segmented region, about 1 cm.
Number of segments, about 40.
Diameter of broadest segment, 1·21 mm.

As already stated, the "heads" are very irregular in form. In the neck region calcareous corpuscles are very numerous.

The oldest proglottides are sexually immature. Only the testes are developed; they lie in the middle layer, occupying the area between the excretory vessels. There are from 16 to 19 follicles in a cross-section through their region of greatest development. The follicles are oval in section and measure from ·019 mm. to ·038 mm. along their longer axis.

Calcareous corpuscles are extremely abundant, especially in the cortical area; they are oval or circular in form, and measure from ·0063 mm. to ·0095 mm.

There is a pair of longitudinal excretory vessels on each side, placed dorsal and ventral, but quite near to each other; only the larger pair appears to be connected by transverse vessels. Both pairs have thick walls.

The longitudinal nerve cords, which lie outside but near to the excretory canals, are very ill-defined.

The question whether this type is normal is somewhat difficult to determine. The ill-defined nature of the scolex region is rather against such a view. Megnin (quoted by Braun) considers that the pseudo-scolex condition is characteristic of the very old stages of worms, but in the present case the worms are immature. Again, this condition may be a case of retarded development. This is not altogether impossible, in view of the marked pathological condition set up in the intestine at the point of attachment, and the occurrence of the parasites in groups within a single cyst, both of which conditions are unusual in other cases of Cestode fixation. On the other hand, their occurrence in this way in several different specimens suggests that the features described are usual with this species.

What positive structural data are available are not sufficient to permit of exact classification, but the type may provisionally be placed near the genus *Hymenolepis* on account of the shape of the segments, the character of the neck, and the limited number of the testes.

Order TETRAPHYLLIDEA, Carus.

Family Phyllobothriidæ, Braun.

Phyllobothrium, sp. (Pl. II. figs. 3 and 4.)

From the areolar tissue under the blubber of Weddell's Seal there were found on two occasions examples of a bladder-worm whose features, especially those of the scolex, are characteristic of the genus *Phyllobothrium*. One of the specimens is incomplete.

The complete specimen consists of a scolex having four much-plaited or folded bothria. Accessory suckers are absent. Behind the scolex is a neck piece slightly flattened, 17 mm. long and about 2 mm. broad. Behind the neck is a long oval bladder, creased or wrinkled upon the surface, thick-walled and hollow, with terminal pore or slightly inverted posterior end. The bladder measures 32 mm. in length, and at its widest part is 10 mm. in diameter.

The incomplete specimen is of interest in so far as it shows a portion of the neck invaginated within the bladder. Since this is the condition in which cysticerci usually occur in the tissues of their host, the existence of another specimen in the fully extended condition in such a situation is worthy of special note.

The presence of these larval Cestodes in the subcutaneous tissue of an animal such as Weddell's Seal is of particular interest. The hosts of adult *Phyllobothria* are, as far as known, mostly Selachians.

With regard to the question as to the probable host of the adult worm, Dr Bruce has made the interesting suggestion that this may be the Grampus. He informs me that *Stenorhynchus leptonyx* and *Lobodon carcinophaga* are frequently seen with large gashes upon their sides, which he is of opinion may be due to the attacks of a Grampus (*Orca*, sp. ?). He considers it likely that Weddell's Seal is liable to similar attacks, and in fact that the whole seal may at times be eaten. The following birds are fond of blubber, and devour the carcases of seals, viz. the Giant Petrel (*Ossifraga gigantea*), Sheathbill (*Chinois alba*), and Skuas (*Magalestris MacCormicki* and *M. antarctica*). Such habits render them liable to infection with the bladder-worm in question, and it is possible that the normal host of the adult occurs amongst these.

Order TETRARHYNCHA, v. Ben.

Family Tetrarhynchidæ.

Tetrarhynchus, sp. (Pl. II. figs. 15 to 18.)

From the muscles of the Bonito (*Thynnus pelamys* Linn.) caught at Station 31, a small number of cysticercoids of a *Tetrarhynchus*-like organism were found. These were not enclosed in a bladder, but lay quite free in the muscles, the proboscides being in a number of instances partially extruded. They were not in any instance fully extended.

The specimens measure about 6 mm. in length and 1½ to 1¾ mm. in width. There is a thick, firm, slightly wrinkled, glistening cuticle upon the exterior. A distinctive feature is the entire absence of suckers at the anterior end. There are four slender retractile proboscides bearing about sixteen longitudinal rows of closely set, recurved hooks. The proboscides are connected with four well-developed muscular bulbs, such as are characteristic of this group.

At the posterior end there is a small spherical bulb which is retractile within a cavity. In most examples the bulb is within, but in one or two instances it occurred exserted, the body of the cysticercoid being constricted closely around its base (fig. 15).

Transverse sections of the bulb show it to contain a deeply staining connective tissue in which there is a transverse row of ten or twelve excretory canals (fig. 18). These merge in each other, converging to a terminal pore. Longitudinal sections show the branches of the canals to be very numerous.

The body of the cysticercoid consists of a peripheral and a central portion. The former is limited by a well-defined, thick cuticle, contains numerous excretory vessels (about 60 in transverse section) and a loose parenchyma. The central region contains the muscular bulbs of the proboscides, and around these a well-developed mass of longitudinal muscles (fig. 16). The central area at its posterior end merges into the protrusible bulb (fig. 17).

The question of the more exact identification of the species to which the form belongs must be left undecided.

G. R. Wagener (5) has described a similar form from *Phycis mediterranea.*

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(3) von Linstow, *Jahrb. Hamb. Wissensch. Anst.*, ix. Jahrg., 1891.

(4) Shipley, A. E., *National Antarctic Expedition Reports,* 1907, "Cestoda," vol. iii.

(5) Wagener, G. R., *Verhdlgn.* (*Nov. Act.*) *d. K. Leop-Carol. Acad. d. Naturf.*, Bd. xxiv., Suppl., Breslau, 1854.

(6) Zschokke, *Fauna Arctica,* "Die Arktischen Cestoden," Bd. iii., Lieferung i., 1903.

REFERENCES TO FIGURES.

c. = cuticula.
c.s. = cirrus sac.
exc.c. = excretory canals.
exc.b. = excretory bulb.
l.m. = longitudinal musculature.
n.c. = nerve cord.
o. = ovary.
per.a. = peripheral area.
r.m. = retractor muscles of proboscides.
s.c. = sub-cuticula.
sh.ov. = shelled ova.
t.f. = testes follicles.
ut. = uterus.
v. = vagina.
y.c. = yolk cells.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. Transverse section of *Dibothriocephalus scoticus,* n. sp., at the level of the ovary.

Fig. 2. (*a*) Entire specimen of *D. scoticus*; (*b*) scolex of *D. scoticus.*

Fig. 3. (*a*) Anterior end of *Anchistrocephalus microcephalus*; (*b*) immature proglottis of *Anchistrocephalus microcephalus.*

Fig. 4. Four specimens of *Dibothriocephalus wilsoni,* Shipley.

Fig. 5. Scolex of *Dibothriocephalus coatsi,* n. sp.

Fig. 6. Transverse section of *D. coatsi.*

PLATE II.

Fig. 7. Entire specimen of *Dibothriocephalus mobilis*, n. sp.

Fig. 8. Scolices of *D. mobilis*, n. sp.

Fig. 9. Transverse section of proglottis of *D. mobilis*.

Fig. 10. „ „ through uterus and cirrus sac of *D. mobilis*.

Fig. 11. Proglottis of *Dibothriocephalus pygoscelis*, n. sp.

Fig. 12. Diagrammatic longitudinal section of proglottides of *D. pygoscelis*, showing position of sex openings and uterine coils.

Fig. 13. Metacestode of *Phyllobothrium* sp., from blubber of Weddell's Seal.

Fig. 14. Scolex of *Phyllobothrium* sp.

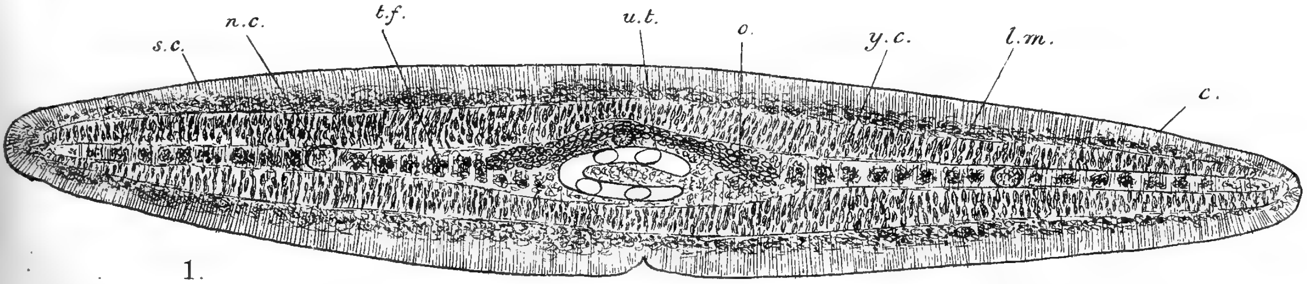
Fig. 15. Larval *Tetrarhynchus* from the muscles of the Bonito.

Fig. 16. Transverse section of larval *Tetrarhynchus* through retractor muscles of proboscides.

Fig. 17. Diagram of posterior end of larval *Tetrarhynchus* showing excretory bulb retracted.

Fig. 18. Transverse section of larval *Tetrarhynchus* through retracted bulb, showing row of excretory vessels.

RENNIE AND REID: "SCOTIA" CESTODA—PLATE I.



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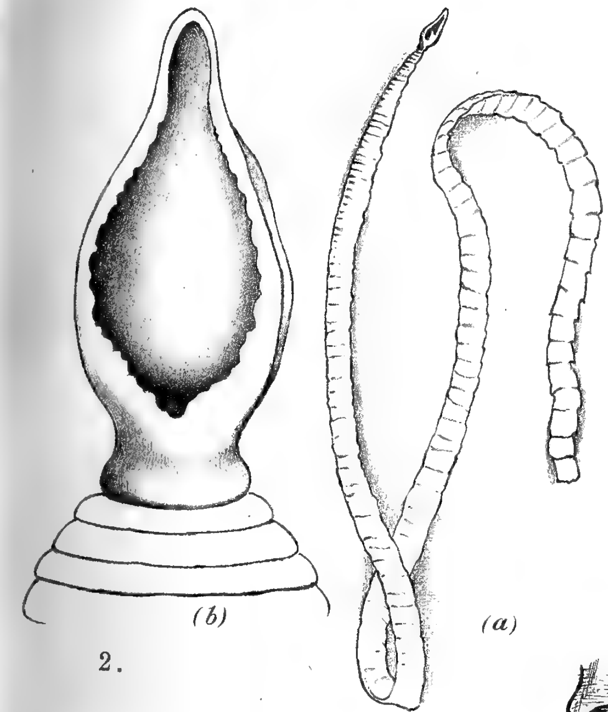

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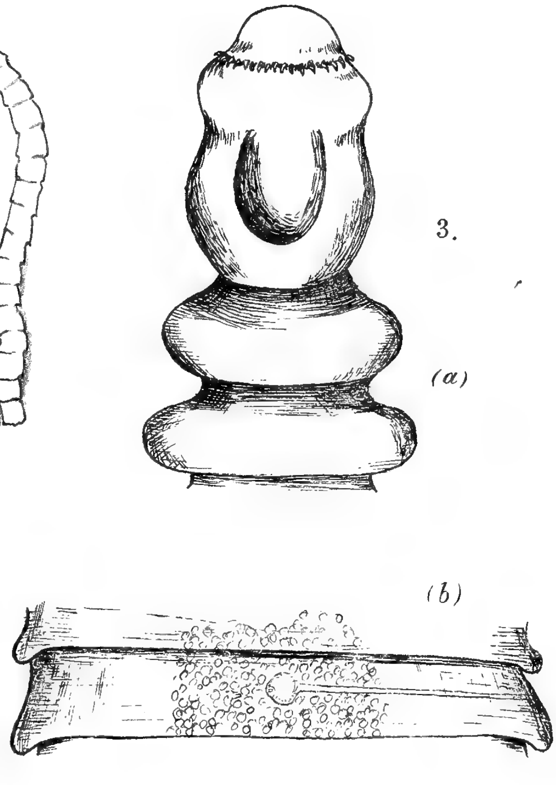

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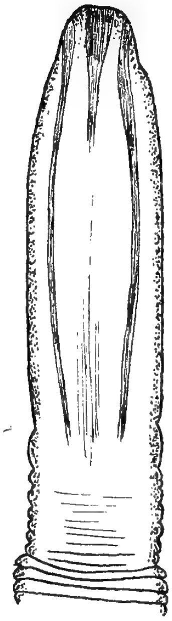

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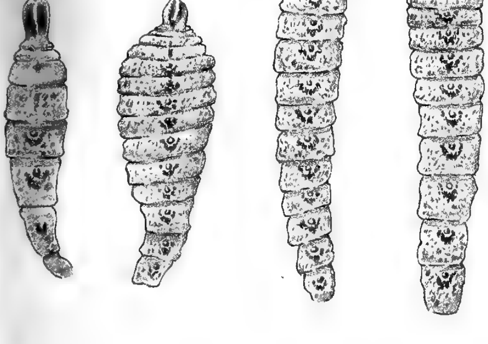

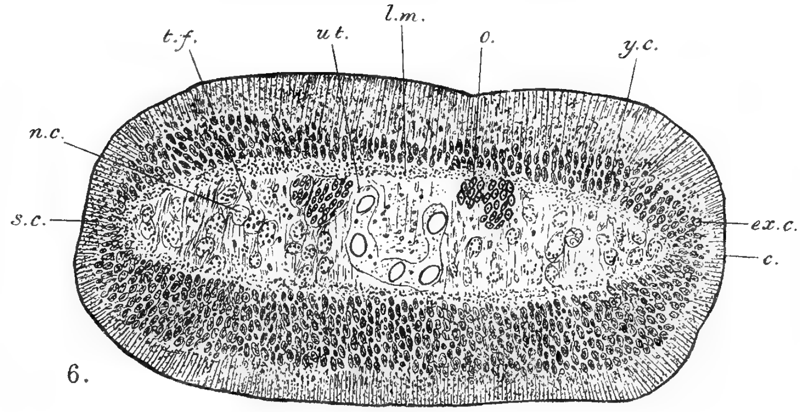

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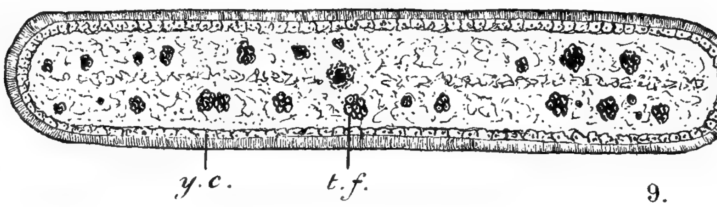
BRITISH MUSEUM NATURAL HISTORY

RENNIE AND REID: "SCOTIA" CESTODA—PLATE II.



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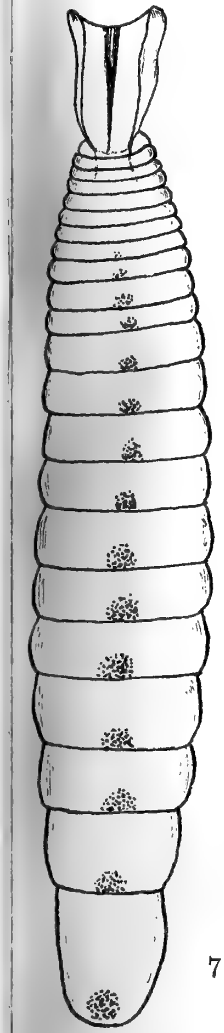

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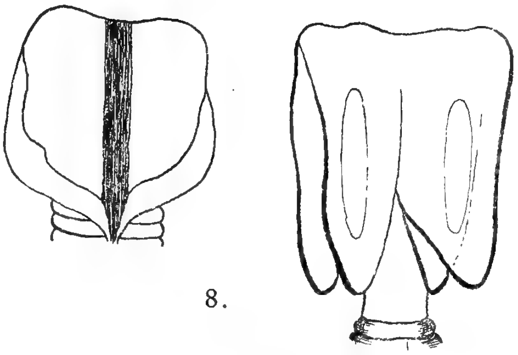

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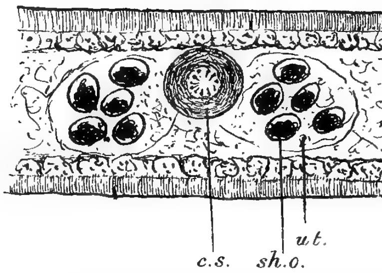

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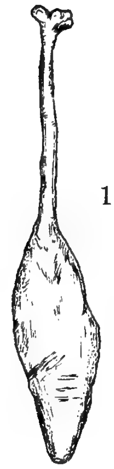

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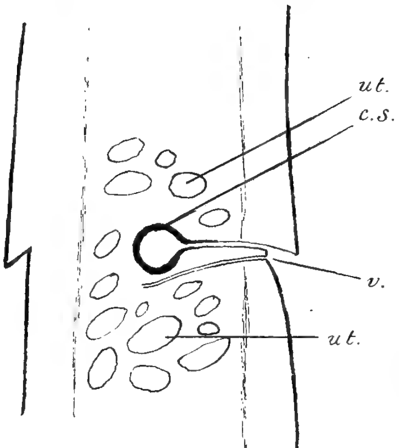

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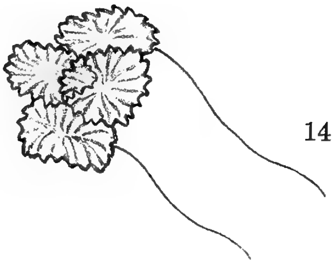

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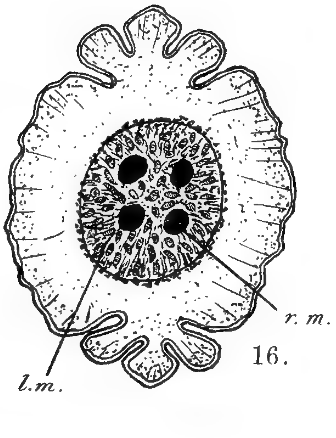

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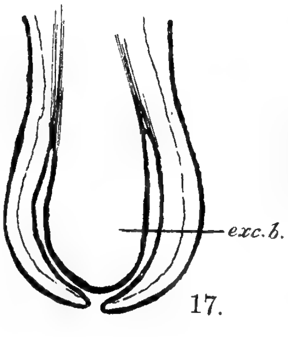

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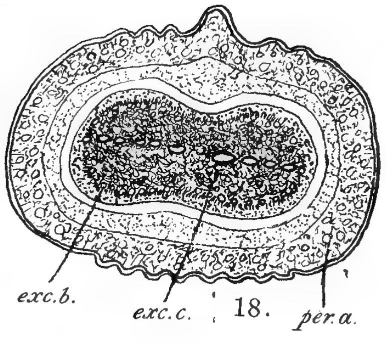

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XXIII.—The Amphipoda of the Scottish National Antarctic Expedition.

By **Chas. Chilton**, M.A., D.Sc. (N.Z.), M.B., C.M. (Edin.), Hon. LL.D. (Aberd.), F.L.S.; Professor of Biology, Canterbury College, New Zealand. *Communicated by* Dr W. S. Bruce. (With Two Plates.)

(MS. received March 30, 1912. Read June 17, 1912. Issued separately September 21, 1912.)

CONTENTS.

I. INTRODUCTION.

Shortly after my arrival in Britain in December 1911 I was honoured by a request from Dr W. S. Bruce, leader of the Scottish National Antarctic Expedition, that I would prepare a report on the Amphipoda collected during the voyage of the *Scotia*. Dr E. J. Allen, Director of the Marine Laboratory, Plymouth, very kindly offered me accommodation in the laboratory for the work, and free access to the library of the laboratory, which, fortunately, is very well supplied with works on the Crustacea. I was assured also of assistance from Mr T. V. Hodgson, the Curator of the Museum and Art Gallery, Plymouth, from Mrs E. W. Sexton, and from other friends; and accordingly I undertook the work. I received the main portion of the collection, contained in sixty-three bottles, on the 8th January 1912, and a few days later I received from Dr W. M. Tattersall of the Manchester Museum eighteen tubes containing additional Amphipoda found among the Schizopoda of the Scottish National Expedition which had been submitted to him for determination; these additional specimens contained three or four species not represented in the collection first received.

Twelve tubes of additional specimens from Dr Tattersall and many further specimens from the *Scotia* collection reached me in May. These consisted chiefly of duplicates of species previously sent, but contained also two species not previously seen. Some additions to the report, which had been sent in at the end of March, were therefore necessary.

With very few exceptions, the Amphipoda proved to have been particularly well preserved, and the localities, depth, and other particulars had been in all cases carefully recorded. I have given full details of these, even at the risk of some slight repetition, as they may prove to be of use in helping to decide questions now unforeseen that may afterwards arise. In several cases, especially among the Lysianassidæ, large numbers of specimens of various sizes had been collected from each locality, and these complete sets have been of very great use in helping me to ascertain the changes that take place in some species during the growth of the animal, and in determining the differences between the sexes. I regret that the time at my disposal has been too short to allow of the complete examination of these series of specimens.

By far the greater part of the collection was made at the South Orkney Islands, mainly at Scotia Bay, Station 325, lat. 60° 43′ S., long. 44° 38′ W., the winter quarters of the *Scotia*. This appears to be a good collecting-ground for Amphipoda, particularly, of course, for the Lysianassidæ, and the forms obtained from this locality are extremely useful for comparison on the one hand with those obtained in 1882–83 by the German Transit of Venus Expedition from South Georgia, and on the other hand with the specimens collected by the French Antarctic Expedition from Port Charcot, Wandel Island, and other neighbouring localities. A few specimens were obtained from stations further south, at localities intermediate between Kerguelen Island and those already mentioned. Besides these, a small number of species was gathered at Gough Island, a locality from which very few Amphipoda had hitherto been described; others at the Falkland Islands; and some were obtained at Cape Town and Saldanha Bay in South Africa, and help to show the relation of the Amphipoda of South Africa to those of the various sub-Antarctic lands.

A few species were collected in the northern and tropical parts of the Atlantic on the voyage out and on the homeward voyage. As the greater part of the collection is from Antarctic and sub-Antarctic regions, I have kept these Atlantic species in a list by themselves, distinct from those gathered in the sub-Antarctic localities, under which I include Gough Island and South Africa.

As I was able to consult the reports on the Amphipoda of some of the Antarctic Expeditions, and already had some acquaintance with several of the sub-Antarctic species, it seemed a favourable opportunity for endeavouring to compare the results as far as possible, and to determine cases where the same species had been described under different names by different authors. In this effort I have been greatly assisted by the kindness of many friends. Dr G. PFEFFER and Dr O. STEINHAUS of the Hamburg Museum very kindly placed at my disposal everything that I needed from the collections made at South Georgia by the German Expedition in 1882–83, and described by Dr PFEFFER in 1888; Monsieur EDOUARD CHEVREUX has sent me co-types of several of his species; from Mr A. O. WALKER and from the British Museum I have had co-types of many of the species obtained by the *Southern Cross* and *Discovery* Expeditions, and described by Mr WALKER; while the Rev. T. R. R. STEBBING and the authorities of the Vienna Museum have supplied still other specimens that have been extremely useful for comparison. Later on, when most of the work was completed, I was able, through the kindness of Dr W. T. CALMAN, to check my results by comparison with types and other specimens in the British Museum. At the same time, I have been able to see the Amphipoda collected by Sir E. SHACKLETON's British Antarctic Expedition in 1908–09, which had been placed in Mr HODGSON's hands; and in several cases I have been able to compare the *Scotia* specimens with New Zealand specimens that I had brought with me to England. To all those who have assisted me in these various ways I desire here to record my most grateful thanks.

It is a pleasure also to mention here my indebtedness to those who have assisted in other ways. I wish particularly to thank Dr E. J. ALLEN of the Marine Laboratory, Plymouth, for allowing me to make such free use of the facilities offered by the institution under his charge; without his assistance it would have been impossible to do the work in the time. Dr W. T. CALMAN of the British Museum, besides sending me co-types of species I required, has assisted me in the examination of others at the Museum itself and by his advice on many difficult points. Professor WOLTERECK of Leipzig and Dr A. BEHNING of the Zoological Station at Saratov have most obligingly communicated to me some of the results of their examination of the Amphipoda of the German South Polar and other Expeditions, which are as yet unpublished, though in the printer's hands. To Mrs E. W. SEXTON I am indebted for the loan of many papers and books that I required, for the keen interest which she has shown in the work during its progress, and for the great care and skill with which she has prepared the drawings of most of the figures for this paper.

In order to make clear the various references that will be given below, it may be well to state very briefly the growth of our knowledge of the Antarctic and sub-Antarctic Amphipoda. That knowledge dates back to the years 1839–40, when three expeditions—the British, French, and American—visited Antarctic seas. The British leader, Sir JAMES CLARKE ROSS, penetrated very far south in his memorable voyage, and during the expedition several Crustacea were collected, including some Amphipoda. No special report on these Amphipoda was published, but they appear to have been deposited in the British Museum, and several of them were afterwards described by SPENCE BATE and other writers. The Crustacea collected by the American Expedition were described by J. D. DANA in his well-known work, which forms one of the fundamental treatises for the study of the Crustacea. In it many Amphipoda are included. For many years after 1840 no further advance was made, and there is nothing noteworthy to be recorded until 1874, when several expeditions were sent out to southern seas for the observation of the Transit of Venus, and during these expeditions various collections were made. The Amphipoda of the British Expedition from Kerguelen Island were described by E. J. MIERS, and others collected by the American Expedition by S. I. SMITH. The French Expedition spent some time at the Campbell Island, and the Crustacea collected were afterwards described by HENRI FILHOL in the *Mission de l'Ile Campbell*, in which he also included a general list of the Crustacea of New Zealand. This report was not published till the year 1885, and in the meantime a beginning had been made with the study of the Crustacea of Australia and New Zealand by Professor W. A. HASWELL and Mr G. M. THOMSON respectively. During the years 1873 to 1876 the *Challenger* Expedition had made numerous collections in sub-Antarctic and a few in Antarctic seas, and these were most fully described and figured by the Rev. T. R. R. STEBBING in his elaborate report published in 1888. In the same year, but at a slightly earlier date, there was published a report by Dr G. PFEFFER on the Amphipoda collected at South Georgia by the German Transit of Venus Expedition of

1882–83. For some time after this no further contribution of any importance was made specially dealing with Antarctic Amphipoda, though those of some of the sub-Antarctic regions were gradually becoming better known. The next contribution to our knowledge of the Antarctic forms was made by the *Southern Cross* Expedition, which visited South Victoria Land in 1898–1900; the Amphipoda collected by this expedition were described by Mr A. O. WALKER in 1903.

Meanwhile, the Antarctic Expeditions of Britain, Germany, Sweden, and France had been wintering in the Antarctic and making numerous collections. The Amphipoda of the French Antarctic Expedition were described by Monsieur EDOUARD CHEVREUX in 1906, and those of the British by Mr A. O. WALKER in 1907. The reports on the German and Swedish Expeditions have not yet been published.

In 1907 a small scientific party from New Zealand visited the sub-Antarctic Islands lying to the south of that land, and the Crustacea collected were described by myself in 1909 in *The Sub-Antarctic Islands of New Zealand*, published by the Philosophical Institute of Canterbury.

A preliminary report on the Amphipoda of the recent French Expedition in the *Pourquoi Pas?* was published by M. CHEVREUX in 1911.*

From the lists given below it will be seen that the *Scotia* collection contained fifty-six species from Antarctic or sub-Antarctic seas and six Atlantic species. The great majority of these were already known, and I have made only nine new species and no new genus. This appears to show that the Amphipoda of the southern seas are becoming fairly well known so far as the mere identification of species is concerned, though there is much to be done in tracing out more completely the distribution of the species and any local varieties that they may present.

On the other hand, it may be noted from his preliminary report on the Amphipoda of the *Pourquoi Pas?* Expedition that M. CHEVREUX has established six new genera and numerous new species.

It will be seen that I have reduced a number of species to the rank of synonyms. I have done this only where there appeared to be good grounds for so doing, and in all cases where there is likelihood of a difference of opinion I have endeavoured to give my reasons in full. In thus reducing the number of described species, I have only continued a necessary work that has been commenced in recent years by other writers. In the earlier days of the study of the Amphipoda, when workers were few and collections scanty, it frequently happened that a collection from a new locality contained many new species. In numerous instances these were described on very meagre material, often from a single specimen; and even when there was an abundant supply of specimens time did not allow of the dissection of more than one or two, hence there

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* M. CHEVREUX's second paper (*Bull. Muséum Nat. Hist.*, 1912, No. 4), containing the diagnoses of the new species collected by this expedition, reached me when the final proofs of my paper had been corrected, and therefore too late for the results to be noticed here, though it is probable that one or two of the new species described below are identical with those established by M. CHEVREUX.

was little opportunity of distinguishing between characters subject to individual variation and those really common to the species. Consequently, when other specimens were obtained it was frequently found that they did not agree in all particulars with any of the species already described, and they were naturally considered to be new and were given a distinctive name. This practice was perhaps the safest at the time, and it was the more desirable when the specimens came from a new locality; but it unfortunately led to the idea that forms from fresh localities were almost necessarily new, and that the distribution of nearly all the species of Amphipoda was very limited. It also led to the introduction of long specific diagnoses, often containing characters of individual importance only. Naturally enough, specimens afterwards examined did not agree in all respects with these detailed descriptions, and thus a vicious circle was set up, leading to the continued establishment of new species, some of them being admittedly described in self-defence, and the fact that many species were widely distributed was long obscured.

As knowledge gradually increased it was found that in many cases the same species had been described under various names, and the preparation of a general survey of the whole group, such as that for *Das Tierreich*, necessarily led to a considerable reduction of species. From the example of a few species which were readily recognised, and hence known to occur at places widely remote from one another, it was found that some species at any rate were more widely distributed than had been originally supposed. Much assistance in clearing up difficulties was obtained from the detailed study by various authors of individual species and the consequent elucidation of the various forms that occur in some species and especially of the differences between the sexes and of the changes that take place during growth; and it is to further work of this kind that we must look for assistance in defining the limits of the different species.

Several of the species—or groups that I refer to under one specific name—are widely distributed in sub-Antarctic seas, and, as might be expected, the specimens from different localities now separate from one another are not always precisely the same, but show what may be considered local varieties. Some authors would doubtless prefer to call these local varieties species and give each a distinctive name; but this must necessarily lead to an indefinite multiplication of species, with ever-increasing difficulty of determining those already established, and as a matter of practical convenience it seems to me to be better at present to endeavour to recognise these widely distributed species and to leave the determination of their varieties until a larger number of forms from many localities have been studied.

In the list below I have indicated briefly the distribution of each species. From this it will be seen that an increasing number are now known to extend around the globe in sub-Antarctic seas, and that there is a greater resemblance between the Amphipodan faunas of South America, New Zealand, Australia, Kerguelen Island, and even South Africa, than appeared to be the case a few years ago. The importance of the facts on the question of the cause of this distribution cannot be discussed here. Another point made clear is that the number of species in northern seas represented by the same or by a closely allied form in the southern is also shown to be increased. Leaving out of account the species known to be cosmopolitan, it has been long known that there were some species identical in Arctic and Antarctic seas, though practically unknown in the tropics; nearly every writer on Antarctic Amphipoda has identified one or more with northern species. It appears from examples like *Orchomenopsis chilensis* (Heller), and others that might be quoted, that in these examples of "bi-polar" species the species is not always entirely absent from the tropics, but exists there in deeper waters, while it can live near the surface in the colder regions; or that the tropical or temperate form is so much smaller than the polar one that it has usually been considered a separate species, and the existence of the species at intermediate localities has been overlooked. It appears that, for some reasons not altogether understood, many Amphipoda find their optimum environment near the Arctic and Antarctic regions, and exist there in greatest abundance, attaining a size far greater than that usual for similar forms in warmer seas. The difficulty of deciding whether these smaller forms are to be considered separate species or not is very great, and it must not be expected in the present state of our knowledge that logically uniform results can be arrived at. In some cases where the animal is abundant and specimens from many localities have been examined, we may be able to group them into one large species, while in other cases where only a few have been studied we are forced to leave them as separate small species. Unfortunately, this leaves the groups distinguished by specific names of very unequal value in the discussion of questions of distribution.

II. List of Species.

ANTARCTIC AND SUB-ANTARCTIC.

Name of Species.	Distribution and Remarks.
1. *Acontiostoma marionis* Stebbing.	Gough Island, Marion Island, Straits of Magellan, New Zealand.
2. *Amaryllis macrophthalma* Haswell.	Australia, South Africa, South America, New Zealand, Indian Ocean.
3. *Cyphocaris anonyx* Boeck.	Widely distributed in both northern and southern seas.
4. *Lysianassa cubensis* (Stebbing).	South Africa and Gulf of Mexico.
5. *Alicella scotiæ*, sp. nov.	South Atlantic; an allied species found in the North Atlantic.
6. *Cheirimedon femoratus* (Pfeffer).	South Orkneys, South Georgia, and Graham Land (Port Charcot).
7. *Tryphosa murrayi* Walker.	Off Coats Land and South Victoria Land.
8. *Tryphosites stebbingi* (Walker).	Off Coats Land and South Victoria Land.
9. *Orchomenella pinguides* Walker.	South Orkneys and South Victoria Land.
10. *Orchomenella macronyx* Chevreux.	South Orkneys and Graham Land (Port Charcot).
11. *Waldeckia zschauii* (Pfeffer).	Off Coats Land, Graham Land, and South Victoria Land.
12. *Orchomenopsis nodimanus* Walker.	South Orkneys and South Victoria Land.
13. *Orchomenopsis chilensis* (Heller).	In all seas, northern and southern.
14. *Orchomenopsis* (?) *coatsi*, sp. nov.	Off Coats Land.
15. *Harpinia obtusifrons* Stebbing.	Widely distributed in Antarctic and sub-Antarctic seas.
16. *Leucothoe spinicarpa* (Abildgaard).	In all seas.
17. *Amphilochus squamosus* G. M. Thomson.	South Orkneys, Marion Island, and New Zealand. Perhaps identical with *A. neapolitanus* of northern seas.

Name of Species.	Distribution and Remarks.
18. *Metopoides sarsii* (Pfeffer).	South Orkneys, South Georgia, and Graham Land (Port Charcot).
19. *Metopella ovata* (Stebbing).	South Orkneys, Straits of Magellan.
20. *Thaumatelson walkeri*, sp. nov.	South Orkneys. An allied species at South Victoria Land.
21. *Thaumatelson inermis*, sp. nov.	South Orkneys.
22. *Thaumatelson herdmani* Walker.	South Orkneys and South Victoria Land.
23. *Bircenna crassipes* (Chevreux).	South Orkneys and Graham Land (Port Charcot). A closely allied species occurs in New Zealand.
24. *Colomastix brazieri* Haswell.	South Orkneys and Australia.
25. *Liljeborgia dubia* (Haswell).	Widely distributed in southern seas.
26. *Epimeria macrodonta* Walker.	Off Coats Land and South Victoria Land.
27. *Pariphimedia integricauda* Chevreux.	South Orkneys and Graham Land (Wandel Island).
28. *Acanthonotozoma australis*, sp. nov.	Only one specimen known, from lat. 71° 22′ S., long. 16° 34′ W.; a deep-sea species (1410 fathoms).
29. *Leptamphopus novæ-zealandiæ* (G. M. Thomson).	Widely distributed in southern seas.
30. *Haliragoides australis*, sp. nov.	South Orkneys. A closely allied species in northern seas.
31. *Eusirus antarcticus* G. M. Thomson.	In all Antarctic seas. Perhaps identical with the northern *E. propinquus*.
32. *Eusirus splendidus*, sp. nov.	South Orkneys. Perhaps only a form of the preceding species.
33. *Eurymera monticulosa* Pfeffer.	South Orkneys, South Georgia, and Graham Land (Wandel Island).
34. *Bovallia monoculoides* (Haswell).	In all southern seas.
35. *Pontogeneia danai* (G. M. Thomson).	Falkland Islands, Australia, New Zealand.
36. *Pontogeneia antarctica* Chevreux.	South Orkneys, Graham Land, and the sub-Antarctic Islands of New Zealand.
37. *Atyloides magellanica* (Stebbing).	In all sub-Antarctic seas.
38. *Atyloides serraticauda* Stebbing.	In all sub-Antarctic seas.
39. *Atyloides calceolata*, sp. nov.	South Orkneys. Closely related to the preceding species.
40. *Paramœra austrina* (Bate).	A very abundant and variable species in sub-Antarctic and Antarctic seas.
41. *Djerboa furcipes* Chevreux.	South Orkneys and Graham Land.
42. *Paraceradocus miersii* (Pfeffer).	South Orkneys, South Georgia, and Graham Land.
43. *Mæra mastersii* (Haswell).	Widely distributed in the warmer southern seas.
44 *Paradexamine pacifica* (G. M. Thomson).	South Orkneys, Graham Land, and New Zealand.
45. *Polycheria antarctica* (Stebbing).	In all southern seas, and extending far to the north in the Indian and Pacific Oceans.
46. *Nototropis homochir* (Haswell).	Australia and South Africa. Closely allied to northern species.
47. *Talorchestia scutigerula* (Dana).	Falkland Islands and Tierra del Fuego.
48. *Hyale grandicornis* (Kröyer).	Gough Island and Chili. A closely allied species in New Zealand.
49. *Hyale saldanha*, sp. nov.	South Africa.
50. *Haplocheira barbimana* (G. M. Thomson).	In all southern seas.
51. (?) *Eurystheus afer* (Stebbing).	Gough Island, South Africa.
52. *Jassa falcata* (Montagu).	Widely distributed in northern and southern seas.
53. *Caprella æquilibra* Say.	South Africa. Very widely distributed.
54. *Hyperia gaudichaudii* Milne Edwards.	Falkland Islands, South Victoria Land.
55. *Vibilia antarctica* Stebbing.	In all southern seas.
56. *Euthemisto thomsoni* Stebbing.	In all southern seas.*

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* The following additional species has been identified by the Rev. T. R. R. Stebbing from material sent to him:—
Lanceola æstiva Stebbing, 1888, p. 1309, pl. cliii.; from Station 421.

NORTHERN AND TROPICAL ATLANTIC.

Name of Species.	Distribution and Remarks.
1. *Synopia schéeleana* Bovallius.	Pacific and Atlantic Oceans.
2. *Hyale grimaldii* Chevreux.	North Atlantic.
3. *Allorchestes plumicornis* (Heller).	Mediterranean and North Atlantic.
4. *Sunamphitoe pelagica* (Milne Edwards).	North Atlantic.
5. *Anchylomera blossevillii* Milne Edwards.	Tropical Atlantic.
6. *Oxycephalus clausi* Bovallius.	Tropical Atlantic and (?) Pacific.

III. Antarctic and sub-Antarctic Species.

Genus Acontiostoma Stebbing, 1888.

Acontiostoma marionis Stebbing.

1. *Acontiostoma marionis* Stebbing, 1888, p. 709, pl. xxx.*
,, ,, ,, 1906, p. 15, fig. 4.
,, *magellanicum* Stebbing, 1888, p. 714, pl. xxxi.
,, ,, ,, 1906, p. 15.

Station 461, Gough Island; 100 fathoms. 23rd April 1904. One specimen, 7 mm. long, 5 mm. high.

This specimen agrees well with the description and figures given by Stebbing. As I have only the single specimen, I have not dissected it, but the maxillipeds can be seen to agree with his description, while the shape of the third uropod and of the telson with its fringe of stout spines leaves no doubt as to the identity of the species.

A. magellanicum Stebbing is, as Mr Stebbing has pointed out, almost certainly the young of this species, which is now therefore known from Marion Island, Gough Island, and Straits of Magellan.

Among the Amphipoda that I brought with me from New Zealand for examination I have a slide from Mr G. M. Thomson's collection that undoubtedly belongs to this genus, and is, I think, not specifically distinct from *A. marionis.* It has the upper antennæ and the first gnathopod rather stouter than is shown in Mr Stebbing's figure; but the peculiar second gnathopod, with the finger sunk in a little cavity at the end of the propod, and the uropoda and telson, agree very closely with the *Challenger* specimen. In some points it approaches rather nearer to *A. magellanicum,* and tends to confirm the view that that species is only the young of *A. marionis.*

This slide was mounted by Mr Thomson from one of a very small number of specimens collected in Lyttelton Harbour by myself about the year 1884, and handed to him in 1895 when I left New Zealand for a lengthy period. When living, the animals, which were all of very small size, were bright red in colour. I had dissected and mounted a slide of one of the other specimens about that date, and I have a drawing

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* The references are made by the year of publication to the works given in the Bibliography on pp. 517 and 518. I have given only those references that appeared to be necessary for the purpose of the present paper.

made at the time of the second gnathopod which closely corresponds with that given by STEBBING of the *Challenger* specimen.

Since this was written I have been able to compare Mr THOMSON's slide with those of the *Challenger* specimens in the British Museum. The *Challenger* specimen of *A. marionis* is considerably larger than the New Zealand specimen, and, as stated above, has the first gnathopod more slender; but the differences are not, I think, of specific importance. The dissected parts of the small specimen of *A. magellanicum* are now so transparent that they are difficult to examine, but so far as they can be made out they seem to agree generally with *A. marionis.*

A. pepinii Stebbing, obtained by the *Challenger* at Kerguelen Island, was placed by Mr STEBBING in a new genus, *Stomacontion,* in 1899, and *A. kergueleni* Stebbing made a synonym of *A. pepinii.*

It seems, however, to be too near to *A. marionis* to be separated generically. Unfortunately, the very minute mouth parts do not show very clearly in Mr THOMSON's prepared slide, and I cannot make out whether the first maxilla in it has the palp one- or two-jointed; but the palp of the maxillipeds certainly seems to have the fourth joint quite vestigial or absent, as described for *Stomacontion*; in *Acontiostoma* it is "very small." There seems to me to be no essential difference between the two genera in the third uropods.

Genus AMARYLLIS Haswell, 1880.

Amaryllis macrophthalma Haswell.

Amaryllis macrophthalmus and *A. brevicornis* Haswell, 1880A, p. 253, pl. viii. fig. 3, and p. 254.
,, *macrophthalma* Stebbing, 1888, p. 707, pl. xxix.
,, ,, ,, 1906, p. 24.
,, ,, ,, 1908, p. 67.
,, ,, ,, 1910A, pp. 569 and 633.
,, ,, ,, 1910B, p. 448.
,, ,, Walker, 1909, p. 327.

Station 483, South Africa, entrance to Saldanha Bay; trawl, 25 fathoms. 21st May 1904. Five specimens, the largest 9 mm. long.

These specimens agree well with the short description given in *Das Tierreich,* and illustrate several of the points in STEBBING's further description given in the reference quoted above, 1908, p. 67.

Another species, *A. bathycephala* Stebbing, has been described from Port Philip, Australia, and is evidently very closely allied, differing mainly in the side plate and basal joint of the third peræopod. In my specimens the hind lobe of the side plate is more produced downwards than in STEBBING's figure of *A. macrophthalma,* and thus is a little more like *A. bathycephala,* but on the other hand the basal joint of the limb is expanded above instead of being narrowed as in the latter species.

The species is now known from Australia, South Africa, Straits of Magellan, and New Zealand, and Mr WALKER has recorded it from Wasin, British East Africa. In

1904 Mr WALKER added another species, *A. tenuipes*, from Ceylon, for which he established a new genus, *Vijaya*; but Mr STEBBING (1910A, p. 570) has pointed out that the difference in the male and female antennæ on which the genus was founded occurs also in *Amaryllis*, and that the new genus is therefore not required.

Genus CYPHOCARIS Lütken and Boeck, 1870.

Cyphocaris anonyx Boeck. (Pl. I. figs. 1–4.)

Cyphocaris anonyx Boeck, *Forh. Selsk. Christian.*, 1870, p. 104.
" " Stebbing, 1906, p. 29.
" " Walker, 1903A, p. 39, and 1903B, pp. 227 and 232.
" *micronyx* Stebbing, 1888, p. 656, pl. xii.
" " Chevreux, 1900, p. 164.

Station 414, lat. 71° 50′ S., long. 23° 30′ W.; 8 ft. vertical net, from the surface to 1000 fathoms. 15th March 1904. One specimen, total length 20 mm.

This specimen in all probability belongs to this species, although it differs from the description given in *Das Tierreich* in several minor points. The first segment of the peræon is more produced in front and much more acute than is shown in STEBBING'S figure of the *Challenger* specimen; the antennæ have more numerous joints in the flagella; there is no accessory flagellum to be seen in either of the upper antennæ—possibly it has been broken off, though I can detect no trace of this. The first and second peræopods (fig. 3) are simple or almost so, the propod being only very slightly widened and the finger apparently not folding back upon it. The basal joints of the third to the fifth peræopods have the margins less serrated.

The gnathopods (figs. 1 and 2), the uropod, and the telson agree fairly well with *C. anonyx*, which has been already recorded from Tristan da Cunha in the South Atlantic, and I think the *Scotia* specimen is only a larger and more fully developed specimen of that species. The whole integument is soft, there is no sign of eyes, and the animal was probably taken at a considerable depth. It is interesting to note that in 1903 Mr WALKER stated that this species would probably be found to occur in Antarctic seas. It is also found in the seas of the northern hemisphere.

Genus LYSIANASSA Milne Edwards, 1830.

Lysianassa cubensis (Stebbing). (Pl. I. fig. 5.)

Lysianax cubensis Stebbing, 1897, p. 29, pl. vii.B.
Lysianassa cubensis Stebbing, 1906, p. 38.

Station 478, South Africa, Cape Town, Coaling Jetty No. 1. 14th May 1904. Two specimens, the larger a female 13 mm. long.

Station 483, South Africa, entrance to Saldanha Bay; trawl, 25 fathoms. 21st May 1904. Two specimens, one a male 8 mm.

These agree well with the descriptions and figures given by STEBBING, except that the larger ones contain rather more joints in the flagella of the two antennæ. In the second antenna of the male the flagellum is long, about two-thirds the length of the animal, and the last joint of the peduncle is longer than the preceding joint, which is rather short. In the second maxilla the inner lobe is specially broad and has the inner margin pretty strongly convex. The second gnathopod has the palm a little projecting so as to approach towards the chelate character. The uropods agree well with the description; the character of the peduncle of third uropod seems fairly characteristic, and is shown in fig. 5. Its outer margin is produced upwards into a vertical flange above the general body of the joint; it curves upwards at the end into a subacute point, and bears three short spinules on the distal half of the upper margin. The two branches are similar in shape, both tapering to the extremity; the outer is slightly longer than the inner, and bears a few long hairs at a little distance from the end.

The species was originally described from specimens in the Copenhagen Museum, coming from the Gulf of Mexico.

Genus ALICELLA Chevreux, 1899.

Alicella scotiæ, sp. nov. (Pl. I. figs. 6 and 7.)

Station 468, South Atlantic, lat. 39° 48′ S., long. 2° 33′ E.; 2645 fathoms. 29th April 1904. One specimen, 20 mm. long.

Integument soft, the body greatly swollen about the middle, tapering considerably posteriorly. The hinder half of the body somewhat compressed, with a slight dorsal ridge, but hardly carinate. Side plates 1–4 increasing in depth, the fourth with its posterior lobe extending about one-third along the fifth, which is shallower than the fourth and broader than deep. Lateral plate of the first pleon segment angular in front but rounded behind, its lower border fringed with long setæ; that of the second segment with both angles rounded; the third with the anterior rounded, posterior angle quadrate, both bearing plumose setæ on the lower margin. Sides of the third segment of the urus upraised alongside the telson. Eyes indistinct, apparently forming a narrow crescentic band along the lateral sides of the head.

Antennæ slender, first shorter than the second, about as long as the head and the first segment of the peræon, the first joint short and thick, as long as the second and third together, the third very short; flagellum of about twenty joints, the first as long as the next five and supplied on the inner side with dense tufts of long setæ, similar setæ being present also on a few of the succeeding joints. Accessory flagellum nearly half as long as primary; of six joints the first as long as the next two.

Second antenna with third joint well exposed; the fourth with long, rather stout setules on the lower margin; fifth slightly longer than the fourth, with long slender setæ on lower margin; flagellum many-jointed, of about thirty-five joints, all except the more distal ones bearing a small tuft of long setæ at the lower distal angle.

First gnathopod (fig. 6) moderately stout; basal joint stout, of equal width throughout; a few tufts of long setæ near the distal end of its posterior margin; ischium, merus, and carpus all short, subequal, and all bearing long setæ on the posterior margin; carpus also with tuft at the antero-distal angle; propod at base as wide as the distal end of the carpus, narrowing slightly distally; anterior margin straight or slightly curved, and with tufts of long setæ; posterior margin slightly concave distally, and bearing numerous long setæ in tufts; the palm transverse, straight, defined by two long spinules; finger long, extending beyond the palm.

Second gnathopod (fig. 7) slender; basal joint curved; ischium much longer than the merus; carpus longer than the propod, which is narrowed at base, slightly curved; palm rather short and slightly oblique; the posterior margin of the merus is furred and bears three tufts of long setæ towards the distal end; carpus furred on both margins, with tufts of long setæ on the lateral surface and anterior margin at distal end, and several tufts, or short transverse rows, on the distal half of the posterior margin; propod with both margins furred, and tufts of long setæ on their distal portions, those on the anterior border towards the base of the finger forming a dense group of very long setæ. The first and second peræopoda rather slender; the merus slightly broadened and produced at the antero-distal angle; propod somewhat curved; finger about half as long as the propod, slender, curved, smooth. The third, fourth, and fifth peræopoda are of increasing lengths, all having the merus much broadened and produced, the propod curved, and the finger long, as in the first and second peræopoda; basal joint of all expanded, that of the third rounded posteriorly, those of the fourth and fifth somewhat angled below, and with the posterior margin convex in its upper part and straight or slightly concave below, the hind margins feebly crenulate.

First uropods with the branches slender, subequal, longer than the peduncle, marginal spines on the peduncle and on the outer branch. Third uropod with peduncle large, shorter than the branches, which are subequal in length, lanceolate, margins fringed with short spinules and long plumose hairs, the inner branch with small second joint. Telson reaching nearly to the end of the third uropod, apparently without spines on its dorsal surface.

This species differs from the typical species *A. gigantea* Chevreux in having both gnathopoda subchelate and the first not slender but moderately stout. As there are only the two species known, it will be well to slightly widen the characters of the genus to include the species now being described. The typical species was of enormous size, one of the specimens being as much as 140 mm. long; probably when specimens of both species of an intermediate size are known, it will be found that the two are more nearly alike than appears from the detailed description above, which is based on the single specimen obtained by the *Scotia*.

Genus CHEIRIMEDON Stebbing, 1888.

Cheirimedon femoratus (Pfeffer).

Anonyx femoratus Pfeffer, 1888, p. 93, pl. ii. fig. 2.
Cheirimedon dentimanus Chevreux, 1905, p. 159, and 1906B, p. 2, figs. 1–4.

South Orkneys, Brown's Bay, Station 326A. November 1903. Many specimens of about 10 mm. in length.

South Orkneys, Scotia Bay, Station 325; dredge, 9–10 fathoms. May 1903. One small specimen.

South Orkneys, Scotia Bay, Station 325; dredge, 4 fathoms, gravel bottom, clumps of weeds; temperature 29°·1. 3rd December 1903. Two specimens.

These specimens agree minutely with the figures and description given by CHEVREUX, and I have been able to compare them with co-types of his species which he has been good enough to send me. I have also compared them with a specimen of *Anonyx femoratus* Pfeffer from South Georgia, kindly placed at my disposal by the authorities of the Hamburg Museum, and I find it is quite the same as the South Orkneys specimens and those from Port Charcot sent to me by Monsieur E. CHEVREUX. Pfeffer's description agrees well with *C. dentimanus*, but his figure shows the telson too broadly rounded posteriorly and the cleft too shallow. The figure was, however, made without dissecting the specimen. His name has priority by many years. M. CHEVREUX states that this species appears to closely resemble *C. fougneri* Walker from South Victoria Land. I have been able to examine co-types of this species from the British Museum, and also specimens obtained by the *Nimrod* Expedition, and find that, though there is considerable resemblance in general structure, *C. fougneri* differs considerably from *C. dentimanus* in the greater length of the antennæ, and also in having the body much less compact, and the first gnathopod more slender.

Genus TRYPHOSA Boeck, 1871.

Tryphosa murrayi Walker.

Tryphosa murrayi Walker 1903A, p. 50, pl. ix. figs. 45–51.
„ „ „ 1907, p. 16 (part).

Station 411, Coats Land, lat. 74° 1′ S., long. 22° W.; 161 fathoms. Many specimens, the largest 22 mm. long.

After much consideration, I have decided to record these specimens under the name given above. I have been able to compare them with the type of Mr WALKER's species obtained by the *Southern Cross* Expedition, and the two agree so closely that they must be considered specifically identical. The eyes are obsolete, the lateral lobes of the head produced and acute or subacute, the hind margin of the third pleon segment straight, and the first segment of the urus bears a well-marked triangular carina. The appendages are in close agreement with those of the type, and in both the inner lobe of the first maxilla bears four setæ instead of two as given in the diagnosis of the genus in *Das Tierreich Amphipoda*, two of the setæ being shorter than the others.

While it is easy to identify the *Scotia* specimens with Mr WALKER's type, the position is not so clear if we try to go a little further. In the *Southern Cross* Amphipoda Mr WALKER described another species, *Tryphosa adarei*, differing from *T. murrayi* in certain minor characters which appeared at the time to be of specific importance. In 1907, however, on the receipt of numerous other specimens from the *Discovery* Expedition, he united the two species under the name *T. murrayi*, as the examination of the specimens showed that the characters at first relied upon were subject to variation. In this he was perhaps right, but a comparison of his specimens of *T. adarei* with my specimens shows that they differ from them as they do from *T. murrayi* in having the first gnathopod rather stouter towards the distal end, and particularly in having the carpus stouter and rather shorter than the propod, while in *T. murrayi* it is as long as or longer than the propod ; though the differences are not great, they appear to be constant in the specimens I have examined. Moreover, Mr WALKER states that *T. adarei* closely resembles *T. barbatipes* Stebbing, but differs in the proportions of the joints of the upper antennæ and of the gnathopoda. Before comparing the *Scotia* specimens with *T. murrayi* Walker I had also noted their great similarity to *T. barbatipes*, except in the shape of the first gnathopods, and comparison of the three shows that *T. adarei* is largely intermediate in this character between *T. murrayi* and *T. barbatipes*, so that, if the first two are united, it will be necessary to unite them both with *T. barbatipes.* This species is, however, now placed by STEBBING in another genus, *Tryphosella*, and the shape of the first gnathopod in the type specimen of *T. barbatipes* which I have also examined is considerably different from that of *T. murrayi*, the carpus being shorter and the propod longer and stouter and slightly different in outline, as may be seen from an examination of the figure in the *Challenger* Report, and there are differences in some other characters. It is quite likely that an examination of specimens from other localities will show complete transitional forms, but at present I cannot go fully into this question, and in the meantime prefer to identify my specimens with *T. murrayi* and to leave that species distinct from *T. adarei* and from *T. barbatipes.* In all three species the side plates of the first and second gnathopoda have a small tooth at the posterior angle. It is to be hoped that a complete revision of this group will be made before long ; such a revision must, however, include the similar forms from northern seas, some of which appear to be very closely allied.

Tryphosa murrayi is known from South Victoria Land and from near Coats Land, though not yet recorded from intermediate localities.

Genus TRYPHOSITES G. O. Sars, 1891.

Tryphosites stebbingi (Walker).

Hoplonyx stebbingi Walker, 1903A, p. 52, pl. ix. figs. 52 to 57.
Tmetonyx stebbingi Stebbing, 1906, p. 720.
„ „ Chilton, 1909A, p. 618.

Station 411, Coats Land, lat. 74° 1′ S., long. 22° W.; 161 fathoms. Many specimens, about 17 mm. long.

I have compared these specimens with those from the *Southern Cross* Expedition on which Mr WALKER established the species, and find that they agree closely in all points, except that the lateral process of the head might almost be called acute instead of " point rounded "—in some of the *Southern Cross* specimens it is almost or quite as acute as in the *Scotia* specimens. The first segment of the urus is slightly compressed, but hardly sufficiently so to be called carinate. The eyes are very indistinct or absent completely. The first gnathopod has the propod slightly narrowed towards the distal end, with the palm short and not well defined; in one specimen the palm was found to be rather oblique on one side of the body, while on the other it was almost transverse; the dactyl has a prominent secondary nail. In this specimen the second uropod had the inner branch somewhat constricted towards the distal end, as shown by STEBBING for *Tryphosa cicadoides* (1888, pl. iv. fig. ur_2); the telson is long and narrow, without marginal spinules, but with two small spinules in the emargination at the end of each lobe.

The species appears to be close to *T. cicadoides* Stebbing, one of the chief differences being apparently in the shape of the telson; but it is to be noted that the drawings of the telson of the two specimens represented on plates iv. and v. of the *Challenger* Report differ to some extent.

The species was described by WALKER under the genus *Hoplonyx*, and compared with *H. kergueleni* (Miers), which is now placed under *Tryphosa*, the genus to which *T. cicadoides* was first assigned. *Tryphosa kergueleni* is certainly not unlike *Tmetonyx stebbingi*, but differs in the points mentioned by WALKER, and particularly in having the propod of the first gnathopod stouter and with the palm regularly rather oblique. The first gnathopod of *Tryphosa trigonica*, as figured in the *Challenger* Report, is more like that of *T. stebbingi*, and in describing that species Mr STEBBING suggested that it was perhaps the young of *T. kergueleni* (Miers).

In the *Scotia* specimens, and also in those collected by the *Southern Cross*, the epistome is produced anteriorly into an acute process as in *Tryphosites longipes* (Bate and Westwood), and the species must be placed in the same genus, though the differences between *Tryphosa*, *Tmetonyx*, and *Tryphosites* are very trifling. *Tryphosites stebbingi* appears to be very close to *T. longipes* of northern seas, differing chiefly in having the peræopoda shorter and stouter and the eyes indistinct.

Tmetonyx stebbingi is now known from South Victoria Land and from Coats Land, and I have recorded a form from the sub-Antarctic islands of New Zealand which appears to belong to this species, but is much smaller, has well-developed eyes, and is darkly pigmented (1909A, p. 618).

Genus ORCHOMENELLA.

Orchomenella pinguides Walker.

Orchomenella pinguides Walker 1903A, p. 46, pl. viii. figs. 24–30.
„ „ „ 1907, p. 13.

South Orkneys, Scotia Bay, Station 325. 2nd January 1904. Several specimens.

These specimens undoubtedly belong to this species, as on comparison I find that they agree closely with co-types of WALKER's species kindly sent me by Dr CALMAN of the British Museum. They show also a pretty close resemblance to *Cheirimedon dentimanus* Chevreux, but differ in having the eyes not black (in spirit specimens), and in having the first gnathopod less strongly developed and the palm not concave; the third segment of the pleon has the posterior angle rather more rounded, and the telson appears slightly more elongated than in CHEVREUX's species. I have also been able to examine specimens of *O. pinguides* from South Victoria Land collected by the *Nimrod* in 1908, and can detect no difference between them and the South Orkneys specimens. In most of the *Nimrod* specimens the eye is colourless in spirit and appears to have been red in the living animal; some of the specimens were labelled "Red Amphipods," and the specimens preserved in formalin still show the red colour of the eyes and a slight pinkish tinge of the whole body. On the other hand, WALKER in describing his species says: "Eyes moderately large, dark, oval, expanded below." There thus appears to be some variation in the eyes of *Orchomenella pinguides*, for in the co-types from the British Museum one specimen has an eye still fairly darkly coloured, but in the others it is pale, as in the South Orkneys specimens, and I have noticed also some variation in the *Nimrod* specimens.

Orchomenella macronyx Chevreux.

Orchomenella macronyx Chevreux 1905, p. 161, fig. 2.
„ „ „ 1906B, p. 8, figs. 5–7.

South Orkneys, Scotia Bay, Station 325. May 1903. Two specimens, 4·5 mm. long.

These two small specimens on the whole agree well with CHEVREUX's description, especially in the shape of the last segment of the pleon and the first of the urus. The eye is rather narrower and less oval, and the first gnathopod appears to have a slightly more transverse palm, against which the finger fits closely without projecting beyond it. The telson is concave above.

Genus WALDECKIA Chevreux, 1906.
(= CHARCOTIA Chevreux, 1905, name preoccupied).

Waldeckia zschauii (Pfeffer).

Anonyx zschauii Pfeffer, 1888, p. 87, fig. 1.
Orchomenopsis zschauii Stebbing, 1906, p. 85 (part).
Charcotia obesa Chevreux, 1905, p. 163, fig. 3.
Waldeckia obesa Chevreux, 1906B, p. 15, figs. 8–10.
" " Walker, 1907, p. 10, pl. ii. fig. 4.

Station 411, Coats Land, lat. 74° 1′ S., long. 22° W.; 161 fathoms. 12th March 1904. Many specimens, the largest 16 mm. long.

Although I have been unable to examine specimens of *Anonyx zschauii* Pfeffer, as those described by him did not belong to the official collection of the German Expedition of 1882–83, and consequently were not deposited in the Hamburg Museum, I feel confident that my specimens must be referred to his species. His description of the great obesity of the body, and particularly of the dorsal process on the first segment of the urus, which is so distinct from that of other species with which it might otherwise be confused, leaves no doubt upon the subject. In this species, in place of the more or less rounded prominence on the first segment of the urus, the process rises abruptly behind the usual depression into a sharp tooth, from which it slopes downwards towards the next segment; this is shown clearly also in PFEFFER's figure, although the figure is rather small. Mr STEBBING in 1906 referred his species *Orchomene cavimanus* to PFEFFER's species, but an examination of the mounted slides of the *Challenger* collection in the British Museum shows that the first gnathopod of *O. cavimanus* has the propod broad and not narrowing distally as in *W. zschauii*, and, judging from the description, the process on the urus does not appear the same as in that species, and it appears to me that *O. cavimanus* Stebbing is more properly referred to the widespread and variable species *O. chilensis* (Heller); see p. 474, where the question is further discussed.

I did not at first compare my specimens with the descriptions of *Waldeckia obesa* Chevreux, but the shape of the basal joint of the third peræopod in one of the slides I had mounted proved to be so similar to the figures given by both CHEVREUX and WALKER that a full comparison was made, with the result that my specimens proved to be identical with that species also. The figures given by CHEVREUX and WALKER show the great obesity of the body and the great prolongation backwards of the fourth side plates better than PFEFFER's; but, on the other hand, they hardly show so well the character of the process on the urus, though from their descriptions it seems evident that they were dealing with the same structure.

I have compared the *Scotia* specimens with those collected by the *Discovery* and referred to this species by Mr WALKER, and find no essential difference; in the *Discovery* specimens the third segment of the pleon is slightly more compressed and elevated into a blunt dorsal tooth, while the tooth on the first segment of the urus is a little shorter than in the *Scotia* specimens.

WALKER's figure is taken from a male specimen, and shows the long second antennæ found in that sex; these are longer than in the males of *Orchomenopsis chilensis* (Heller) and some other allied species. The occurrence of some specimens with long lower antennæ was pointed out by PFEFFER in his original description.

Whether it was necessary to establish the new genus *Waldeckia* for this species appears to me to be doubtful, but as that has been done I am referring the species to it. As mentioned above, STEBBING in his *Tierreich Amphipoda* placed the species under *Orchomenopsis*, and the affinities of the species seem to me to be distinctly with species of that genus such as *O. chilensis* (Heller) and *O. nodimanus* Walker. It is true that CHEVREUX has described the propod of the first gnathopod of *W. obesa* as being simple and not subchelate; but in my specimens, although the propod narrows very considerably distally, there is a distinct though short palm, and this is shown also in the figures given by PFEFFER and WALKER. Moreover, there are considerable differences in the breadth of the propod in other species of *Orchomenopsis*, as will be seen from my discussion of *O. chilensis* (Heller); and in the South African specimens which I refer to that species the propod narrows distally in the same way, though not to the same extent, as in *W. zschauii.*

The other important point in which *Waldeckia* differs from *Orchomenopsis*, as first pointed out by CHEVREUX, is in the possession of finger-like accessory branchiæ. CHEVREUX describes one of these as being present on all the legs, and two on the fourth. In the specimens I examined I found them on the fourth, fifth, and sixth legs only, and only one on the fourth. They appear to arise either from or near the base of the branchia. They are long and finger-like in shape, but seem to differ in internal structure from the branchia, being filled with granules or globules of some kind, and whether they are really branchial in function is perhaps doubtful. This, however, is neither the time nor the place for a discussion of their physiological importance; the question that concerns us now is their presence or absence, and their value when present as a generic character.

Secondary or accessory branchiæ have been described in several genera of the Amphipoda belonging to quite different families, and it seems probable that they may be independently developed in cases where there is special need for them, and that their presence is not of great taxonomic importance. For example, they occur in some species of *Hyalella* and not in others, and the species in which they occur are nevertheless retained under the genus *Hyalella.* It was not till after I had written down the general considerations given above that I had an opportunity of specially looking for accessory branchiæ in other allied species; but afterwards, on examining large specimens of *Orchomenopsis chilensis* Heller (= *O. rossii* Walker), from Station 411, whence the *Waldeckia zschauii* had been obtained, I found them in that species also, though they appear to be present only on the fifth and sixth legs. Unfortunately, my attention was not specially directed to this question till it was too late to make an examination of other specimens, but the facts detailed above show, I think, that *Waldeckia* is nearer to *Orchomenopsis* than might appear at first sight.

The small amount of difference between some of these genera, and the difficulty of referring a species to its proper genus, is shown by the fact that while CHEVREUX established for the species in question the new genus *Waldeckia*, and compared it with *Menigrates* and *Lepidepecreum*, Mr WALKER, who was independently working at the same species, had at first classified it under *Socarnes*, and Mr STEBBING has since stated that he would have been inclined to concur in this view. Mr STEBBING has, however, now accepted the genus *Waldeckia*, and has described a new species, *W. chevreuxi*, from Australia (1910A, p. 572, pl. xlvii.B). This species, which, though undescribed, has been long known to me from New Zealand, differs from *W. zschauii* (Pfeffer) in having the first gnathopod quite simple, and thus offers an additional reason for retaining the genus *Waldeckia*, unless indeed *W. chevreuxi* could not have been as appropriately placed under one of the existing genera.

Genus ORCHOMENOPSIS Sars, 1893.

Orchomenopsis nodimanus Walker.

Orchomenopsis nodimanus Walker, 1903A, p. 44, pl. vii. figs. 13–17.
„ „ Stebbing, 1906, p. 721.

South Orkneys, Scotia Bay, Station 325; trap. Many specimens, averaging about 15 mm.

South Orkneys, Scotia Bay; 10 fathoms. March 1903. Three specimens, the largest 13 mm.

South Orkneys, Scotia Bay; 9–10 fathoms. April 1903. One specimen.

Also taken at other times along with *O. chilensis* (Heller).

These specimens agree well with the description given by WALKER, and I have been able to compare them with co-types of his species from the British Museum, and find no essential difference between the specimens from the South Orkneys and those from South Victoria Land. The species in most respects is very similar to *O. chilensis* (Heller), but can be distinguished by the slight carination of the hinder part of the body and by the peculiar structure of the propod of the first gnathopod; in most of my specimens this is a little stouter than is shown in WALKER's figure, and it bears a tubercle on the posterior surface as described by him.

This species occurred along with *O. chilensis* (Heller) in many captures.

Orchomenopsis chilensis (Heller).

Anonyx chilensis Heller, 1865, p. 129, pl. xi. fig. 5.
Orchomenopsis obtusa Sars, 1891 and 1895, p. 74, pl. xxvi. fig. 2, and p. 684.
Orchomene musculosus Stebbing, 1888, p. 673, pl. xx.
(?) „ *abyssorum* Stebbing, 1888, p. 676, pl. xxi.
(?) „ *cavimanus* Stebbing, 1888, p. 679, pl. xxii.
Orchomenopsis musculosa and (?) *abyssorum* Stebbing, 1906, p. 84.
(?) „ *zschauii* Stebbing (part), 1906, p. 85.

Orchomenopsis proxima Chevreux, 1903, p. 93, fig. 6*a–c*, and 1906B, p. 13.
„ *rossii* Walker, 1903A, p. 45, figs. 18–23, and 1907, p. 14.
(?) „ *abyssorum* Walker, 1903B, pp. 224 and 227.
(?) „ „ Chevreux, 1903, p. 92.

South Orkneys, Scotia Bay, Station 325 ; trap, 15 fathoms. May 1903. Several hundred specimens up to 15 mm. in length, all "taken from trap in one day ; bait—penguin." Taken along with *O. nodimanus.*

Station 411, Coats Land, lat. 74° 1′ S., long. 22° W. ; 161 fathoms. 12th March 1904. Many specimens, most of them of large size, about 20 mm.

South Orkneys, Station 325 ; 21 fathoms. September 1903. "Through hole in ice made for seal skeleton." Many hundreds of specimens of varying size up to 15 mm. Taken along with *O. nodimanus.*

South Orkneys, Station 325 ; 13–25 fathoms. August 1903. Many specimens ; *O. nodimanus* being taken at the same time.

South Orkneys, Scotia Bay ; 9–10 fathoms. May 1903. Many specimens ; also taken along with *O. nodimanus.*

South Orkneys, Station 325 ; 27 fathoms ; temperature 29°. June 1903. Many specimens ; *O. nodimanus* being taken at the same time.

In order to make clear the discussion of this species it will be well to give the following historic account. The genus *Orchomenopsis* was established by SARS in 1893 for the species *O. obtusa.* In 1888 Mr STEBBING had described three species under the genus *Orchomene*, namely :—*Orchomene musculosus*, described from one specimen about 12 mm. long, taken near the south of Japan ; *Orchomene abyssorum*, from the Atlantic, east of Buenos Aires, 1100 fathoms, one specimen, male ; and *O. cavimanus*, from Kerguelen Island, two or three specimens, the one described being 12 mm. long. Of these species SARS included the first two, and with some doubt also the third, in his genus *Orchomenopsis.* Many years before this, however, in 1865, HELLER had described the species *Anonyx chilensis* from Chili, and in his revision of the Amphipoda for *Das Tierreich* STEBBING puts the whole of his three species under *Orchomenopsis*, giving *Anonyx chilensis* Heller as a doubtful synonym of *O. abyssorum*, and identifying his species *O. cavimanus* with *Anonyx zschauii* Pfeffer, which had been described from South Georgia in 1888. In 1903 CHEVREUX described *Orchomenopsis proxima* from specimens obtained from deep waters in the tropical Atlantic Ocean, at the same time identifying other specimens from the Northern Atlantic with *O. abyssorum*, and describing a new species, *O. excavata*, which he stated comes close to *O. cavimanus* (Stebbing). In 1906 he identified specimens obtained by the French Antarctic Expedition from Graham Land with *O. proxima*, pointing out a few small differences between the specimens from the two localities, and stating that the species was very close to *O. obtusa* Sars. Meanwhile, in 1903, WALKER had described *O. rossii* from Cape Adare, also referring to its close resemblance to *O. obtusa* ; in 1907 he examined many specimens obtained from South Victoria Land by the *Discovery* Expedition, and modified his original description in one or two points in which he found that the additional specimens showed some slight variation from those at first described. In 1903 he also had identified as *O. abyssorum* specimens obtained from the Atlantic by the *Oceana*.

The *Scotia* collections contain an enormous number of specimens from the various localities given above, and a comparison of these with co-types of WALKER's species showed that they were the same as the forms described by him under the name *O. rossii*. A comparison of the different specimens from the South Orkneys and other *Scotia* localities with co-types of WALKER's species supplied by the British Museum, and with specimens collected by the *Nimrod* Expedition, showed that the species varied greatly not only in size but also in several points which had been relied upon by previous authors for the description of different species—for example, in the second gnathopod, some of the specimens having the palm strictly transverse, while in others it was slightly produced so as to give the gnathopod almost a chelate character; in the postero-lateral angle to the third pleon, which in some is quadrate and in others more or less broadly rounded; and in the proportions of the two branches of the third uropods. There are, of course, also differences between the sexes, the males having the lower antenna considerably longer than the females, and having the branches of the third uropod supplied with more numerous long plumose setæ, though some similar setæ are present in the female. An examination of young forms appears to show that these setæ are only developed to the full extent in older specimens, there being fewer in younger forms.

I was able also to compare these specimens with a specimen of *O. proxima* Chevreux from Port Charcot, kindly sent to me by Monsieur CHEVREUX, and I have come to the conclusion that this species is the same as *O. rossii*, the differences which M. CHEVREUX points out being accounted for by the variations mentioned above. In the character of the eyes and in other points it is quite the same as a specimen of *O. rossii* of moderate size; on the other hand, as M. CHEVREUX points out, it is considerably larger than the forms from the North Atlantic on which he originally described the species *O. proxima*. From the Vienna Museum I obtained specimens of *Anonyx chilensis* Heller, taken by the *Novara* at Chili. This proved to be about half the size of *O. proxima*; it differs a little in the shape of the eye and in the somewhat smaller size of the rounded prominence on the first segment of the urus, but in all other points I can find nothing to distinguish it from *O. rossii* Walker. In *Anonyx chilensis* the eye is almost oval, widening slightly below, and it is colourless in the spirit specimens and probably was red in the living animal, as described by SARS in *O. obtusa*. In large specimens of *O. rossii* from Antarctic regions, the eye usually differs somewhat in shape, being much narrower above and wider below, and in most of them it is dark in colour in spirit specimens, though in many, and especially in forms preserved originally in formalin, there is still a reddish tinge to be seen. Moreover, even in the Antarctic specimens there is some variation in the size, shape, and colour of the eyes, and consequently I do not think this slight difference sufficient to distinguish *Anonyx chilensis*

Heller from *O. rossii* Walker. Monsieur CHEVREUX had also kindly sent me a specimen of *O. obtusa* Sars from Norway, and an examination of this showed that in size and in all essential characters it was identical with the specimens of *Anonyx chilensis* Heller, though the eye was less oval and more widened below, and hence more like the specimens of *O. rossii.* Consequently I am forced to the conclusion that *O. obtusa* Sars also belongs to this widely distributed species. *O. musculosa* Stebbing was described from a single specimen obtained from the south of Japan, and from the description given I think there can be no doubt that it is the same as the other forms already described. *O. abyssorum* Stebbing is supposed to be distinguished from the other species mainly by the more strictly chelate character of the second gnathopod, and the figure of the *Challenger* specimen shows the palm much more produced than it is in any of the forms I have already referred to, though, as I have pointed out, there is considerable difference among them in this character. In all other points there seems little to distinguish *O. abyssorum* from the others, and, as mentioned above, STEBBING has already given *Anonyx chilensis* Heller as a possible synonym of this species, although the second gnathopod in that form can hardly be described as truly chelate.

For some considerable time I was inclined to think that perhaps it would be wise to keep *O. abyssorum* as a separate species; however, after having finished my examination of the forms already mentioned, I found in the *Scotia* collection a number of specimens from Saldanha Bay in South Africa which in most points are quite similar to *O. rossii*, but in which the second gnathopod has the palm so much produced that it could quite strictly be called chelate, as in *O. abyssorum* Stebbing.

If this form had agreed in other points with STEBBING's *O. abyssorum* it would confirm the opinion that this is a distinct species; but this is not the case, for the first gnathopod, instead of having the basos slender and the propod rather broad, as in the type specimen, is somewhat stouter than usual, and differs also in having the propod considerably narrowed distally, so that its palm is much shorter.* In it the eyes are black, usually oval, though slightly widening below, and they vary in size and in the amount of widening at the lower part. After careful consideration I think it best to include this form also in the same species as the others, although they might perhaps be looked upon as different variety, though not corresponding in all points with the form described as *O. abyssorum* by STEBBING.

If all these forms are combined they must be known under the name of *Orchomenopsis chilensis* Heller, as that name has priority by many years. With regard to *O. cavimanus* Stebbing, from the Kerguelen Islands, STEBBING himself has identified it with *O. zschauii* (Pfeffer); but, as I have shown elsewhere, PFEFFER's species is quite distinct in the shape of the dorsal process on the urus and in the greater stoutness of the body and the character of the first gnathopod, and has been since redescribed by CHEVREUX under the name *Waldeckia obesa.*

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* In the stout basos and in the character of the propod the first gnathopod in these specimens shows considerable approach to *O. nodimanus* Walker, but it lacks the tubercle present in that species.

I have examined a mounted slide of *O. cavimanus* Stebbing in the British Museum. The palm of the second gnathopod is hardly so oblique as shown in the figure of the whole appendage in the *Challenger* Report, but is distinctly concave, the finger impinging against a rather narrow projection of the propod and being thus separated from the rest of the palm. This structure seems rather more marked in the one gnathopod than in the other of the same specimen, and the difference from typical specimens of *O. chilensis* is not greater than, or indeed so great as, that of the specimens from South Africa mentioned above, and the other parts of the specimen seem to agree well with that species. In the same way, *O. excavata* Chevreux, from the Atlantic, might perhaps also be looked upon as only a form of the widespread *O. chilensis* Heller, but I have not been able to examine specimens of *O. excavata.*

ORCHOMENOPSIS (?) COATSI, sp. nov. (Pl. I. figs. 8–9.)

Station 411, Coats Land, lat. 71° 1′ S., long. 22° W.; 161 fathoms. 12th March 1904. Many specimens, about 13 mm. long.

In general possessing the characters of an *Orchomenopsis*, but differing markedly in the first gnathopoda (fig. 8), which are long and very slender. The basos is long, slender, but expanding at the middle so as to be elongate fusiform; the ischium is fully half as long as the basos; merus shorter; carpus about as long as the ischium, slender; propod longer than the carpus but not broader, narrow, oblong, about four times as long as broad; palm a little oblique; small tufts of setæ on the propod toward the distal end.

The second gnathopod (fig. 9) is of the form normally found in the genus; the carpus is expanded so that the posterior margin is strongly convex, both margins being furred; the propod is much shorter than the carpus, narrowed at the base; palm short, transverse or a little projecting; the margins of the propod are furred, and supplied with long setæ in the usual manner.

Remarks.—The first gnathopoda of this species differ so much from those of other species of *Orchomenopsis* that it should perhaps be classed in some other genus, but I cannot find any genus that seems more appropriate, for in all the other characters it is closely similar to a typical species such as *O. chilensis*, and I therefore prefer to place it provisionally under *Orchomenopsis* rather than to add another genus to the Lysianassidæ.

Genus HARPINIA Boeck, 1871.

Harpinia obtusifrons Stebbing.

Harpinia obtusifrons Stebbing, 1888, p. 820, pl. lvi., and 1906, p. 143.
" " Walker, 1907, p. 17.
" " Chilton, 1909A, p. 619.

South Orkneys, Scotia Bay, Station 325; dredge, 9–10 fathoms. May 1903. One female, 4 mm. long; another female (from Scotia Bay), 7 mm.

These specimens resemble those examined by me from Campbell Island, and differ from the description of the genus as given by STEBBING in *Das Tierreich Amphipoda* in having the eye present and formed of many facets, though it is pale in colour in the smaller specimen.

The species is widely distributed in Antarctic and sub-Antarctic seas.

Genus LEUCOTHOE Leach, 1813–14.

Leucothoe spinicarpa (Abildgaard).

Gammarus spinicarpus Abildgaard, 1789, in O. F. Muller, *Zool. Dan.*, 3rd ed., vol. iii. p. 66, pl. cxix. figs. 1–4.
Leucothoe antarctica Pfeffer, 1888, p. 13, pl. ii. fig. 4.
„ *spinicarpa* Stebbing, 1906, p. 165.
„ „ Walker, 1907, p. 18.
„ *commensalis* Haswell, 1880, p. 261, pl. x. fig. 3.
„ „ Stebbing, 1906, p. 166.
„ „ „ 1910A, p. 580 and p. 630.

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. April 1903. One specimen, 8 mm. long.

I have been able to compare this specimen with some obtained at South Victoria Land by the *Nimrod*, and with specimens from Plymouth, England, and I agree with Mr WALKER that there is no appreciable difference between them and the European species. The South Orkneys specimen has the conical process on the propod at the base of the finger a little more obtuse than in the others, but in all other points they agree.

With regard to *L. commensalis* Haswell, Mr STEBBING says: "It is perhaps only a matter of taste or convenience whether this should be taken as a distinct species or as a variety of *L. spinicarpa* Abildg." In my South Orkneys specimen the propod of the second gnathopod contracts a little more towards the finger hinge than is shown in SARS' figure of the European form, as it does in the Australian specimens examined by Mr STEBBING; on the other hand, the tuberculation of the palm is practically intermediate between that shown by SARS and by HASWELL, and the resemblance throughout is so very close that I see no good object in retaining a different name for the Australian specimens.

Three other species are at present included in the list of Australian Crustacea, viz. *L. brevidigitata* Miers, *L. diemenensis* Haswell, and *L. gracilis* Haswell; but, as STEBBING points out, it is probable that they should all be included in *L. spinicarpa*, though, as yet, I have not been able to examine specimens. I have, however, examined the type of *L. antarctica* Pfeffer from the Hamburg Museum, and find that it also belongs to this cosmopolitan species.

I may take this opportunity of stating that I have recently (1912, p. 129) united *L. tridens* Stebbing, obtained in New Zealand waters by the *Challenger*, with the earlier described *L. traillii* G. M. Thomson, as the small differences given in the descriptions were found not to hold for all specimens or to be based on misconceptions. It is not unlikely that this species will also prove to be only a form of *L. spinicarpa* Abildg.

Genus AMPHILOCHUS Bate, 1862.

Amphilochus squamosus G. M. Thomson.

Amphilochus squamosus G. M. Thomson, 1880, p. 4, pl. i. fig. 4.
,, *marionis* Stebbing, 1888, p. 743, pl. xxxviii.
,, ,, ,, 1906, p. 151 and p. 723.
,, ,, Walker, 1901, p. 300.

South Orkneys, Scotia Bay, Station 325. Several specimens, all of small size, about 3 mm. long.

These specimens certainly agree with STEBBING's species described from Marion Island, but they are also the same as the species previously described by THOMSON under the name *Amphilochus squamosus*, from New Zealand. This latter species, which has been accidentally omitted from the list in *Das Tierreich Amphipoda*, is fairly common in New Zealand, and I have long noted that it is very closely allied to the *Challenger* species, and the present opportunity of examining specimens from another locality that undoubtedly belong to STEBBING's species confirms this. The New Zealand specimens are usually covered with dark, reddish-black spots, and some of the South Orkneys specimens still show signs of similar coloration. Mr THOMSON described a small accessory flagellum on the first antenna, and, though this does not appear to have been noted by others in this genus, which is described in *Das Tierreich* as being "without accessory flagellum," it is undoubtedly present also in the South Orkneys specimens. WALKER has pointed out that *A. neapolitanus* Della Valle, 1893, is perhaps the same as *A. marionis*; in describing his species STEBBING originally compared it to *A. tenuimanus* Boeck. It will probably be found to be either the same as or very closely allied to one of the northern species. Mr THOMSON's name has priority over all except *A. manudens* Bate and *A. tenuimanus* Boeck.

Genus METOPOIDES Della Valle, 1893.

Metopoides sarsii (Pfeffer). (Pl. I. fig. 10.)

Metopa sarsii Pfeffer, 1888, p. 84, pl. ii. figs. 3, 8, and pl. iii. fig. 2.
Metopoides walkeri Chevreux, 1906A, p. 37, fig. 1; 1906B, p. 28, figs. 15–17.

South Orkneys, Scotia Bay, Station 325; shore pools; temperature 30°–32°. 6th December 1903. Eight specimens, the largest measuring 7 mm. in length in the usual position with the pleon folded under the peræon.

In the collection of Amphipoda in the Hamburg Museum there is a single specimen of *Metopa sarsii* Pfeffer. This specimen I have been allowed to dissect and mount permanently as a micro-slide, and I find it agrees precisely with *M. walkeri* Chevreux, a name which must therefore be dropped in favour of the older *M. sarsii.*

My specimens agree minutely with CHEVREUX's description; the accessory flagellum is, I think, present in all the specimens, but it is exceedingly small, so small that it would hardly be inaccurate to say that it is absent. CHEVREUX describes the palp of the mandible as two-jointed; I think there is a minute third joint present in the specimen from which I dissected the mouth parts, but if so it is almost as small as the accessory flagellum; yet the presence or absence of these minute joints is one of the distinguishing marks for some of the genera into which the family Metopidæ is now divided.

CHEVREUX was unable to identify his species with any of those described by STEBBING in the *Challenger* Report, but says it seems to be nearest to *Metopa ovata*; but this species has the basal joints of peræopods four and five narrow, and is now placed in the genus *Metopella.* I would rather be inclined to compare it to *M. magellanica* or *M. compacta,* species now placed in the genus *Metopoides,* while the small acute teeth which are present on the palm of the second gnathopod, as described by CHEVREUX, show an approach to the more irregular palm found in *M. crenatipalma,* a species now known as *Proboloides crenatipalma.*

From the *Challenger* collections STEBBING described six species of *Metopa*—one from Kerguelen Island, the other five from Cape Virgins, off Patagonia; each of which, with one exception, was represented by one specimen only, though of one species another specimen was found at Nightingale Island in the Tristan da Cunha group. Of these six species three are placed in *Das Tierreich Amphipoda* under *Metopoides,* two under *Metopella,* and the other under *Proboloides.* As these genera are separated from one another and from *Metopa* by small points such as those I have mentioned above, and as there are altogether twenty-one species of *Metopa,* six of *Metopella,* three of *Metopoides,* and seven of *Proboloides,* it is not to be wondered at that the classification of the family is admittedly in an unsatisfactory condition, and I think it wisest not to attempt to identify the species under consideration with any of the *Challenger* species, although it is probably the same as one of the species described from Cape Virgins.

The sides of the last segment of the urus are raised into a vertical plate on each side of the telson, and this is continued by a similar vertical plate on the outer edge of the peduncle of the third uropod, so that a groove is formed, protected on each side by these vertical plates or flanges, in which the telson may rest when the animal swims by backward strokes of the hinder part of the body (see Plate I. fig. 10).

Genus METOPELLA G. O. Sars, 1892.

Metopella ovata (Stebbing).

Metopa ovata Stebbing, 1888, p. 764, pl. xlii.
„ „ „ 1906, p. 183.

South Orkneys, Scotia Bay, Station 325A; dredge, 2–8 fathoms; temperature 29°–30°. 6th December 1903. Several specimens, none exceeding 3 mm. in length.

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. April 1903. Three small specimens.

Several of these are females bearing eggs, and none can be said to be certainly males. These specimens agree closely with the description given by STEBBING, and have the basal joints of the fourth and fifth peræopods narrowed as given in the diagnosis of the genus. The gnathopods, uropods, and telson are all in close agreement with the figures given in the *Challenger* Report; the accessory flagellum on the upper antenna is present, though extremely small, being about the same size as in *Metopoides sarsii* Pfeffer. The palp of the mandible is short, and consists of a very short first joint, an expanded second joint bearing three setæ along one margin, and a very short third joint tipped by a setum.

Genus THAUMATELSON Walker, 1906.

This genus was established by WALKER in 1907 for his species *T. herdmani* obtained by the *Discovery* Expedition. The *Scotia* obtained several specimens from the South Orkneys of what appear to be two additional species of the same genus. The genus is mainly characterised by the very peculiar telson, which was described by WALKER as "large, entire, oval, and set in a vertical plane on its longer edge." The telson in the two species I have now to describe agrees well with this description. The shape of the telson is probably associated with the extremely large side plates which cover all the appendages when these are withdrawn, and enclose the animal so that it looks like a small bivalve shell; when this is done the pleon is folded in under the side plates which appear to overlap the telson all except a small thicker ridge along its dorsal margin, which fills the small slit between the right and left side plates.

In the mouth parts the genus agrees well with the characters of the family Metopidæ; one species, however, is peculiar in having the second gnathopod chelate.

Thaumatelson walkeri, sp. nov. (Pl. I. figs. 11–15.)

South Orkneys, Scotia Bay, Station 325. April and May 1903. Several specimens, the largest 3 mm. in length.

Specific Description.—In general characters (see fig. 11) similar to *T. herdmani*, but with the side plates even larger, the fourth segment being longer than any of the others and having an extremely large side plate. The second and third pleon segments not produced into a postero-dorsal tooth, but the third bearing a stout conical tooth projecting at right angles to the dorsal surface of the segment. The first antenna has the first joint much larger than the second or third, and produced at the upper margin into a broad, hood-like process; a minute accessory flagellum is present.

Further Description.—The antennæ (fig. 12) are quite short, the upper one being slightly longer than the lower. It has its basal joint very stout, and is produced above at the distal end into a broad process overlapping the second and nearly as long. The second joint is slightly broader than the third, which is about the same length. The flagellum tapers gradually, and consists of about thirteen joints, all with very few setæ. There is a small accessory appendage.

In the second antenna the last joint of the peduncle is slightly longer and more slender than the preceding; the flagellum is of about the same length as the peduncle, and contains about ten joints.

The mandibles have the same general shape as in *Metopa*; the palp, though small, is less vestigial than in some of the other genera of the family; the first joint is short, the second moderately long and broad, and the third is about as long as the first. There is no molar process. The first maxilla has the palp two-jointed. In the second maxilla the outer lobe is rather longer and broader than the inner. Both these maxillæ, and also the maxillipeds, have the same general character as in the next species, *T. inermis*.

The first gnathopod (fig. 13) has the basos long, widening a little distally; the merus is rather longer than the ischium, and ends in a rounded lobe bearing three long setæ, the posterior margin being furred; the carpus is about half as long as the propod, and is produced posteriorly into a short lobe fringed with setæ; the propod sub-oblong, about twice as long as broad, with anterior margin rather strongly convex; the palm oblique, straight, and defined by stout spinules.

The second gnathopod (fig. 14) is similar in general structure, but is longer; the ischium is not produced into a lobe; the carpus is shorter, but has the lobe longer; and the propod is longer, being considerably more than twice as long as broad.

The peræopoda are slender, and bear only a few short setæ.

The segments of the urus (fig. 15) cannot be made out distinctly, and appear more or less completely fused; the uropoda are long and slender, and bear few setæ; the first uropod reaches beyond the others, and has the peduncle longer than the subequal branches; in the second uropod the peduncle is about the same length as the equal branches; the third has the peduncle slightly longer than the basal joint of the single branch. The telson is flattened so as to form a vertical plate, and has a slight thickening along the dorsal margin.

When the side plates are folded together the strong tooth on the third pleon segment projects backwards, and the whole animal looks very like an Ostracod, some of which were found along with it, having been at first sorted out along with specimens of this species.

Thaumatelson inermis, sp. nov. (Pl. I. figs. 16 and 17.) *

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. April and May 1903.
Several specimens, the largest 3 mm. long.

Specific Description.—Very similar to *T. herdmani* Walker, but differing in having the second gnathopod long and chelate, the propod being produced into a long acute process as long as half the whole propod, the fixed finger finely pectinate and fitting closely against the dactyl, which has its inner margin furnished with small, widely separated serrations.

Further Description.—The form described above is the female, several of the specimens examined bearing eggs. The lateral angle of the head is rather acute; and in the shape of the body, the proportions of the segments and of the side plates, the species closely resembles *T. herdmani.* The eye is fairly large, round, and colourless in spirit, having been probably red in the living animal. In the first antenna the first joint is large and produced at its upper distal angle, though to a slightly less extent than in *T. walkeri*, and I can find no accessory flagellum. In other respects the antenna is similar to that of *T. herdmani*, and the joints of the flagellum bear long sensory setæ. In the lower antenna the last joint of the peduncle is about as long as the preceding, and the flagellum is of the same length. The mandible has the palp small, the first joint is short, the second moderately long, the third small and slender, the cutting edge and other parts having the character common to the family. The first maxilla has the palp two-jointed, its extremity furnished with four or five small spinules and one or two longer setæ; the inner lobe is rounded at the end, and bears three or four setæ; the outer lobe bears several stout spinules and one or two longer setæ, and has its inner margin furred. The second maxilla is of the ordinary form.

The maxillipeds have the inner lobes separate, rounded at the end, and bearing two rather large setæ. The outer lobe is small, being merely a slight extension of the joint as in *Metapoides sarsii.* The palp is similar to that in *T. herdmani.*

The first gnathopod (fig. 16) has the side plate undeveloped; in general shape it is similar to that of *T. herdmani*, but has both the merus and the carpus produced posteriorly into a lobe tipped with long setæ, the process of the merus reaching to the end of that of the carpus. The propod is rather large, and is slightly distended at the palm, which is nearly transverse and is defined by three or four stout spinules.

The second gnathopod (fig. 17) has the basal joints similar to those of *T. herdmani*, but is chelate, as already described. The peræopoda are long, very slender, and bear few setæ or spinules. The side plates of the fourth pair are particularly large, and cover up the fifth, sixth, and seventh pairs, the side plates of which are not developed and the basal joints slender. The first uropod extends considerably beyond the second; the branches are subequal, shorter than the peduncle. The second uropod is short, but extends beyond the third and a little beyond the telson; its branches are subequal.

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* This species is perhaps the same as *Thaumatelson nasutum* Chevreux (*Bull. Muséum Hist. Nat.*, 1912, No. 4, p. 5), though the descriptions of the mandibular palp do not agree.

The third uropod reaches a little beyond the peduncle of the second; its single branch is about as long as the peduncle, but rather more slender, and bears a minute second joint. The telson reaches slightly beyond the third uropod, is greatly flattened vertically, and has the dorsal border somewhat thickened, as described in *T. walkeri.*

In many respects this species shows close approximation to *T. herdmani*, described by Mr WALKER, from South Victoria Land, but is clearly distinguished by the large chelate second gnathopod. This may, however, ultimately prove to be a sexual character.

Thaumatelson herdmani Walker.

Thaumatelson herdmani Walker, 1906, p. 15, and 1907, p. 21, pl. vii. fig. 11.

South Orkneys, Scotia Bay, Station 325. 1903. A few specimens.

After I had drawn up the description of the preceding species, with the remarks thereon, I found in the "residues" of some collections made during 1903 both additional specimens of that species and also others with subchelate second gnathopoda agreeing in all respects with *T. herdmani* Walker, so that that species also does occur at Scotia Bay. I can find very little difference between the two except in the second gnathopoda, and, as stated above, strongly suspect that both forms belong to the same species; but the additional specimens came into my hands too late to allow of the question being fully investigated.

Genus BIRCENNA Chilton, 1884.

Bircenna crassipes (Chevreux).

Wandelia crassipes Chevreux, 1906A, p. 87, figs. 1 and 2.
" " " 1906B, p. 45, figs. 24–26.
Bircenna crassipes Chilton, 1909B, p. 62.

South Orkneys, Scotia Bay, Station 325; dredge, 9–10 fathoms. May 1903. One specimen, 2 mm. long.

This small specimen agrees very closely with CHEVREUX's description and figures.

The species is very close to *B. fulva* Chilton from New Zealand, and differs from it only in the longer and more slender gnathopods, and in having the branches of the first and second uropods equal and shorter in proportion to the peduncles.

Kuria longimana Walker and Scott (1903, p. 228), from the Indian Ocean, appears to be nearest ally of the genus *Bircenna.*

Genus COLOMASTIX E. Grube, 1861.

Colomastix brazieri Haswell.

Colomastix brazieri Haswell, 1880, p. 341, pl. xxii. fig. 4.
" " Stebbing, 1906, p. 206.

South Orkneys, Scotia Bay, Station 325. 1903. Two small females, the larger 3·5 mm. long.

These specimens certainly belong to this genus, and probably to HASWELL's species;

but as they are both females of small size, and perhaps not fully mature, the identification is not free from doubt. They agree generally with the description of the species in *Das Tierreich Amphipoda*, but appear to differ in the following points :—

The upper antenna is rather longer and stouter than the lower ; the flagellum is very small, and consists of one short joint and two, or perhaps three, very minute ones.

The lower antenna has the fifth joint of the peduncle a little longer than the fourth, and both considerably longer than the third ; the flagellum consists of one small joint, followed by one or more very minute ones. There are no serrations to be seen on the lower antenna, the animal in this point agreeing with the description.

The mouth parts were not examined.

The first gnathopod is long and slender, agreeing well with the description.

The second gnathopod has the carpus as long, and at distal end as broad, as the propod. The inner branch of the third uropod scarcely reaches beyond the extremity of the preceding uropods ; its upper margin is minutely serrulate ; the outer branch is more slender, and is about two-thirds as long. Very minute serrulations are present on the inner branches of the first and second uropods also.

The telson apparently agrees with the description, but could not be fully examined.

It is perhaps doubtful if this species is really distinct from *C. pusilla* (Grube), from the North Atlantic and the Mediterranean, but the *Scotia* specimens appear to differ from it in the proportions of the joints of the lower antenna, and in the absence of serrations on the peduncle. On the other hand, the second gnathopods and the uropods agree quite as well, or perhaps better, with *C. pusilla* than with *C. brazieri*. Another species, *C. hamifera* Kossmann, has been recorded from the Red Sea, but is thought to be probably an immature male of *C. pusilla*. All the three species were combined under the name *C. pusilla* by Della Valle in 1893.

C. brazieri was described from the east coast of Australia. I have taken a specimen in Otago Harbour, New Zealand, that probably belongs to the same species ; in the living animal the eye was red as in *C. pusilla*.

Genus Liljeborgia Bate, 1862.

Liljeborgia dubia (Haswell).

Eusirus dubius Haswell, 1880, p. 331, pl. xx. fig. 3.
Liljeborgia dubia Stebbing, 1906, p. 233, 1910A, p. 638, and 1910B, p. 454.
" " Walker, 1907, p. 35.
" " Chilton, 1909A, p. 619.

South Orkneys, Scotia Bay, Station 325 ; dredge, 9–10 fathoms. June 1903. One imperfect specimen, anterior half of body only ; the length of the whole animal would be fully 15 mm.

This fragment seems to belong, without doubt, to this species ; it agrees in the peduncles of the antennæ and in the narrower basal joints of the third to fifth peræopods. In these characters it differs from *L. consanguinea*, which has been taken off South Africa and at Kerguelen and Heard Islands.

Another species, *L. æquabilis*, described by STEBBING, 1910A, pp. 588 and 638, from Australian seas, seems to be closely allied, and all three species present many points of resemblance to *L. fissicornis* (Sars), found in the Arctic and North Atlantic Oceans.

L. dubia is now known from Australia, New Zealand, South Victoria Land, the South Orkneys, and South Africa.

From Mangareva Island, Gambier Archipelago, M. CHEVREUX has described a species, *L. proxima*, 3 mm. long, which is, he says, very near to *L. pallida* (Sp. Bate) and *L. brevicornis* (Bruzelius). It seems also to be very close to *L. dubia* or to *L. æquabilis*, the latter of which is, according to STEBBING, in close agreement with *L. brevicornis*.

Genus EPIMERIA.

Epimeria macrodonta Walker.

Epimeria macrodonta Walker, 1906, p. 16, and 1907, p. 24, pl. viii. fig. 14.

Coats Land, Station 411; trap, 161 fathoms; lat. 74° 1′ S., long. 22° W. 10th March 1904. One specimen, 25 mm. long.

This specimen must, I think, undoubtedly belong to WALKER's species, but it differs a little in the arrangement of some of the numerous teeth. The first segment of the peræon has a short dorsal tooth and a small lateral tooth; there are no teeth on the short second segment; the other segments of the peræon and those of the pleon bear dorsal and lateral teeth as described by WALKER. The first segment of the urus bears a strong dorsal tooth as described, but on the second segment there is a tooth placed a little laterally on each side on the posterior margin, and there is a lateral carina ending in sharp teeth on the third segment. The first joint of the peduncle of the first antenna bears a long tooth on the under side at the extremity, in addition to the two lateral teeth; the inner tooth on the second joint is much longer than the outer one. The eye is large, round, and projects as a hemisphere from the side of the head; in the spirit specimen it is yellowish in colour.

This species seems to come near to *E. loricata* Sars, which is widely distributed in northern seas, and appears to differ only in the arrangement of the teeth on the pleon and urus, and in the acuteness of the dorsal teeth—points which are probably subject to variation.

Mr WALKER's specimens were from the Winter Quarters of the *Discovery* in M'Murdo Strait, South Victoria Land.

Genus PARIPHIMEDIA Chevreux, 1906.

Pariphimedia integricauda Chevreux.

Pariphimedia integricauda Chevreux, 1906A, p. 39, fig. 25, and 1906B, p. 39, figs. 21–23.

South Orkneys, Scotia Bay, Station 325; shore pools. 4th February 1904. Temperature 32°–35°. One specimen, 13 mm. long.

South Orkneys, Scotia Bay, Station 325; dredge, 4 fathoms, gravel bottom and clumps of weed. 3rd December 1903. Temperature 29°·1. One specimen, 11 mm. long.

These specimens agree well with M. CHEVREUX's description and figures so far as the external characters are concerned. I have not examined the mouth parts in detail. His specimens were obtained at Wandel Island.

Genus ACANTHONOTOZOMA Boeck, 1876.

Acanthonotozoma australis, sp. nov. (Pl. II. fig. 19.)

Scotia, 18th March 1904. Lat. 71° 22′ S., long. 16° 34′ W.; 1410 fathoms. Station 417. One female specimen; length of body (head to base of telson), 35 mm.

Head and anterior six segments of peræon dorsally rounded; last segment of peræon, the three segments of pleon, and first of urus dorsally carinate. On the first four of these the carina forms a large tooth produced acutely backwards; on the first segment of the urus it is confined to the posterior half of the segment, and is preceded by a slight notch, the whole of the portion in front of which is folded under the preceding segment when the body is fully extended. The carina itself is convex anteriorly, and produced backwards into a very acute point (fig. 19).

Head broad, dorsally convex, curving slightly downwards in front, and ending in a short acute rostrum reaching about half way to end of first segment of upper antenna; lateral margin with a short subacute process below the upper antenna, and with the lower margin produced anteriorly into a rounded process and separated from the rest of the head by a slight furrow.

First side plate produced anteriorly, with anterior angle rounded and posterior angle quadrate; second, anterior angle rounded, posterior subacute; third, much deeper than first and second, posterior angle produced, almost acute; fourth, posterior angle produced acutely inferiorly, the posterior process between the two emarginations subacute; fifth, anterior lobe regularly round, posterior lobe a little deeper, acute, and with a groove below for basal joint of peræopod; sixth, similar, but with anterior lobe smaller and concealed by the fifth side plate; seventh, small and rounded. Lower border of first pleon segment rounded below, the second with lower margin straight and posterior angle produced acutely; both with an oblique ridge running towards the posterior angle. Third segment similar to the second segment, but without ridge.

Eyes completely absent. Upper antennæ reaching considerably beyond peduncle of lower. First joint of peduncle very stout, produced at inner upper angle into a long acute spine reaching beyond the end of second joint, and with a blunter and shorter spine on under outer side; second joint produced into subacute spine on the outer side; third joint with small spines on the outer and inner sides, the outer one tipped with setæ, flagellum longer than peduncle, rather stout, especially towards base, and having some of the basal joints slightly produced below and bearing the sensory setæ.

Lower antennæ as long as head and first five segments of peræon; last joint of peduncle somewhat compressed laterally, longer than preceding, which is slightly keeled above and produced at the extremity.

First gnathopod simple, fairly stout; carpus much broader and longer than propod; the lower margin of merus, carpus, and propod spinose. Second gnathopod similar to first in size and form.

First and second peræopods longer than gnathopods and somewhat slender. Third peræopod much longer than second, its basal joint narrow, with ridge running down the middle of outer side; propod much longer than carpus. Fourth peræopod similar to third, but considerably longer; lower posterior angle of basal joint quadrate and not produced. Fifth peræopod much longer than the fourth; basal joint broader, produced posteriorly at upper part into a rounded lobe below which the margin is deeply concave; postero-inferior angle produced into an acute point reaching almost as far as the end of the ischium.

First uropod with base much longer than the subequal branches and grooved above; branches narrow-lanceolate, ending acutely, the outer one folded in under the inner.

Second uropod similar, but with peduncle as long as inner branch; the outer branch not much more than half the length of inner. Third uropod with peduncle very short, produced above on outer margin into an acute spine which reaches as far as the end of the telson; the two branches subequal, narrow-lanceolate, flat, the outer one folded under the inner. Telson flat, laminar, scarcely narrowed, emarginate posteriorly.

On the whole, this species seems to come fairly well under *Acanthonotozoma*, though it would not be difficult to find points in which it does not quite fit the generic description. Both gnathopoda are simple, but the first is neither slender nor feeble. The mouth parts have not been examined in detail, but do not appear especially drawn out for piercing; the palp of the mandible is slender, that of the maxilliped is small and slender, and shorter than the very large outer plate, which is much larger than the inner plate.

Genus LEPTAMPHOPUS G. O. Sars, 1893.

Leptamphopus novæ-zealandiæ (G. M. Thomson).

Pherusa novæ-zealandiæ G. M. Thomson, 1879, p. 239, pl. x.c, figs. 2, 2*a–c*.
Panoplœa debilis G. M. Thomson, 1880, p. 3, pl. i. fig. 3.
Oradarea longimana Walker, 1903A, pp. 40 and 56, pl. x. figs. 77–89.

Oradarea longimana Walker, 1907, p. 32.
" " Chevreux, 1906B, p. 54.
Leptamphopus novæ-zealandiæ Stebbing, 1906, pp. 294 and 727.
" " Chilton, 1909A, p. 621.

South Orkneys, Scotia Bay, Station 325. 1903. A few specimens.

This species is widely distributed in Antarctic and sub-Antarctic seas. It very closely resembles *Djerboa furcipes*, except in the telson, which is undivided. Fuller details concerning it will be found under the last reference given above.

Genus HALIRAGOIDES O. Sars, 1893.

Haliragoides australis, sp. nov.

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. May 1903. A few small specimens, about 3 mm. long; all very delicate and fragile.

The specimens are almost too delicate and fragile to allow of a full description, but there is no doubt that they belong to this genus, and that they come pretty close to *H. inermis* (O. Sars) from the northern seas. They appear to differ in having the first and second segments of the pleon slightly produced backwards into a small dorsal tooth; the postero-lateral angle of the third pleon segment is produced to a small acute tooth. The head has a more distinct rostrum curving considerably downwards; the eye is large, well-developed, oval, but colourless in spirit specimens. The first gnathopod differs in having the propod somewhat narrowed at the base and the palm slightly shorter than the hind margin. In all other points that can be observed the specimens seem to be very close to *H. inermis.*

The occurrence of this species at the South Orkneys adds another to the list of cases where a northern species of a genus is represented in the south by the same species or by one closely allied.

Genus EUSIRUS Kröyer, 1845.

In order to make clear what is now known about the species of *Eusirus* from sub-Antarctic seas it seems desirable to give the following historical account:—

In 1880 G. M. THOMSON identified specimens from New Zealand with the northern species *E. cuspidatus* Kröyer, but distinguished them as a new variety, *antarctica.*

In 1888 STEBBING examined two specimens collected by the *Challenger*, one from Kerguelen and the other from Heard Island, and referred them to *E. longipes* Boeck, another northern species, saying that they were distinguished from *E. cuspidatus* by the absence of the spine-teeth from the apex of the second joint of the maxilliped palp.

In 1893 SARS in identifying specimens from the Lofoten Isles with *E. longipes* gave the points which he considered distinguish it from the other species, and said that the form recorded under this name from the *Challenger* Expedition is scarcely identical with BOECK's species.

In the same year Della Valle included all the forms mentioned above under *E. cuspidatus.*

In 1903 Walker described a new species, *E. lævis,* from the *Southern Cross* Expedition, and said: "It may be easily distinguished from the other known species by the absence of dorsal teeth on the segments and by the entire margins of the third metasome segment and the first joints of the peræopoda. From *E. cuspidatus,* var. *antarctica,* Thomson, it is separated by the conspicuous dactylus of the maxillipeds."

In 1906 Stebbing combined the *Challenger* specimens with those described by Thomson, and gave them under the name *E. antarctica,* thus raising Thomson's variety to the rank of a species. In describing it he says it is "exceedingly like *E. propinquus*"—another northern species.

In 1907, from the National Antarctic Expedition, Walker examined many specimens of *Eusirus,* some of them of large size. These he referred to *E. propinquus* G. O. Sars, giving a few points in which they differ, but stating that these are due to age. At the same time he described another new species, *E. microps,* "recognisable by the relatively small eyes and slender hirsute legs. From its nearest ally, *E. holmi* H. J. Hansen, it differs in the structure of the gnathopoda." He makes no further comparison of these specimens with either *E. antarctica* or *E. lævis.*

In the same year Chevreux described two specimens obtained by the French Antarctic Expedition as the male and female of a new species, *E. laticarpus.*

It will thus be seen that the question is already pretty complicated, and that the path of anyone endeavouring to identify species of *Eusirus* from Antarctic seas is by no means free from difficulty.

Eusirus antarcticus G. M. Thomson.

Eusirus cuspidatus, var. *antarctica,* G. M. Thomson, 1880, p. 4, and 1881, p. 26.
„ *longipes* Stebbing, 1888, p. 965, pl. lxxxvii.
„ *antarcticus* Stebbing, 1906, p. 340.
„ *propinquus* Walker, 1907, p. 30.
„ *laticarpus* Chevreux, 1906B, p. 149, figs. 27–30.
(?) „ *lævis* Walker, 1903A, p. 55, pl. x. figs. 70–76.

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. June 1903. One male, not well preserved.

Station 201, lat. 59° 43′ S., long. 30° 44′ W.; in clear water among floe, surface. 13th February 1903. Temperature 30°·1. One female.

Off Coats Land, lat. 72° 31′ S., long. 19° 00′ W.; vertical net, 1–1000 fathoms. 5th March 1904. Temperature 30°. One female.

Station 411, Coats Land, lat. 74° 1′ S., long. 22° W.; 161 fathoms. One specimen.

These specimens agree in nearly all respects with the description given by Chevreux of *E. laticarpus.* The females agree with his, and differ from the male in the much longer and more slender antennæ and in the greater depth of the cleft in the telson; the eye is rather small, oval, or very slight reniform. These specimens are therefore somewhat different from the specimens from Kerguelen Island described by STEBBING in the *Challenger* Reports. I think, however, that CHEVREUX is right in considering the two specimens examined by him as male and female of the same species, for, in addition to the female specimens of which I have spoken above, I have one specimen from Station 325 which by the character of the antennæ is almost certainly a male, and it agrees very closely with the form described by CHEVREUX as the male. It has the teeth at the end of the antennal joints a little longer than is shown in his figures, but they are arranged in the same way, and the difference in degree is probably due to age. This specimen, like his, has the eyes large, oval, and, in the spirit specimen, of a reddish-brown colour. I have carefully compared it with the full description given by STEBBING of the *Challenger* specimens, and it agrees minutely in everything except that the telson is less deeply cut. My specimen is, however, about 12 mm. long, while his is only 7·5 and was probably immature. This seems to be confirmed by the fact that the antennæ in it are not modified in the special way described by CHEVREUX. In the young male we would naturally expect to find the telson more like that of the female. WALKER also has stated that the cleft in the telson becomes shallower in older forms.

From the resemblance of my specimens to those described by CHEVREUX, and of the male to STEBBING'S, I cannot help coming to the conclusion that *E. laticarpus* must be specifically identical with *E. antarcticus*.

To this species must, I think, be added the forms referred by WALKER to *E. propinquus*. I have been fortunately able to examine two specimens obtained by the *Nimrod* in the same locality as WALKER'S specimens, and I cannot find sufficient differences to separate them from the *Scotia* specimens. They are 7·5 mm. long, and appear to be males, having the antennæ short and provided with calceoli; the eyes are nearly round, of moderate size, and the telson has the cleft deeper—nearly as deep as in the form figured by CHEVREUX as the female. The other characters agree very closely, and the points of difference noted are probably due to age. The back of the pleon and of the posterior portion of the peræon is somewhat scabrous.

STEBBING has given the apparent absence of calceoli as one of the characters of *E. antarcticus*, but I expect they will, as in so many other species, be found to be normally present in fully mature males. They are certainly present in my *Nimrod* specimens, though, as stated above, these specimens may be more or less immature; the calceoli are, however, extremely delicate, and appear much more elongated than is usually the case, and a character that is much more easily observed is the downward projection of every second joint of the flagellum as described and figured by CHEVREUX. The male specimen from Station 325 is not in a sufficiently good state of preservation (having apparently been partially dried) to show the calceoli, but the antennæ show the other modifications of the male. WALKER makes no mention of calceoli in his specimens, nor of the sexual differences, but states generally that the length of the flagellum of the antennæ and of the cleft in the telson varies with age.

It will be seen that, as STEBBING points out, this Antarctic species is very close to *E. propinquus* of northern seas, and probably WALKER is correct in definitely identifying it with that species; the resemblance, however, to other northern species, *e.g. E. longipes*, is also very close, and I think it will be better in the meantime to leave the southern form under a distinctive name. The differences between all the described species of the genus are very slight, and probably further research will lead to a reduction of the number.

E. lævis Walker was described from a single specimen, the size of which is not given; from the shortness of the flagella of the antennæ and of the projections of the carpus, and from the absence of dorsal teeth, it seems likely that it was an immature specimen, perhaps belonging to this species.

With regard to *E. microps* Walker I do not feel able to express any definite opinion; some of the specimens were of large size, and the long antennæ would indicate that they were females, but, on the other hand, the telson is only very slightly cleft.

M. CHEVREUX has recently (1911B, p. 405, fig. 3), described another species, *E. bouvieri*, from the South Sandwich Islands, but in view of the variations in this species described above, it seems doubtful if the differences noted in the dorsal margin of the first segment of the urus, and in the smaller depth of the cleft of the telson, are of very much importance. His single specimen was an ovigerous female, but has the short antennæ which appear to be the mark of the male as pointed out by CHEVREUX himself in *E. laticarpus.*

Eusirus splendidus, sp. nov. (Pl. II. fig. 20.) *

South Orkneys, Scotia Bay, Station 325. 15th August 1903. 54 fathoms. Two specimens, both males: No. 1, 30 mm., No. 2, 35 mm. in length of body.

First four segments of peræon slightly compressed; hinder portion of body much compressed, carinate, with pronounced dorsal teeth projecting backwards on the three last segments of peræon and on the three segments of pleon; first segment of urus with dorsal depression followed by slight carina on the posterior portion; second and third rounded. Side plates 1–4 slightly deeper than their respective segments; first produced anteriorly into a rounded lobe reaching nearly to anterior margin of head, its posterior angle with two or three teeth; second and third rounded below, with two or three small teeth at the posterior angle; fourth broader, its posterior margin produced into a subacute lobe below the fifth, lower margin rounded, posterior margin below production serrate; fifth with the posterior lobe deeper than the anterior; sixth with the posterior lobe produced downwards, much deeper and broader than the anterior; seventh, small, rounded below, not divided into lobes. Epimeral plate of the first pleon segment narrowly rounded below; second, much broader, rounded anteriorly, posterior

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* Probably the same as *Eusirus perdentatus* Chevreux (*Bull. Muséum Hist. Nat.*, 1912, No. 4, p. 10).

angle quadrate and very slightly produced; third, rounded anteriorly, inferior margin slightly convex, posterior more strongly convex, posterior angle quadrate (fig. 20).

Eyes large, prominent, oval, less darkly pigmented in the larger specimen. Upper antennæ more than half the length of the body, first segment stout, with sharp tooth below and smaller lateral teeth at its extremity; second as long as the first, but much more slender, ending in numerous sharp teeth which are almost as long as the third joint; third joint very short, also ending in sharp teeth; flagellum much longer than the peduncle, many-jointed, each second joint produced below and bearing calceoli in addition to other setæ, proximal joints very short; accessory flagellum slender.

Gnathopoda similar to those of *E. antarcticus*, but with the propod broader; second gnathopod slightly larger than the first; first and second peræopoda very slender, longer than the gnathopoda; third, fourth, and fifth pairs increasing in length, the fifth being about as long as the peræon and pleon combined. First uropod with outer branch about two-thirds the length of the inner, which is as long as the peduncle; second with outer branch half the length of the inner and as long as the peduncle; third with peduncle short, branches subequal and slender; telson more than twice as long as the peduncle of third uropod, very narrow, with two slight lateral ridges on the upper surface and a shallow central groove between them; cleft not more than one-sixth the length, the two posterior lobes very acute and widely divergent.

Length of body: up to 35 mm.

It is only with great reluctance that I establish this new species, but the compression of the hinder part of the body and its production into carinal teeth is carried to a much greater degree than in any of the species of *Eusirus* known to me. In all the specimens of *E. antarcticus* only the pleon segments are produced into teeth, with occasionally a small tooth on the last segment of the peræon; and until transitional forms are known it will, I think, be safer to rank the present specimens as a separate species. There are also some differences in the uropoda, but whether these are merely associated with age or not I cannot say.

The general resemblance to *E. antarcticus* in the appendages is, however, so great that I should not be surprised if it proves ultimately to be a special form of that species. Walker has, however, had larger specimens before him which apparently showed only the normal amount of carination.

Genus Eurymera Pfeffer, 1888.

Eurymera monticulosa Pfeffer.

Eurymera monticulosa Pfeffer, 1888, p. 103, pl. i. fig. 3.
„ „ Stebbing, 1906, p. 357.
„ „ Chevreux, 1906B, p. 59, figs. 34–36.

South Orkneys, Scotia Bay, Station 325; dredge, 4 fathoms, gravel bottom, clumps of weed. 3rd December 1903. Temperature 29°·1. One specimen, imperfect, 15 mm.

This agrees well with the descriptions given by PFEFFER and CHEVREUX, except that the third uropod does not extend much beyond the others. In the upper antennæ every second joint of the flagellum is slightly expanded below and bears sensory setæ, thus having somewhat the appearance of the flagellum in *Paramœra austrina*; in this character the antennæ agree exactly with the original description given by PFEFFER.

I have been able to compare my specimen with those in the Hamburg Museum originally described from South Georgia by Dr PFEFFER, and thus to confirm the identification.

M. CHEVREUX records the species from Booth Wandel Island.

Genus BOVALLIA Pfeffer, 1888.

Bovallia monoculoides (Haswell).

Atylus monoculoides Haswell, 1880, p. 327, pl. xviii. fig. 4.
Bovallia gigantea Pfeffer, 1888, p. 96, pl. i. fig. 5.
„ „ Chevreux, 1906B, p. 54, figs. 31–33.
„ „ Stebbing, 1906, p. 357.
Eusiroides monoculoides Stebbing, 1906, p. 345, and 1910A, p. 595.
„ „ Chevreux, 1908, p. 475.
„ *crassi* Stebbing, 1906, p. 346, and 1910A, p. 594.
„ *cæsaris* Stebbing, var. Walker, 1904, p. 264, pl. iv. fig. 22.
Bovallia monoculoides Chilton, 1909A, p. 622.

Several specimens from shore pools and moderate depths at South Orkneys, Scotia Bay, Station 325. Largest specimen 37 mm. long.

These specimens agree well with the descriptions of *Bovallia gigantea* given by PFEFFER and CHEVREUX. They have the last segment of the peræon and the first two segments of the pleon carinate and produced into an acute dorsal tooth; the third segment of the pleon bearing a blunt tooth. In smaller specimens these teeth are less marked. They thus agree also with the description originally given by STEBBING for *Eusiroides cæsaris*, but they differ from it in having the posterior margin of the third segment of the pleon slightly convex and without serrations. The accessory flagellum of the first antenna is present, but is small, and appears to be united with the third joint of the peduncle much in the same way as I have described for the specimens of *Atylus megalophthalmus* Haswell, which are now considered to be a form of the widely spread *Paramœra austrina* (Bate).

Through the kindness of the authorities of the Hamburg Natural History Museum, I have been able to examine co-types of *Bovallia gigantea* Pfeffer from South Georgia. These are larger than the largest *Scotia* specimens, and the dorsal teeth are slightly less acute, but there is no difference of any importance. That the dorsal teeth are subject to considerable variation was already known from their varying development in the three species of *Eusiroides* originally described by STEBBING. Two of these, *E. cæsaris* and *E. pompeii*, were united by STEBBING in the *Das Tierreich Amphipoda*, and identified with *Atylus monoculoides* Haswell. In 1909 I urged reasons for uniting with it the third species also, *i.e. E. crassi*, and pointed out the identity of the whole with *Bovallia gigantea.*

About the same time STEBBING independently examined additional specimens from Australia, and, speaking of *E. crassi*, said: "Whether this can be retained as a species distinct from *E. monoculoides* seems doubtful."

The amount of serration on the posterior margin of the third pleon segment may be considerable, as in the form described under the name *E. cæsaris*, or may be altogether absent, as in the specimens now before me. This variation has already been referred to by STEBBING, WALKER, CHEVREUX, and myself, and need not be further discussed.

Along with some of the specimens which he described under the name "*E. cæsaris* Stebbing, *var.*" WALKER found an ovigerous female, 5 mm. long, which with some hesitation he described as a new species, *E. orchomenopsis*, the main difference being that in the third uropoda the outer branch is much the longer and has a terminal joint. Mr WALKER is disposed to think that, though sexually mature, this specimen has not attained the full mature characters.

Genus PONTOGENEIA Boeck, 1871.

Pontogeneia danai (G. M. Thomson).

Atylus danai G. M. Thomson, 1879, p. 238, pl. x.c, fig. 1.
„ *lippus* Haswell, 1880, p. 328, pl. xx. fig. 1.
Eusiroides lippus Stebbing, 1906, p. 346.
Pontogeneia danai Stebbing, 1906, p. 360.
„ „ Chilton, 1912, p. 130.

Falkland Islands, Cape Pembroke, Station 118; among calcareous algæ. January 1903. Several specimens, some poorly preserved, the largest 6 mm. long.

Some specimens appear to have been partially dried, and it is not easy to make out the necessary points in the antennæ with certainty, but others better preserved show that they differ from the next species in having every fourth or fifth joint of the flagellum of the upper antennæ produced below and crowned with a tuft of sensory setæ; in *P. antarctica* every *third* joint is dilated to a less extent. In both species the dilatations are closer together on the six or seven basal joints of the flagellum. In the present species, too, the antennæ are more nearly equal in length, the gnathopoda are more slender, and the telson is perhaps rather more deeply cleft. The differences—particularly the one last mentioned—are all rather slight.

I have been able, since the above paragraph was written, to compare the Falkland Island specimens with specimens of *P. danai* G. M. Thomson from New Zealand, and think they must be considered the same. In the Falkland Island specimens the peduncle of the upper antenna bears rather longer setæ on the under surface, but it also bears on that surface a number of calceoli on slight projections, giving a scabrous appearance which is well marked in the New Zealand specimens.

Mr Stebbing has put *Atylus lippus* Haswell down as a doubtful species of *Eusiroides*, but I have specimens from Sydney Harbour that I think certainly belong to Haswell's species, and these I cannot distinguish from the species common on New Zealand coasts which was described as *Atylus danai* by Mr Thomson. The species is therefore now known from Australia, New Zealand, and the Falkland Islands, and probably extends round the globe in sub-Antarctic seas.

Pontogeneia antarctica Chevreux.

Pontogeneia antarctica Chevreux, 1906a, p. 72, fig. 2, and 1906b, p. 69, figs. 40 and 41.
" " Chilton, 1909a, p. 624.

South Orkneys, Scotia Bay, Station 325; in shore pools and at moderate depths. Several specimens, the largest 6 mm. long.

These specimens agree well with Chevreux's description, and can be distinguished from the preceding most easily by the character of the upper antennæ, as described above.

Though this species seems to be a true *Pontogeneia*, yet in the somewhat slender antennæ it makes some approach towards the genus *Paramœra*, and at the end of the third joint of the upper antenna there is a short process tipped with one or two long hairs that appears to represent a vestigial accessory flagellum, but it is fused with the third joint of the peduncle somewhat as appears to be the case in *Atylus megalophthalmus* Haswell, which is looked upon as a variety of *Paramœra austrina* (Bate). *Pontogeneia antarctica* is, however, clearly distinguished from *Paramœra* by having every *third* joint of the primary flagellum expanded below, instead of every second, and also by the lobes of the telson being rounded posteriorly.

The species is known from Auckland and Campbell Islands, from Flanders Bay and Booth Wandel Islands, as well as from the South Orkneys, and thus appears to represent *P. danai* in colder and more southerly seas.

Genus Atyloides Stebbing, 1888.

Atyloides magellanica (Stebbing). (Plate I. fig. 18.)

Atylopsis magellanica Stebbing, 1888, p. 925, pl. lxxix.
Pontogeneia magellanica Stebbing, 1906, p. 360.
" " Walker, 1907, p. 33, pl. xii. fig. 20.
" " Chevreux, 1906b, p. 64, figs. 37–39.
Atyloides magellanica Chilton, 1909a, p. 627.

South Orkneys, Scotia Bay, Station 325; shore pools. 2nd February 1904. Temperature 32°–35°. Numerous specimens, the largest about 10 mm. long.

These agree well with the description of this species given by Chevreux. It is evident that the telson varies to some extent. Chevreux figures it with a seta arising from a slight notch on each half. Walker says "the divisions of the telson are smooth and rounded at the tips," and shows it with the sides converging and convex, without terminal setæ or notch. In one specimen I find one half with a notch and the other without (Plate I. fig. 18); in others it closely resembles the figure given by CHEVREUX.

The species is found in all sub-Antarctic seas.

Atyloides serraticauda Stebbing.

Atyloides serraticauda Stebbing, 1888, p. 920, pl. lxxviii., and 1906, p. 36.
" " Walker, 1907, p. 33.
" " Chevreux, 1906B, p. 87.
" " Chilton, 1909A, p. 627.
(?) *Schraderia gracilis* Pfeffer, 1888, p. 141, pl. ii. fig. 5 (no description, only one figure).

South Orkneys, Scotia Bay, Station 325; shore pools. 2nd February 1904. A few specimens, the largest 12 mm. long.

In fully grown specimens this species may be recognised by the long antennæ, gnathopoda, and peræopoda, and particularly by the serrations on the side plates and on the hinder margin of the third pleon segment. These serrations may, however, be almost completely absent in smaller specimens, and the species is by no means so easy to recognise, and the identification then depends mainly on the telson.

Schraderia gracilis was named in 1888 by PFEFFER, but not described, only a general figure of the whole animal being given. This figure without drawings of the separate appendages is quite insufficient for identification in this group, which contains so many species very nearly alike in general appearance; and as it is not now possible to ascertain from which individual specimen the drawing was made, PFEFFER's species must remain doubtful. There are several specimens in the collection of the Hamburg Museum labelled "*Schraderia gracilis*," and these prove to belong to the species now under consideration, *Atyloides serraticauda* Stebbing.

The species is widely distributed in Antarctic and sub-Antarctic seas.

Atyloides calceolata, sp. nov. (Plate II. figs. 21–23.)

South Orkneys, Scotia Bay, Station 325; 10 fathoms. A few specimens, mostly imperfect, about 5 mm. long.

Specific Description.—Similar to *Atyloides serraticauda* in general shape of body, in the serrations on the anterior side plates, the posterior margins of the basal joints of the peræopoda, the posterior margin of the third segment of the pleon, and in the telson; differing mainly in the antennæ. The first antenna (fig. 21) with the first joint longer and considerably stouter than the second, its lower margin bearing distally an acute spine with another shorter spine placed laterally, a few long setæ near the end joint; second joint bearing on its under surface two well-marked calceoli of characteristic shape, one on a little prominence at a short distance from the proximal end and the other near the distal end, some fine setæ at the end of the joint; third joint short; the whole antenna about as long as the body.

Second antenna (fig. 21) with the gland cone very acute; the third joint short, produced inferiorly into one or two distal teeth, and with a spinule on the upper side; fourth joint twice as long as the third, bearing on its upper surface two calceoli, each on a slight projection similar to those on the second joint of the upper antenna, a few fine setæ scattered on both margins of the joint and at the distal end (rest of antenna missing).

Gnathopods (figs. 22 and 23) similar in general shape to those of *A. serraticauda*, but not quite so slender, the second gnathopod having the propod much longer than the carpus, sub-oblong, but expanding somewhat towards the palm, which is slightly oblique and defined by one or two small spinules, the whole of the long hind margin bearing short tufts or transverse rows of spinules.

The peræopoda similar to those of *A. serraticauda*; the third uropod rather short, branches not very much longer than the base, lanceolate, and bearing spinules and fine serrations on the margin; telson cleft for about two-thirds its length, each half oblong, posterior margin of each truncate and divided into about eight or nine fine teeth.

I have only a few specimens of this species, and in most of them portions of the antennæ and some of the other appendages are broken off; but the arrangement of the calceoli on the peduncles of the antennæ seems characteristic, and differs from that in any of the allied species known to me.

Genus PARAMŒRA Miers, 1875.

Paramœra austrina (Bate).

Atylus austrinus Spence Bate, 1862, p. 137, pl. xxvi. fig. 4.
Paramœra australis Miers, 1875, p. 75.
Atyloides australis and *A. assimilis* Stebbing, 1888, p. 914, pl. lxxv., and p. 918, pl. lxxvii.
Megamœra fasciculata G. M. Thomson, 1880, p. 5, pl. i. fig. 5.
Stebbingia gregaria Pfeffer, 1888, p. 110, pl. ii. fig. 7.
„ „ Stebbing, 1906, p. 358.
Paramœra austrina Stebbing, 1906, p. 363, 1910A, p. 640, and 1910B, p. 450.
„ „ Chilton, 1909A, p. 625.

Specimens of this species were obtained from the following stations:—

South Orkneys, Scotia Bay, Station 325; 10 fathoms.
„ „ Scotia Bay, Station 325A; dredge, 2–8 fathoms, gravel and clumps of weed; temperature 29°–30°. 6th December 1903.
„ „ Scotia Bay, Station 325; dredge, 9–10 fathoms. April 1903.
„ „ Scotia Bay, Station 325; dredge, 4 fathoms, gravel bottom and clumps of weed; temperature 29°·1′. 3rd December 1903.
„ „ Scotia Bay, Station 325; 5–10 fathoms; temperature 31°·5′. 2nd January 1904.
Falkland Islands, Station 118; shore. 7th January 1903.
„ „ Cape Pembroke, Station 118; shore pools. January 1903.
Gough Island, Station 461; trap, 75 fathoms. 21st April 1904.
„ „ Station 461; off floating kelp. 21st April 1904.

A special variety of the species was obtained as follows :—

South Africa, entrance to Saldanha Bay ; 25 fathoms. 21st March 1904.

This species is one that is very widely distributed in sub-Antarctic seas, and is usually found in shore pools or in shallow waters around the coast. It has been pointed out by several authors that specimens of it vary considerably ; probably when the different forms are carefully compared it may be possible to distinguish several local varieties, but I think, in the present state of our knowledge, that Mr STEBBING is right in uniting the various forms under this one name.

Through the kindness of the authorities of the Hamburg Museum I have been able to examine the type and other specimens of *Stebbingia gregaria* Pfeffer, and I find that they undoubtedly belong to this species. Several of them are of comparatively large size, but they show no distinction of importance from the ordinary form, and the small accessory flagellum of the upper antenna is present. Various authors have described this accessory flagellum as being absent in the specimens examined by them, and, though I have usually been able to find it, there are a few specimens that I have seen in which I have been unable to do so, although in all other points they seem to belong to the species; and there seems little doubt, as pointed out by WALKER and others, that in this as in some other species the small accessory flagellum may sometimes be actually absent; probably this is more commonly the case in older forms.

Of the local varieties I can at present indicate two :—

(1) The form described under the name *Atylus megalophthalmus* Haswell. In this form the head has a rostrum nearly half as long as the first joint of the upper antenna ; the accessory flagellum, though apparently present, is small, short, and fused to the third joint of the peduncle ; and the telson has the posterior portion of each lobe somewhat rounded and without setæ.

(2) The forms mentioned above from South Africa, Saldanha Bay. In general appearance, and in the antennæ and gnathopods, etc., these agree closely with forms from other localities, but they differ somewhat markedly in the telson, the posterior portion of each lobe of which is cut into three or four acute teeth and is without setæ. In some forms from other localities there may be two such teeth, but, so far as I know, not more, and the telson usually bears two or more long setæ on each lobe. The telson in the Saldanha Bay variety closely resembles that described by CHEVREUX for *Atyloides longicornis* from Port Charcot, etc., a species which appears to me to be little more than a variety of *Paramœra austrina* in which the accessory flagellum is absent and the gnathopods are rather small.

Even in the more typical forms there seems to be considerable variation in the size and shape of the gnathopods. In some the propod is oblong, with the palm almost transverse, as shown by Mr STEBBING in his drawings of *Atyloides australis* Miers; in others the propod is more oval, with the palm somewhat oblique; the length of the carpus is also subject to variation, and the setæ seem to be more abundant on the antennæ and gnathopods in some specimens than in others.

This species had been recorded from South Africa by Mr STEBBING under the name of *Atyloides assimilis*, from a specimen found on the screw of the *Challenger* off Cape Agulhas. Mr STEBBING's figure of the telson shows some approach to that of the Saldanha Bay specimens, but each lobe bears only two acute teeth.

Genus DJERBOA Chevreux, 1906.

Djerboa furcipes Chevreux.

Djerboa furcipes Chevreux, 1906B, p. 74, figs. 42–44.

South Orkneys, Scotia Bay, Station 325; 10 fathoms. (No date.) A few specimens, the largest 15 mm.

South Orkneys, Scotia Bay, Station 325; 15 fathoms. April 1903. Six specimens, the largest 18 mm. long.

These specimens agree well with the description and figures given by CHEVREUX. They bear a very close and striking resemblance to *Leptamphopus novæ-zealandiæ*, and it is very difficult to distinguish the two species without dissecting off the telson, which is deeply cleft in *Djerboa furcipes* but undivided in *Leptamphopus novæ-zealandiæ*; in the first species, however, the integument is marked by a number of short marks arranged more or less in parallel lines, and in doubtful cases this helps as a guide to their identification.

Genus PARACERADOCUS Stebbing, 1899.

Paraceradocus miersii (Pfeffer).

Megamœra miersii Pfeffer, 1888, p. 121, pl., fig. 3.
Paraceradocus miersii Stebbing, 1906, p. 429.
„ „ Chevreux, 1906B, p. 93.

South Orkneys, Station 325; from stomach of Weddell seal. 4th January 1904. One male, 45 mm. long.

South Orkneys, Station 325; dredge, 9–10 fathoms. 17th August 1903. One female, 22 mm. long; June 1903, one female, 20 mm.

In the large specimen all the segments of the peræon and pleon are rounded dorsally; the pleon is slightly compressed but not carinate; teeth are present on the first and second segments of the urus as described; the third uropods are missing. The female specimens also show no carination on the peræon or pleon, and have the third uropods of moderate size only. The upper antennæ are considerably longer than half the body; the second joint of peduncle is as long as the first, and the flagellum is considerably longer than the peduncle. In the lower antennæ the flagellum is longer than the last joint of the peduncle. Except for the absence of carination, the specimens agree closely with PFEFFER's description.

This fine species is now known from South Georgia, South Orkneys, Port Charcot, Booth Wandel and Hovgaard Islands.

Genus MÆRA Leach, 1813.

Mæra mastersii (Haswell).

Megamœra mastersii Haswell, 1880A, p. 265, pl. xi. fig. 1.
„ *thomsoni* Miers, 1884, p. 318, pl. xxxiv. fig. B.
Mæra mastersii Stebbing, 1906, p. 439.
„ „ Chilton, 1911, p. 594.

South Africa, entrance to Saldanha Bay, Station 483; 25 fathoms. Five specimens, the largest 10 mm. long.

Although they show some differences, I think these specimens may be referred to this species. On the whole they agree fairly well with HASWELL's description; and if the form described as *Megamœra thomsoni* by MIERS really belongs here, the species is evidently a variable one. My specimens differ from the description given by STEBBING in *Das Tierreich* in the following points:—The third segment of the pleon has the posterior angle produced so as to be acute, but the hind margin is hardly denticulate; the eyes are small, almost round; in the upper antenna the first joint has a stout spinule at its lower distal margin, the accessory flagellum contains seven joints; the flagellum of the second antenna is considerably longer than the last joint of the peduncle. In the first gnathopod the carpus and propod are hardly slender, each having the posterior margin convex and agreeing fairly well with HASWELL's description; this appendage shows considerable resemblance to that of *Elasmopoides chevreuxi* Stebbing, but the carpus and propod have the hind margins less strongly convex than in that species. The second gnathopod agrees well with the description. The third, fourth, and fifth peræopoda are fairly stout, the basal joint has the hind margin only finely serrated. The uropoda and the telson agree well with HASWELL's description. The specimens are colourless (in spirit) and do not show the light yellowish-brown colour mentioned by STEBBING, which was present in the Kermadec Island specimens I examined in 1911. In the rather stout peræopoda and in some other points they have rather the appearance of an *Elasmopus*.

This species is widely distributed in the warmer southern seas.

Genus PARADEXAMINE Stebbing, 1899.

Paradexamine pacifica (G. M. Thomson).

Dexamine pacifica G. M. Thomson, 1879, p. 238, pl. X.B, fig. 4.
Paradexamina pacifica Stebbing, 1906, p. 518.
„ „ Chilton, 1909A, p. 632.
Paradexamina fissicauda Chevreux, 1906B, p. 88, figs. 51–53.

South Orkneys, Station 325; 9–10 fathoms. April and May 1903. Four specimens, the largest 17 mm. long.

South Orkneys, Scotia Bay, Station 325; 2–8 fathoms, gravel and clumps of weed. Temperature 29°–30°. 6th December 1903. Several specimens, the largest 14 mm. in length.

These specimens are in most respects intermediate between *P. pacifica* and *P. fissicauda.* They agree with the latter species, except that the last segments of the peræon are without dorsal teeth, or, in the largest, with a small tooth on the last segment only. In this species, as in so many others, the dorsal teeth evidently vary, for STEBBING notes the same thing in his description of *P. pacifica.* The *Scotia* specimens have the lateral angle of the head rounded, as in *P. fissicauda,* and they resemble that species also in the greater stoutness and the proportions of the joints of the antennæ and peræopoda; the telson, however, is not split right to the base, but only very deeply, as in *P. pacifica.*

Through the kindness of Mr STEBBING I have been able to examine specimens of *P. pacifica* from New Zealand sent to him years ago by Mr THOMSON. The comparison of these with the *Scotia* specimens shows that it is not possible to maintain the two as separate species. In the carination of the body, in the uropoda and telson, the New Zealand specimens resemble those from the South Orkneys. They differ, however, in having the appendages slightly more slender; thus the upper antennæ may have the second joint of the peduncle considerably longer than the first, and in the peræopoda the propod may be nearly as long as the carpus, instead of being shorter, as described by CHEVREUX. In them, too, the lateral angle of the head is produced into a small, sharp, acute point.

If we had to deal only with the New Zealand specimens and those from Wandel Island, it might be possible to look upon the latter as a separate but closely allied species; but, if that were done, a new species would have to be made for the South Orkneys specimens, with characters almost precisely intermediate between those of the other two, while future examination of specimens from some fresh locality would probably necessitate the establishment of another intermediate species on very trivial points of difference. I therefore think it much the best course to consider all the specimens as belonging to one widely spread sub-Antarctic and Antarctic species which, through isolation, has become slightly modified into two or three local varieties.

Genus POLYCHERIA Haswell, 1879.

Polycheria antarctica (Stebbing).

Dexamine antarctica Stebbing, 1875, p. 184, pl. xv.A, fig. 1.
Polycheria tenuipes Haswell, 1880B, p. 345, pl. xxii. fig. 8.
„ „ Stebbing, 1906, p. 520.
„ *brevicornis* Haswell, 1880B, p. 346.
„ *obtusa* G. M. Thomson, 1882, p. 233, pl. xvii. fig. 3.
Tritæta kergueleni Stebbing, 1888, p. 941, pl. lxxxiii.
„ *antarctica* Walker, 1904, p. 266, pl. iv. fig. 25.

Polycheria antarctica Stebbing, 1906, p. 520.
,, ,, Walker, 1907, p. 34.
Tritæta osborni Calman, 1898, p. 268, pl. xxxii. fig. 2, and p. 288.
Polycheria atolli Walker, 1905, p. 926, pl. lxxxviii. figs. 1–5.

Entrance to Saldanha Bay, Station 483. One specimen, 6 mm. long.
South Orkneys, Scotia Bay, Station 325. Many specimens, all of small size, averaging 2 mm. in length.

The specimen from Saldanha Bay is, I think, specifically identical with the *Challenger* form described under the name *Tritæta kergueleni.* The eye is very large, occupying the greater part of the side of the head; the posterior angle of the third pleon segment is quadrate, with a very short tooth, and the pleon and urus have the carination described, though to a less degree; the antennæ agree with the description as regards the proportions of the joints, the lower being a little longer than the upper; the branches of the third uropods are slightly unequal.

In the large eye and in other essential points it also agrees with *P. tenuipes* Haswell, and with *P. obtusa* G. M. Thomson, whose description of the terminal joints of the peræopoda applies exactly to the specimen under consideration. In describing his specimen Mr Thomson pointed out that it was probably the same as *P. tenuipes* Haswell. On the other hand, the Saldanha Bay specimen differs from the Kerguelen Island one in the side plates, which are not so acutely produced anteriorly.

The specimens from South Orkneys are all small. The eye is of much smaller size, and the carination of the pleon is absent altogether or only slightly marked; the joints in the flagella of the antennæ are fewer in number, and the two antennæ are about equal in length; the outer branch of the third uropod is only about half the length of the inner; both the third and the fourth side plates are produced anteriorly into an acute lobe exactly like that figured by Stebbing for *P. antarctica* (1906, p. 520, fig. 91). In this respect, therefore, they differ from his description of *P. tenuipes*, with which they agree in some of the other points mentioned, for that species is described in *Das Tierreich Amphipoda* as having the fourth side plate reduced to a short, blunt lobe, this character being apparently taken from Calman's description of *P. osborni*, which Stebbing gives as a synonym of *P. tenuipes.*

These South Orkneys specimens are apparently immature, although the characteristic form of the terminal joints of the peræopoda and of the third and fourth side plates is already present, and I think there can be no doubt they belong to the same species as the Saldanha Bay specimen. In the smaller eye they resemble *P. brevicornis* Haswell, which does not seem to be separated from *P. tenuipes* by any other character of importance. Mr Walker (1907, p. 34) has pointed out that Haswell's description of the second gnathopod of *P. tenuipes* and of *P. brevicornis*, and his figure of that of the first species, are quite unlike those of *P. antarctica.* The figure is undoubtedly very rough and insufficient, but the descriptions, so far as they go, are not inconsistent with either the Saldanha Bay or the South Orkneys specimens before me, and these, as I have said, must, I think, be referred to *P. antarctica.*

STEBBING, in 1906, made *P. osborni* Calman a synonym of *P. tenuipes* Haswell, to which he also assigned *P. obtusa* G. M. Thomson and, with a "?", *P. brevicornis* Haswell.

In describing *P. osborni*, CALMAN referred to the southern species described, and said they "are probably all referable to one." If this is done, however, it will then certainly be impossible to retain his species as distinct. This will be seen if we take the points of difference in order :—

1. Dorsal processes of urus much less prominent. This applies also to the South Orkneys specimens, and, to a less degree, to the Saldanha Bay specimen.

2. Maxillipeds with outer plates nearly equalling the palp in length and bearing only about eleven spines. In the South Orkneys specimens the plates bear only eleven spines, though they are rather shorter than the palp. In *P. atolli*, too, WALKER describes the spines on the outer plate as few in number and present on the distal portion of the margin only.

3. Propod of first gnathopod with palmar edge short and not more than one-third the length of the dactyl. In the Saldanha Bay specimen the gnathopod agrees well with CALMAN'S description, except that the palm is perhaps a little longer. From the appearance of this specimen, however, I think the palm is really longer than is shown in CALMAN'S figure, and that the lobe against which the dactyl is represented as impinging is overlapped by the dactyl folding in on one side of it. If this is so, there is no essential difference between the palm of *P. osborni* and that of *P. antarctica* as figured by STEBBING under the name *P. kergueleni.*

CALMAN'S description of the second gnathopod agrees quite well with that of the Saldanha Bay specimen.

4. Fourth side plate having the anterior process reduced to a short, blunt lobe. This applies also to the Saldanha Bay specimen and to *P. atolli* Walker.

5. Propod of third peræopod not widening distally. Both the Saldanha Bay and the South Orkneys specimens agree in this point with CALMAN'S figure rather than with STEBBING'S; the difference is one of degree only, and the widening is probably more marked in older specimens.

In view of all the considerations mentioned above, I feel compelled to unite also *P. atolli* Walker, from the Male Atoll, Maldive Archipelago, with *P. antarctica.* His description of the gnathopoda and of the first and second peræopoda, and of the side plates corresponding to these appendages, applies very well indeed to the Saldanha Bay specimen and also fairly well to *P. osborni*; but in the fewer spines and teeth on the outer plate of the maxillipeds and on the uropoda, *P. atolli* agrees rather with the South Orkneys specimens. Its chief peculiarity seems to be the fact that the palp of the first maxilla has "the top squarely truncate and crowned with short teeth," but in view of the other characters this is hardly sufficient to maintain it as a separate species.

The very large eye (red in colour, at least sometimes) found in some of the forms is certainly a very striking characteristic, and if it were constantly associated with other characters or with certain localities it would be entitled to great weight; but some specimens have the large eye associated with side plates which are not acutely produced anteriorly, while in the Kerguelen specimen the eye is large (black in this case) and the side plates are acutely produced; again, both the large-eyed and the small-eyed forms are found together in Port Jackson. It is just possible that the large eye is a sexual character, or it may be developed in older specimens which live at moderate depths, as appears to be the case in *Eusirus antarcticus.*

I have thus failed to find the characters relied upon for specific distinction in this genus constantly associated in any definite way, and am forced to conclude that all the forms belong to one species widely spread in southern seas and found also in the North Atlantic and in the Indian Ocean.

In addition to the localities mentioned above, the species *P. antarctica* has more recently been recorded from Ceylon by Mr WALKER, so that the conclusion that we are dealing with one species only, first arrived at on morphological grounds, is now confirmed by the geographical distribution of the species.

After the discussion as given above had been written, I was able to visit the British Museum and examine there the types of the different species; Mr WALKER also kindly sent me a specimen of *P. atolli*, and in doing so said that he now considered it probably not distinct from *P. antarctica.* I was able at the Museum to examine the type slides of *Tritæta kergueleni* Stebbing and of *P. atolli* Walker, and also to examine named specimens of *P. osborni* Calman, *P. antarctica* from the *Discovery* Expedition, and of *P. antarctica* recorded from Ceylon by Mr WALKER. The slide of the dissected parts of the *Challenger* specimen of *Tritæta kergueleni* is not in very good condition, but it is evidently the one from which Mr STEBBING's excellent figures were made, and these are sufficient for our present purpose.

The type specimen of *P. atolli* has the first maxilla with short spinules on the palp as described, and the maxillipeds also correspond closely to the figure given, but in all other essentials it agrees with my Saldanha Bay specimen, both gnathopods closely agreeing, except that in the first the flange on the propod has the margin minutely serrate; the first and second peræopoda, again, have side plates similar to those in the Saldanha Bay specimen. An examination of *P. osborni* showed that this species also was the same as the Saldanha Bay specimen, and therefore the same as *P. atolli.* The side plate of the first gnathopod is produced in front a little more acutely than in the type of *P. atolli*, and is tipped with two small setæ; the side plate of the second gnathopod is also produced in front, but not so acutely as the first, and might be described as being narrowly rounded anteriorly; that of the first peræopod is acutely produced, while the second is rounded as described by CALMAN. The eye is large.

The *Discovery* specimens labelled *P. antarctica* undoubtedly agree specifically with STEBBING's type of *Tritæta kergueleni* in having the side plates all more or less acute, those of both the first and second peræopoda being acutely produced in front; the eye is large, showing a little colour in the spirit specimens and probably having been red in the living animal, but it is not so large as in the Saldanha Bay specimen. The terminal joints of the peræopoda are rather wide distally, as shown in STEBBING'S figure.

It seemed possible, therefore, that after all we might perhaps be dealing with two species: one *P. antarctica*, with side plates more or less acutely produced in front, the other *P. tenuipes* (including *P. osborni* and *P. atolli*), in which some of the side plates were rounded in front, although, as already shown, the differences did not appear to be constant. Considerable interest was therefore attached to the examination of the specimens from Ceylon referred by WALKER to *Tritæta antarctica*, to see if they were really distinct from *P. atolli*. It was found that in some points they are a little nearer to *P. antarctica* than the type specimen of *P. atolli* is; thus, for example, the side plates of the first gnathopod are acutely produced in front as in *P. antarctica*; the side plates of the second gnathopod, however, are rounded below. The side plates of the first and second peræopoda cannot be very clearly made out, but they appear to be fairly acute in front, though projecting rather more posteriorly than shown in STEBBING'S figure. In other points, however, these Ceylon specimens were clearly the same as *P. atolli*, and the eye is large and shows little colour in the spirit specimens. Consequently, after considerable hesitation, I was forced to remain at the conclusion at which I had previously arrived, that it is impossible to separate the various forms into two species. The species has more recently been recorded from the east coast of Africa by Mr WALKER under the name of *P. atolli*, and it was some confirmation of the conclusion I arrived at to find that specimens in the Museum from this locality, though recorded under the name *P. atolli*, were in the separate tube labelled by him *P. antarctica*.

It seems clear that here, as in other cases, we have one widely distributed species, most abundant in Antarctic and sub-Antarctic seas, but extending far to the north both in the Indian seas and in the Pacific, and that, although it is impossible to find constant characters for the separation of it into two distinct species, there are slight local differences, some showing one combination of characters, others another combination.

A small specimen of this species was among some undetermined Amphipoda, collected at South Georgia in 1882–83, that were submitted to me by the authorities of the Hamburg Museum.

[After the whole discussion of this species as given above had been written, I found further specimens from South Orkneys in a bottle of "residues" received in May 1912 from various collections made at Scotia Bay in 1903. Some of these specimens were larger than those from the South Orkneys mentioned above, the largest being about 5 mm. long. In the largest specimens the eye was very large, and red in colour, as in the Saldanha Bay and other specimens already referred to; in smaller specimens the eye showed intermediate sizes, though in none of those examined was it quite so small as in the small South Orkneys specimens first examined. The side plates seem to be acutely produced as described for *Tritæta kergueleni*; but in at least one specimen the anterior lobe of the second peræopod was only subacute, and was shorter than that in the first peræopod. In the third uropods the outer branch is about half as long as the inner; in both branches the extremity is narrowed, almost free from setæ, and curves upwards.

In these respects, therefore, these additional specimens tend to confirm the conclusion arrived at that all the forms of *Polycheria* are referable to one species. They present a peculiarity, however, in having the telson particularly long, reaching to the end of the third uropod; in side view it appears thick, scarcely narrowing distally, and the margin is fringed with stout spinules. In the smaller South Orkneys specimens it is much shorter, reaching hardly half way along the branches of the uropod, and the spinules on it are few and much less prominent. In the specimen figured in the *Challenger* Report the telson is intermediate, reaching more than half way to the end of the third uropod, and bearing numerous spinules. In the smallest of the additional specimens now being described it is hardly so long as in the largest, but still longer than in some *Discovery* specimens from M'Murdo Sound that are themselves larger in size. It seems probable that the especially long and strong telson is a character developed beyond the average, like the large eye, and that it attains its full size only in specimens of a definite age—possibly it lengthens rapidly at a particular moult.]

Genus Nototropis A. Costa, 1853.

Nototropis homochir (Haswell).

Atylus homochir Haswell, 1885, p. 101, pl. xiii. figs. 5–7.
Nototropis homochir Stebbing, 1906, p. 333, figs. 77 and 78.
„ „ „ 1910A, p. 639.
„ „ „ 1910B, p. 455.

South Africa, entrance to Saldanha Bay, Station 483; 25 fathoms. 21st May 1904. Several specimens, largest 10 mm. long.

These agree with Stebbing's description, except in a few small points: *e.g.* the third joint of the palp of the mandible is not longer than the second, but barely equal to it in length; the lower hind corner of the basal joint of the third peræopod (in the female) is slightly produced into a small subacute lobe; that of the fourth is not produced, but in the fifth peræopod it is produced as a subacute lobe reaching about to the end of the ischium.

The points which distinguish this species from some of those found in northern seas, *e.g.* from *N. vedlomensis* (Bate and Westwood), do not seem to be very great; it appears to differ from that species, however, in the amount of production of the basal joints of the peræopoda three to five, and in the size and arrangement of the carinate teeth on the pleon and urus. DELLA VALLE in 1893 united both these two species and several others under the name *Atylus swammerdamii* (Milne Edwards).

The southern species is known from Australia and South Africa.

Another species which appears to belong to this genus was described in 1862 by SPENCE BATE under the name *Atylus villosus*, from specimens obtained at Hermit Island in the South Atlantic by the Antarctic Expedition under Sir JAMES CLARKE ROSS.

Genus TALORCHESTIA.

Talorchestia scutigerula (Dana).

Orchestia scutigerula Dana, 1853 and 1855, p. 863, pl. lviii. fig. 2.
,, ,, Spence Bate, 1862, p. 26, pl. iv. fig. 7.
Talorchestia scutigerula Stebbing, 1906, p. 545.

Falkland Islands, near Port Stanley, Station 118; from banks of a fresh-water, peaty stream. 7th January 1903. Two males and three females, the largest male 15 mm. in length.

These specimens agree very well with the description as given in *Das Tierreich Amphipoda*. The large expansion on the second joint of the fifth peræopod is very striking, and is very similar to the expansion on the fifth joint in *Talorchestia telluris* (Bate).

The species is known from Tierra del Fuego as well as from the Falkland Islands, and it was taken at Hermit Island in the South Atlantic, during the Antarctic Expedition under Sir J. C. Ross in 1840.

Genus HYALE.

Hyale grandicornis (Kröyer).

Orchestia grandicornis Kröyer, 1845, p. 292, pl. i. fig. 2 *a–n*.
Allorchestes verticillata and *A. peruviana* Dana, 1855, p. 886, pl. lx. figs. 2 and 3.
Hyale grandicornis Stebbing, 1906, p. 566.

Gough Island, Station 461; shore. One male, 12 mm. long.

I refer this specimen to KRÖYER'S species without much doubt. It agrees minutely with the description of all its characters given by STEBBING in *Das Tierreich*, particularly in the pectination of the finger of the peræopoda; the setule on the finger is rather long and fairly distinct, but not strong. The hind margin of the basal joint of the fourth peræopod is furnished with small spinules as described, but they are very small, and they are also present, though not in quite such numbers, in the third and fifth peræopoda. Both the first and the second gnathopoda agree very closely with the description.

This species was described originally from Valparaiso, and *H. novæ-zealandiæ* (G. M. Thomson), which is found in New Zealand itself and in the sub-Antarctic islands lying to the south of it, appears to be almost the same.

Hyale saldanha, sp. nov. (Pl. II. figs. 24–29.)

South Africa, entrance to Saldanha Bay, Station 483; 25 fathoms. 21st May 1905. Several specimens, males and females, the largest about 9 mm. long.

Specific Description.—*Male.*—Back rounded, not carinate, and without dorsal teeth. Pleon segment three, with postero-lateral corner quadrate with slightly produced point. Eyes of moderate size, round. The first antenna (fig. 24) reaches to the middle of the flagellum of the second; peduncle with first joint much longer and broader than the second, and produced below at its distal end into a rather broad expansion, which appears to have a vertical flange, and at the lower part of this a thicker conical portion tipped with two setæ; second joint with a smaller similar expansion; flagellum of sixteen joints all bearing a fairly distinct tuft of long setæ at the lower distal angle. Second antenna (fig. 24) about one-third the length of the body; last two joints of the peduncle subequal; flagellum of about thirty-five joints. First gnathopod (fig. 27) with the basos rather broad except at the base; the carpus short, triangular, its posterior margin produced into a rounded fringed lobe; propod oblong, widening slightly distally, front margin convex and smooth, hind margin straight or very slightly concave, with a group of spinules at the centre; palm oblique, slightly convex, shorter than hind margin, defined by two stout spinules, the finger fitting closely up against the palm.

Second gnathopod (fig. 28) with basos expanded distally into a flange on the outer margin, ending in a rounded lobe at the extremity; ischium with a similar rounded process; merus short, its apex subacute; carpus very short, fitting closely into the emargination on the base of propod; propod large, oval, slightly narrowing distally, its anterior border regularly convex and smooth; palm oblique, longer than the hind margin, straight except for a rounded process near the base of the finger, fringed with a double row of short spinules and defined by two stout spines; finger stout, fitting into a small pocket at the end of the palm. Peræopoda one to five robust; propod slightly curved, especially in the last three pairs, its concave margin bearing at regular intervals three stout spinules of about equal size, all minutely serrated towards the end, but without a specially large serrated spine; posterior border of propod unarmed; finger strong, about half the length of the propod, much curved, inner setule very small; in the third peræopod (fig. 29) the basos is rounded, projecting inferiorly as far as the end of the ischium, in the fourth and fifth similar, but in the fourth the basos is slightly narrower than in the third and fifth; hind margins of basos in all either smooth or only faintly crenulate. Uropoda short, the first with peduncle about as long as the branches, and with two or three spinules along its lateral margins and a stout curved spine at the distal end; branches subequal, with lateral and terminal spinules. Second uropod similar, but with peduncle shorter than the branches. Third uropods with the branch rather shorter than the base, both with stout terminal spinules. Telson with a stout spinule on each half.

Female.—Similar to the male, except in the gnathopoda, which are shown in figs. 25 and 26.

I have been forced to make a new species for these specimens from South Africa, from which locality no species of *Hyale* appears to have been hitherto recorded. The species appears to come very close to *H. camptonyx* (Heller), from the Mediterranean and North Atlantic, but it differs in a few points mentioned in the description above, and particularly in the peculiar and apparently characteristic expansion of the first joint of the peduncle of the upper antenna. *H. schmidtii* (Heller), also from the North Atlantic, seems to be pretty closely allied also, but has the second antenna much longer.

In many respects the present species is similar to *H. media* (Dana), which is known from several localities on the borders of the Atlantic Ocean, but it seems to be clearly distinguished from that species by the absence of the "very large submedian serrate spine" on the propod of peræopoda 3 to 5.

Genus HAPLOCHEIRA Haswell, 1879.

Haplocheira barbimana (G. M. Thomson).

Gammarus barbimanus G. M. Thomson, 1879, p. 241, pl. x.D, fig. 1.
Haplocheira barbimana Stebbing, 1906, p. 609.
" " Walker, 1907, p. 35.

South Orkneys, Scotia Bay, Station 325; 9–10 fathoms. May 1903. Five specimens.

The largest of these specimens is 7 mm. long. They agree closely with New Zealand specimens.

The species is widely distributed in southern seas.

Genus EURYSTHEUS.

(?) *Eurystheus afer* (Stebbing). (Pl. II. figs. 30-34.)

Gammaropsis afra Stebbing, 1888, p. 1097, pl. cxiii.
Eurystheus afer Stebbing, 1906, p. 612.
" " " 1910B, p. 461.

Gough Island, Station 461; trawl, 100 fathoms. 23rd April 1904. Two small specimens: the one a male, 4 mm., probably immature; the other a female, 5 mm.

I refer these specimens to this species with considerable doubt; but if, as Mr STEBBING suggests, *E. atlanticus* is only a variety of this species, it appears to be a variable one, and it may perhaps be extended sufficiently to include forms now being considered. The male specimen probably has not acquired the fully adult characters.

The female specimen differs from STEBBING's description in having the eyes oval and of normal shape; the first gnathopod (fig. 30) has the carpus longer than the propod, and the whole limb is more slender; the second gnathopod (fig. 31) is also longer, the carpus is not cup-shaped but sub-triangular, widening distally, and is about two-thirds as long as the propod. The third uropods have the branches equal in length and rather longer than the peduncle. In other respects the specimen agrees fairly well with STEBBING's description, and the lateral lobe of the head is acutely pointed as in that species.

The form that I consider the immature male differs from the female in the second gnathopods (fig. 33), which are of the same general shape, with a moderately long carpus but with the propod larger and stouter, its palm more oblique and bearing three short conical acute teeth, one near the base of the finger, one beyond the point on which the end of the finger impinges, and one midway between these two. The third and fifth peræopoda are peculiar in having the merus widely dilated so as to be fully half as broad as long (see fig. 34); in the fourth peræopod the merus is of the usual shape. Whether this expansion of the merus is a sexual character, or an individual variation in the particular specimen examined, I cannot say.

Genus JASSA.

Jassa falcata (Montagu).

Cancer (*Gammarus*) *falcatus* Montagu, 1808, *Trans. Linn. Soc.*, vol. ix. p. 100, pl. v. fig. 2.
Podocerus falcatus and *P. validus* Stebbing, 1888, p. 1132, pl. cxix., and p. 1135, pl. cxxxviii.B.
„ *ingens* Pfeffer, 1888, p. 131.
„ *australis* Haswell, 1880, p. 338, pl. xxi. fig. 8.
Jassa pulchella Stebbing, 1906, p. 654.
„ „ Chilton, 1909A, p. 647.
„ *goniamera* Walker, 1903A, p. 61, pl. xi. figs. 98–106A.
„ *wandeli* Chevreux, 1906B, p. 94, figs. 54–56.
„ *falcata* E. W. Sexton, 1911, p. 212.

[I have given only the chief references relating to the occurrence of this species in southern seas. The very numerous references to its occurrence in the northern hemisphere can be readily traced from those here given.]

South Orkneys, Scotia Bay, Station 325, and Macdougal Bay, Station 326B. Several specimens of both sexes and of various ages.

Station 414, lat. 71° 50′ S., long. 23° 30′ W.; vertical net, from surface to 1000 fathoms. 15th March 1904. One specimen.

Mrs SEXTON, who has specially studied this species, believes that there are at least two different forms of the adult male.

When I came to examine the South Orkneys specimens it became quite clear that some of them were almost, if not quite, the same as the northern species, and that the males belonged to what Mrs SEXTON has described as the "second form." The males agree almost exactly in the characters given of the second antenna and of the gnathopods for this form; and females of this form were also present. As there are two forms known of this species in European seas, it was to be expected that, if the South Orkneys species was really the same species, the "first form" would also be found there. This actually proved to be the case, for two specimens from Macdougal

Bay agree almost exactly with Plymouth males of the first form. I have been able to compare my specimens with specimens of both forms determined by Mrs SEXTON, and she has been good enough to examine them along with me, and agrees that the South Orkneys specimens are not sufficiently distinct to be looked upon as a separate species.

I have also been able to compare my specimens with numerous forms labelled *Podocerus ingens* Pfeffer, from South Georgia, kindly sent to me by the authorities of the Hamburg Museum. Most of these appear to belong to the "first form," and agree closely with Plymouth specimens; they differ a little in the shape of the side plate of the second gnathopod, but the difference is slight, and there is a gap between this and the preceding side plate as described by Mrs SEXTON. The second gnathopod itself agrees almost precisely with Plymouth specimens, both in the fully mature form and in the immature stages. In the flagellum of the lower antenna the joints are usually a little more distinct than in typical Plymouth specimens, but in the South Georgia specimens there is some variation in this point; apparently the joints are more distinct in younger forms and become more fully coalesced in the older ones; they bear the characteristic plumose hairs as described by Mrs SEXTON. PFEFFER's type of *Podocerus ingens*, which I have also been able to examine, is a very large specimen, 26 mm. in length. Though apparently belonging to the first form, it differs a little in the shape of the second gnathopod; the thumb is comparatively small, and at its base on the outer side there is a small secondary notch or tooth that does not seem to be represented in the smaller specimens labelled *Podocerus ingens.* It is possible that this large form may be a separate species, but I am inclined to think that it is only a very large form of *Jassa falcata*, and that the differences are merely those that we might expect to meet in such a very large form. *Jassa goniamera* Walker seems certainly to belong to *J. falcata*; the specimen he described and figured under this name is an immature male of the first form. He states that the third uropod bears no secondary teeth on the outer branch. In all the specimens that I have been able to examine I have found teeth present, as in the Plymouth specimens, though small; occasionally these may become lost in preserved specimens, and I presume that is what has happened in the specimens examined by Mr WALKER. *Jassa wandeli* Chevreux, again, appears undoubtedly to be another specimen of the same species; his figure 54 is taken from a male not quite fully mature, and shows the characteristic gap between the first and second side plates, while the lower antenna exactly corresponds, both in his figure and description, to that of the first form of the male. In the specimen he figures, the various joints of the flagellum appear to be slightly more completely coalesced than they are in some of the South Georgia and South Orkneys specimens, and thus more like Plymouth specimens of this form.

I have long been familiar with this species under the name of *Podocerus validus* Dana in New Zealand, and it has been described from Australia by Professor HASWELL under the name *Podocerus australis.* In his report on the *Challenger* Amphipoda Mr STEBBING recorded it from Kerguelen Island under the name *Podocerus falcata*, and suggested that it had possibly been carried out from northern seas by attaching itself to the hull of the vessel. Though marine crustacea doubtless are occasionally dispersed in this way by ships, we now know that *Jassa falcata* is a cosmopolitan species, and its occurrence in Kerguelen Island can therefore be otherwise accounted for. It has been pointed out by Mr G. M. THOMSON and myself that the animal often temporarily attaches itself to the carapace of large crustacea, such as *Jasus edwardsii* Hutton, and probably its dispersal is assisted in this way.

The brief notice I have given above gives only a faint idea of the complex forms of this species and of the changes it passes through. These forms and its full life history are being worked out by Mrs SEXTON and others at the Marine Laboratory, Plymouth, and I have been greatly assisted in the identification of my specimens by the communication of some of the results already obtained but not yet fully published.

Genus CAPRELLA Lamark, 1801.

Caprella æquilibra Say.

Caprella æquilibra Say, 1818, p. 391.
„ „ Mayer, 1903, pp. 75, 89, pl. iii. figs. 29–34, pl. vii. figs. 66–69.
„ „ Stebbing, 1910B, p. 466.

South Africa, entrance to Saldanha Bay, Station 483; trawl, 25 fathoms. 21st May 1904. One immature male.

The specimen is not fully mature, but I think undoubtedly belongs to this widely distributed species.

It is worthy of note that this is the only Caprellid taken during the expedition, and that the family seems to be quite absent from the Antarctic fauna, and only very poorly represented in the sub-Antarctic.

Genus HYPERIA Latreille and Desmarest, 1823.

Hyperia gaudichaudii Milne Edwards.

Hyperia gaudichaudii Milne Edwards, 1840, vol. iii. p. 77.
„ „ Stebbing, 1888, p. 1394, p. 169.
„ „ Walker, 1907, p. 7.

Falkland Islands, Stanley Harbour, Station 118; "ectoparasitic on jelly-fish." 7th January 1903. Several males, females, and young; the largest female being 15 mm. long.

Station 541; 37° 41′ N., 29° 25′ W., surface; hand-net. 3rd July 1904. "Associated with Aurelia caught at the same time." Two males.

Station 112; surface, lat. 46° 3′ S., long. 56° 30′ W. 3rd January 1903. Many specimens, all of small size, the largest 6 mm.

These specimens all seem undoubtedly to belong to this widely distributed species, which has already been recorded from Antarctic regions by Mr WALKER.

Genus VIBILIA.

Vibilia antarctica Stebbing.

Vibilia antarctica Stebbing, 1888, pp. 1290, pl. cl.
,, *propinqua* Walker, 1907, p. 6.

Station 422, lat. 68° 32′ S., long. 12° 49′ W.; 8 ft. vertical net, surface to 800 fathoms. 23rd March 1904. Two specimens, 10 mm. long.

These specimens appear to be the adults of this species, which was described from an immature form by Mr STEBBING. Dr A. BEHNING, who has worked out the Vibilidæ of the German South Polar and other Expeditions, informs me that this species appears to be the typical Antarctic species, though extending also some distance north, and that it is very close to *V. propinqua*, but is distinguished by the long carpal process and the poor development of the eyes. I presume this is the same species as that recorded by WALKER under the name of *V. propinqua* from the *Discovery* Expedition.

Genus EUTHEMISTO.

Euthemisto thomsoni Stebbing.

Themisto antarctica G. M. Thomson, 1879, p. 243, pl. x.D, figs. 2 and 3.
Euthemisto thomsoni Stebbing, 1888, p. 1414, pls. cxxiv. and cxxv.
,, ,, ,, 1910B, p. 655.

Station 468, lat. 39° 48′ S., long. 2° 33′ E.; "trawl, 2645 fathoms." 29th April 1904. One specimen, doubtless obtained from the surface.

This specimen agrees closely with the description given by STEBBING in the *Challenger* Report, and I give it under the name that is used both there and in his recent report on the collections of the *Thetis* from Australia, without entering into discussion of the validity of the actual name.

IV. TROPICAL AND NORTH ATLANTIC SPECIES.

Genus SYNOPIA Dana, 1852.

Synopia schéeleana Bovallius.

Synopia schéeleana Bovallius, 1886, *N. Acta. Soc. Upsal.*, ser. 3, vol. xiii., No. 9, p. 16, pl. ii. figs. 22–29.
,, ,, Stebbing, 1888, p. 799, pl. cii.
,, ,, ,, 1906, p. 272.
,, ,, Chevreux, 1900, p. 64.

Station 62, Tropical Atlantic, lat. 4° 15′ S., long 33° 38′ W. 13th December 1901. Three or four small, delicate specimens, the largest 3 mm. long.

These specimens agree closely with the description and figures given by **Stebbing** in his *Challenger* Report.

The species is known from the warm waters of the Pacific and the Atlantic Oceans. It is perhaps not distinct from *Synopia ultramarina* Dana, with which it is united by **Della Valle.**

Genus HYALE H. Rathke, 1837.

Hyale grimaldii Chevreux.

Hyale grimaldii Chevreux, 1891, p. 257, figs. 1–5, and 1900, p. 10, pl. ii. fig. 2.
„ „ Stebbing, 1906, p. 567.

St Vincent, Station 24; among seaweed on shore. 1st December 1902. One male and one female; the male 3 mm. long.

Although these specimens are too small for certain identification, I think they must belong to this species. The gnathopoda of the male agree well with **Chevreux**'s description, having the flange on the side of the basal joint, as described, and the propod is of the same shape, though the rounded lobe on the palm near the base of the finger is not so well marked. The lower antennæ are hardly so stout as shown in **Chevreux**'s figure.

The species was previously known from the North Atlantic.

Genus ALLORCHESTES Dana, 1849.

Allorchestes plumicornis (Heller).

Nicea plumicornis Heller, 1866, p. 5, pl. i. figs. 8 and 9.
Allorchestes plumicornis Stebbing, 1906, p. 583.
„ „ Walker, 1901, p. 299, pl. xxvii. figs. 20 and 21.
„ „ Chevreux, 1911, p. 241, pl. xvii. figs. 1–3.

St Vincent, Station 24; north-east beach. 1st December 1902. Four small specimens.

There is no fully developed male among these specimens, but from the characters of the females I think they must belong to this species. The largest is probably immature, as the upper antennæ have only eleven joints in the flagellum and the lower fourteen; about half the joints in the latter bear tufts of long sensory setæ, the tufts decreasing in size distally; there is also a tuft on the distal end of the last joint of the peduncle, but none on the other parts of the peduncle. The second gnathopod agrees well with **Walker**'s figure; the dactyl of all the peræopoda bears the prominent setule on the inner margin, and in the remaining characters the specimens agree well with the descriptions given by **Stebbing** and **Chevreux**.

The species is well known from various parts of the Mediterranean, but does not appear to have been recorded from St Vincent.

Genus SUNAMPHITOE Bate, 1857.

Sunamphitoe pelagica (Milne Edwards).

Amphithoe pelagica Milne Edwards, 1830, *Ann. Sci. Nat.*, vol. xx. p. 378.
Sunamphitoe pelagica Chevreux, 1900, p. 102, pl. xi. fig. 4.
„ „ Stebbing, 1906, p. 645.

St Vincent, Station 24; north-east beach. 1st December 1802. One female, 5 mm. long.

Gulf Weed, Station 538, lat. 32° 11′ N., long. 34° 10′ W.; surface. 30th June 1904. Several of both sexes, largest about 6 mm. long.

These specimens agree in all essential respects with the descriptions given by STEBBING and CHEVREUX.

The species is widely distributed in the North Atlantic, but I know of no previous record from St Vincent.

Genus ANCHYLOMERA.

Anchylomera blossevillii Milne Edwards.

Anchylomera blossevillii Milne Edwards, 1830, *Ann. Sci. Nat.*, vol. xx. p. 394.
„ „ Stebbing, 1888, p. 1433, pl. xvii.
„ „ Chevreux, 1900, p. 147.

Station 62, Tropical Atlantic, lat. 4° 15′ S., long. 33° 38′ W.; tow-net. 13th December 1902. One specimen.

Station 57, Tropical Atlantic, 2° 1′ S., 32° 18′ W.; tow-net. 12th December 1902. Four specimens, 4 mm. long.

This is a common species in the warmer parts of the Atlantic Ocean.

Genus OXYCEPHALUS Milne Edwards, 1830.

Oxycephalus clausi Bovallius.

Oxycephalus clausi Bovallius, 1887, p. 35.
„ „ Stebbing, 1888, p. 1578, pl. cci.
„ „ Chilton, 1911, p. 567.

Station 40, Tropical Atlantic, lat. 5° 57′ N., long. 25° 56′ W. 7th December 1902. One specimen.

This specimen agrees very closely with those described and figured by STEBBING from the *Challenger* Expedition, and it is also the same as specimens from the Kermadec Islands examined by me in 1911.

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[VI. EXPLANATION OF PLATES.

VI. EXPLANATION OF PLATES.

Plate I.

Fig. 1. *Cyphocaris anonyx* Boeck. First gnathopod.
,, 1*a*. ,, ,, ,, ,, extremity more highly magnified.
,, 2. ,, ,, ,, Second gnathopod.
,, 3. ,, ,, ,, Second peræopod.
,, 4. ,, ,, ,, Third peræopod.
,, 5. *Lysianassa cubensis* Stebbing. Third uropod.
,, 6. *Alicella scotiæ*, sp. nov. First gnathopod.
,, 7. ,, ,, ,, Second gnathopod.
,, 8. *Orchomenopsis* (?) *coatsi*, sp. nov. First gnathopod.
,, 8*a*. ,, ,, ,, ,, extremity more highly magnified.
,, 9. ,, ,, ,, Second gnathopod.
,, 10. *Metopoides sarsii* Pfeffer. Last segment of urus, with third uropod and telson.
,, 11. *Thaumatelson walkeri*, sp. nov. Side view.
,, 12. ,, ,, ,, Antennæ.
,, 13. ,, ,, ,, First gnathopod.
,, 14. ,, ,, ,, Second gnathopod.
,, 15. ,, ,, ,, Urus, with uropoda and telson.
,, 16. ,, *inermis*, sp. nov. First gnathopod.
,, 17. ,, ,, ,, Second gnathopod.
,, 18. *Atyloides magellanica* (Stebbing). Telson of specimen, showing unsymmetrical lobes.

Plate II.

Fig. 19. *Acanthonotozoma australis*, sp. nov. Side view of whole animal.
,, 20. *Eusirus splendidus*, sp. nov. Side view of whole animal.
,, 21. *Atyloides calceolata*, sp. nov. Basal joints of antennæ.
,, 22. ,, ,, ,, First gnathopod.
,, 23. ,, ,, ,, Second gnathopod.
,, 24. *Hyale saldanha*, sp. nov. Anterior portion of head of female, with antennæ.
,, 25. ,, ,, ,, First gnathopod of female.
,, 26. ,, ,, ,, Second gnathopod of female.
,, 27. ,, ,, ,, First gnathopod of male.
,, 28. ,, ,, ,, Second gnathopod of male.
,, 29. ,, ,, ,, Third peræopod of male.
,, 30. (?) *Eurystheus afer* (Stebbing). First gnathopod of female.
,, 31. ,, ,, ,, Second gnathopod of female.
,, 32. ,, ,, ,, First gnathopod of male.
,, 33. ,, ,, ,, Second gnathopod of male.
,, 34. ,, ,, ,, Third peræopod of male, with widened merus.

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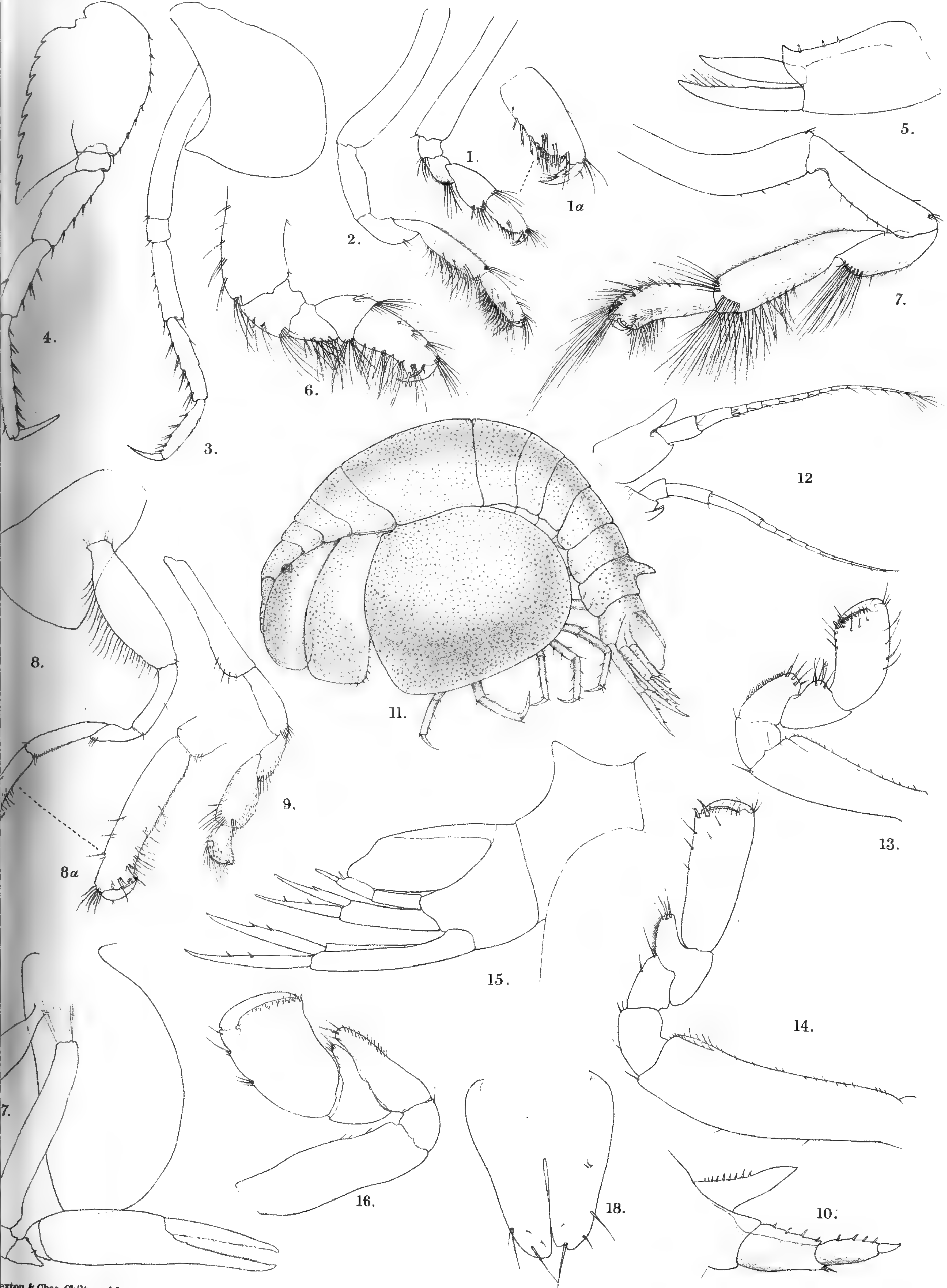
CHILTON: "SCOTIA" AMPHIPODA.—PLATE I.



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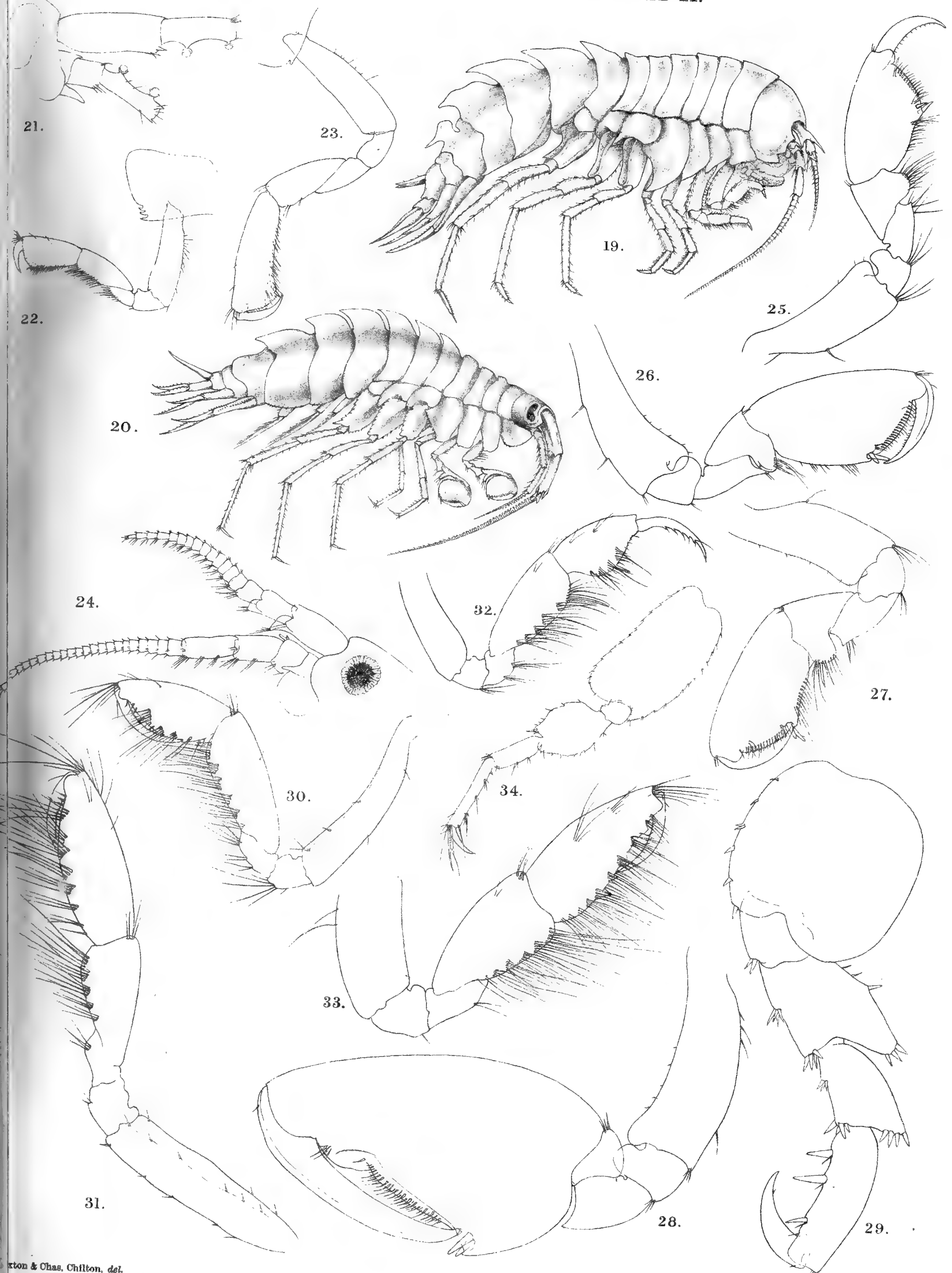
CHILTON: "SCOTIA" AMPHIPODA.—PLATE II.



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CONTENTS.

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XXIV.—The Entomostraca of the Scottish National Antarctic Expedition, 1902–1904. By Thomas Scott, LL.D., F.L.S. *Communicated by* Dr J. H. Ashworth. (With Fourteen Plates.)

(MS. received January 24, 1912. Read February 19, 1912. Issued separately November 15, 1912.)

CONTENTS.

Introductory Statement.

The Entomostraca recorded here were collected by the s.y. *Scotia* on its way to and from the Antarctic, and also while carrying on investigations there during the years 1902 to 1904. The Entomostraca in these collections belong chiefly to the Copepoda, but the Cladocera and Ostracoda are also represented, the last by a considerable number of species. These three groups are described below in the order mentioned.

The Copepoda.

The Copepoda recorded in the following pages number considerably over one hundred species. A fairly large proportion of them belong to the Calanoida and to one or two other groups of pelagic forms; these were, for the most part, obtained in samples of plankton—chiefly surface gatherings collected by tow net at various stations on the outward voyage betweeen Cape Verde and the Falkland Islands. On the other hand, most of the Harpacticoida, of which there are a good number, are from the neighbourhood of the South Orkney Islands, but some of them were also obtained in siftings from material brought up in the dredge or trawl net, and amongst organisms washed from floating Gulf-weed.

Most of the pelagic or free-swimming species from the tow-net collections are more or less widely distributed, and have been described in various published works, but some of them are tolerably rare. The Harpacticoida and other demersal forms are, however, not so well known, and a considerable number of those recorded here appear to be undescribed; a few of them are closely related to British or other northern species, and seem to lend some support to the idea of a bipolar distribution.

The occurrence at places so far distant as the Falklands and South Orkneys of demersal forms identical with, or closely allied to, those of Britain and Norway has a bearing on the question of distribution different from that concerning organisms living freely in the open sea. Such free-swimming species are subject to dispersal over wide areas by tidal and other currents, and numerous examples of such dispersal are indicated or described by various authors; but the wide distribution of an Harpactid such, for example, as *Orthopsyllus linearis*, Claus, may not be so easily explained. This Copepod is one of a group which have an elongated and moderately slender body, provided with short appendages that are scarcely, if at all, fitted for swimming, but are rather adapted for living among branching zoophytes or on the roots and stems of seaweeds. The transporting action of currents can have much less effective influence on the distribution of such species than on species living a free life in the open sea. Nevertheless, *Orthopsyllus linearis* has been recorded from the British Islands, from Norway, the Mediterranean, the Suez Canal, the Gulf of Manaar, and the Gulf of Guinea. More recently it has been obtained in material collected in the Malay Archipelago during the *Siboga* Expedition of 1899–1902,* and now this non-swimming species is here recorded from gatherings collected by the *Scotia* among the South Orkney Islands.

Another species—*Asterocheres suberites*, Giesbrecht—belonging to a different group of Copepods, is usually found living as a commensal in the water passages of certain sponges.†

The wide dispersal of this *Asterocheres* cannot, from its peculiar habitat, be to any large extent attributed to oceanic currents, yet it has been recorded from the British Islands and the Mediterranean; and one or two specimens from a gathering collected among the South Orkneys by the *Scotia* can scarcely be distinguished from those living on British sponges. Other species equally interesting and showing the near relationship of the non-pelagic Copepoda of the far South with those of our Northern Seas will be noticed in the sequel, but two may be briefly referred to here. One of them —an Harpactid, obtained in a small gathering of minute Molluscan shells collected on the shore at Port Stanley, Falkland Islands—has a remarkable likeness to a species that was dredged in the Firth of Forth off St Monance in 1891,‡ and which has been described more recently by G. O. Sars from Norwegian specimens.§ The female of this species is distinguished by having the last pair of thoracic legs large and leaf-like,—hence the generic name *Phyllopodopsyllus*. The other form is also interesting because it may be regarded as supplying a "missing link" in the little group of nearly related species representing four genera, viz.—*Cervinia*, Norman, *Cerviniopsis*, G. O. Sars, *Zosime*, Boeck, and *Pseudozosime*, Scott. In the first genus the inner ramus of the first pair of thoracic legs is three-jointed and that of the next three pairs two-jointed; in the second all the four pairs of thoracic legs have the inner ramus three-jointed. In the third the inner ramus of the first pair is two-jointed, and that of the next three pairs three-jointed; while in *Pseudozosime* the inner ramus of all the four pairs is composed of

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* *The Copepoda of the "Siboga" Expedition*, by Andrew Scott, A.L.S., p. 225 (1909).

† *Fauna u. Flora des Golfes von Neapel*, 25. Monogr., "Asterocheriden," by Dr W. Giesbrecht, p. 70.

‡ *Tenth Annual Report of the Fishery Board for Scotland*, part iii. p. 253, pl. ix. figs. 19–32.

§ *An Account of the Crustacea of Norway*, vol. v. part xix. (1907), p. 231, pl. clv.

two joints. These differences become more apparent when arranged in tabular form, thus :—

Name of the Genus.	Inner Ramus of			
	1st pair.	2nd pair.	3rd pair.	4th pair.
Cervinia	3-jointed	2-jointed	2-jointed	2-jointed
Cerviniopsis . . .	3- „	3- „	3- „	3- „
Zosime	2- „	3- „	3- „	3- „
Pseudozosime . . .	2- „	2- „	2- „	2- „

The small Harpactid, for which it has been necessary to institute the new generic name, *Pseudozosime*, was obtained by washing some material dredged in Scotia Bay, South Orkneys, in June 1903. Only one specimen—a female—was observed; it so closely resembled *Zosime*, Boeck, that only after careful dissection could the differences referred to be detected.

In this account of the Copepoda from the *Scotia* collections, the general arrangement followed is that outlined by G. O. Sars in his *Crustacea of Norway*, vol. iv. p. 2. He divides the Copepoda into seven sub-orders or tribes, viz. the Calanoida, Harpacticoida, Cyclopoida, Notodelphyoida, Monstrilloida, Caligoida, and the Lernæoida. The first three contain all the Copepoda recorded here except *Dysgamus atlanticus*, which belongs to the Caligoida. Dr G. S. Brady's Report on the *Challenger* Ostracoda and other papers on these organisms have been of much assistance in dealing with this group.

As several of the species recorded here, particularly among the Harpacticoida, appear to be undescribed, drawings of these have been prepared to show their distinguishing features, and to illustrate the descriptive notes relating to them. A few other more or less rare and interesting forms are also figured to show peculiarities of structure and some of the characteristics by which they may be determined from others closely allied to them. My son, Andrew Scott, A.L.S., has prepared a number of these drawings, and I desire to express my indebtedness to him for these, as well as for assistance in determining some of the more critical and troublesome species.

I have also to express my thanks to the Executive Committee of the Carnegie Trust for the Universities of Scotland for defraying the expenses of the plates.

I have not considered it necessary to give a list of the authors whose works have been consulted, but reference to the more important of them will be found throughout the systematic part of the Report.

SYSTEMATIC LIST OF SPECIES RECORDED OR DESCRIBED IN THIS REPORT.

COPEPODA.

CALANOIDA.

CALANIDÆ.

- *Calanus*, Leach.
  - *minor* (Claus).
  - *tenuicornis*, Dana.
  - *acutus*, Giesbrecht.
  - *propinquus*, G. S. Brady.
- *Calanoides*, G. S. Brady.
  - *brevicornis* (Lubbock).
- *Megacalanus*, Wolfenden.
  - *robustior* (Giesbrecht).
  - *gracilis* (Dana).
- *Undinula*, A. Scott.
  - *vulgaris* (Dana).
  - *darwinii* (Lubbock).

EUCALANIDÆ.

- *Eucalanus*, Dana.
  - *attenuatus*, Dana.
  - *crassus*, Giesbrecht.
  - *subtenuis*, Giesbrecht.
- *Rhincalanus*, Dana.
  - *gigas*, G. S. Brady.
  - *cornutus*, Dana.
- *Mecynocera*, I. C. Thompson.
  - *clausi*, I. C. Thompson.

PARACALANIDÆ.

- *Paracalanus*, Boeck.
  - *aculeatus*, Giesbrecht.
- *Acrocalanus*, Giesbrecht.
  - *longicornis*, Giesbrecht.
- *Calocalanus*, Giesbrecht.
  - *pavo* (Dana).
  - *plumulosus* (Claus).
- *Clausocalanus*, Giesbrecht.
  - *arcuicornis* (Dana).
  - *furcatus* (G. S. Brady).

EUCHÆTIDÆ.

- *Euchæta*, Philippi.
  - *marina* (Prestandrea).

SCOLECITHRICIDÆ.

- *Scolecithrix*, G. S. Brady.
  - *danæ* (Lubbock).
  - *glacialis*, Giesbrecht.
- *Racovitzanus*, Giesbrecht.
  - *antarcticus*, Giesbrecht.

CENTROPAGIDÆ.

- *Centropages*, Kröyer.
  - *furcatus* (Dana).
  - *violaceus* (Claus).
  - *brachiatus* (Dana).
  - *calaninus* (Dana).
  - *typicus*, Kröyer.

TEMORIDÆ.

- *Temora*, Baird.
  - *stylifera* (Dana).
  - *turbinata* (Dana).

METRIDIIDÆ.

- *Metridia*, Boeck.
  - *lucens*, Boeck.
  - *gerlachei*, Giesbrecht.
- *Pleuromamma*, Giesbrecht.
  - *abdominalis* (Lubbock).
  - *gracilis* (Claus).
  - *gracilis* var. *esterlyi*, nov.

LUCICUTIDÆ.

- *Lucicutia*, Giesbrecht.
  - *flavicornis* (Claus).

HETERORHABDIDÆ.

- *Heterorhabdus*, Giesbrecht.
  - *papilliger* (Claus).
  - *austrinus*, Giesbrecht.

HALOPTILIDÆ.

- *Haloptilus*, Giesbrecht.
  - *acutifrons*, Giesbrecht.

CANDACIIDÆ.

- *Candacia*, Dana.
  - *pachydactyla*, Dana.
  - *curta*, Dana.
  - *bipinnata*, Giesbrecht.
  - *æthiopica*, Dana.
  - *bispinosa*, Claus.
  - *simplex*, Giesbrecht.
  - *longimana*, Claus.

PONTELLIDÆ.

Calanopia, Dana.
  americana, Dahl.
Labidocera, Lubbock.
  nerii (Kröyer).
  acutifrons (Dana).
Pontella, Dana.
  atlantica (M.-Edw.).
  securifer, G. S. Brady.
  spinipes, Giesbrecht.
Pontellina, Dana.
  plumata, Dana.

PONTELLIDÆ—continued.

Pontellopsis, G. S. Brady.
  regalis (Dana).
  perspicax (Dana).
  brevis (Giesbrecht).
  villosa, G. S. Brady.

ACARTIIDÆ.

Acartia, Dana.
  negligens, Dana.
  danæ, Giesbrecht.

HARPACTICOIDA.

CERVINIIDÆ.

Pseudozosime, n. g.
  browni, n. sp.

ECTINOSOMIDÆ.

Ectinosoma, Boeck.
  antarcticum, Giesbrecht.
Bradya, Boeck.
  proxima, n. sp.
Microsetella, Brady & Robertson.
  norvegica (Boeck).
  rosea (Dana).

MACROSETELLIDÆ.

Macrosetella, A. Scott.
  gracilis (Dana).
Miracia, Dana.
  efferata, Dana.

EUTERPINIDÆ.

Euterpina, Norman.
  acutifrons (Dana).

CLYTEMNESTRIDÆ.

Clytemnestra, Dana.
  scutellata, Dana.

HARPACTICIDÆ.

Harpacticus, M.-Edw.
  fucicolus, n. sp.
  piriei, n. sp.

PELTIDIIDÆ.

Alteutha, Baird.
  austrina, n. sp.
  dubia, n. sp.
Paralteutha, n. g.
  typica, n. sp.

PORCELLIDIIDÆ.

Porcellidium, Claus.
  affine, Quidor.

TISBEIDÆ.

Tisbe, Liljeborg.
  austrina, n. sp.
  gracilipes, n. sp.
Psamathe, Philippi.
  longicauda, Philippi.
  fucicola, n. sp.
Machairopus, G. S. Brady.
  australis, n. sp.
  major, n. sp.

THALESTRIDÆ.

Parathalestris, G. O. Sars.
  clausi (Norman).
  coatsi, n. sp.
  affinis, n. sp.
Idomene, Philippi.
  forficata, Philippi.
Dactylopusia, Norman.
  frigida, n. sp.
  ferrieri, n. sp.
  perplexa, n. sp.
Pseudothalestris, G. S. Brady.
  intermedia, n. sp.
  assimilis, G. O. Sars, var. *antarctica*.

DIOSACCIDÆ.

Diosaccus, Boeck.
  tenuicornis, Boeck.
Amphiascus, G. O. Sars.
  fucicolus, n. sp.

CANTHOCAMPTIDÆ.

- *Ameira*, Boeck.
  - *simulans*, n. sp.
- *Parastenhelia*, I. C. Thompson & A. Scott.
  - *antarctica*, n. sp.
- *Phyllopodopsyllus*, T. Scott.
  - *mossmani*, n. sp.

LAOPHONTIDÆ.

- *Laophonte*, Philippi.
  - *rottenburgi*, n. sp.
  - *australis*, n. sp.
  - *wiltoni*, n. sp.
  - *exigua*, n. sp.
- *Laophontodes*, T. Scott.
  - *whitsoni*, n. sp.

CLETODIDÆ.

- *Orthopsyllus*, Brady & Robertson.
  - *linearis* (Claus).

CYCLOPOIDA.

OITHONIDÆ.

- *Oithona*, Baird.
  - *plumifera*, Baird.
  - *minuta*, T. Scott.
  - *similis*, Claus.

CYCLOPIDÆ.

- *Cyclopina*, Claus.
  - *belgica*, Giesbrecht.
- *Euryte*, Philippi.
  - *similis*, n. sp.

LICHOMOLGIDÆ.

- *Lichomolgus*, Thorell.
  - *fucicola*, G. S. Brady.
- *Pseudanthessius*, Claus.
  - *fucicolus*, n. sp.

ASTEROCHERIDÆ.

- *Asterocheres*, Boeck.
  - *suberites*, var. *antarctica*, n. var.

ARTOTROGIDÆ.

- *Artotrogus*, Boeck.
  - *proximus*, n. sp.

SAPPHIRINIDÆ.

- *Sapphirina*, J. V. Thompson.
  - *ovatolanceolata*, Dana.
  - *gemma*, Dana.
  - *iris*, Dana.
  - *angusta*, Dana.
  - *lactens*, Giesbrecht.

SAPPHIRINIDÆ—continued.

- *Sapphirina vorax*, Giesbrecht.
  - *auronitens*, Claus.
  - *nigromaculata*, Claus.
  - *intestinata*, Giesbrecht.
  - *opalina*, Dana.
  - *gastrica*, Giesbrecht.
  - *stellata*, Giesbrecht.
  - *darwini*, Haeckel.
- *Saphirella*, T. Scott.
  - *abyssicola*, T. Scott.
- *Copilia*, Dana.
  - *mirabilis*, Dana.
  - *denticulata*, Claus.

ONCÆIDÆ.

- *Oncæa*, Philippi.
  - *venusta*, Philippi.
  - *mediterranea*, Claus.
  - *conifera*, Giesbrecht.

CORYCÆIDÆ.

- *Corycæus*, Dana.
  - *venustus*, Dana.
  - *ovalis*, Claus.
  - *obtusus*, Dana.
  - *flaccus*, Giesbrecht.
  - *rostratus*, Claus.
  - *speciosus*, Dana.
  - *longistylis*, Dana.
  - *carinatus*, Giesbrecht.
  - *longicaudis*, Dana.
  - *elongatus*, Claus.

CALIGOIDA.

CALIGIDÆ.

- *Dysgamus atlanticus*, Stp. & Ltkn.

CLADOCERA.

- *Evadne*, Loven.
  - *tergestina*, Claus.
- *Evadne spinifera*, P. E. Müller.

OSTRACODA.

PODOCOPA.

CYPRIDÆ.

- *Macrocypris*, G. S. Brady.
  - *maculata*, G. S. Brady.

CYTHERIDÆ.

- *Cythere*, O. F. Müller.
  - *inornata*, n. sp.
  - *quadridens*, n. sp.
  - *latibrosa*, n. sp.
  - *foveolata*, G. S. Brady.
  - *antarctica*, n. sp.
  - *peregrina*, n. sp.

CYTHERIDÆ—continued.

- *Xestoleberis*, G. O. Sars.
  - *reniformis*, G. S. Brady.
- *Cytherura*, G. O. Sars.
  - *ornata*, n. sp.
  - *porrecta*, n. sp.
  - *sculptilis*, n. sp.
- *Paradoxostoma*, Fischer.
  - *retusum*, G. S. Brady.
  - *antarcticum*, n. sp.
  - *læve*, n. sp.

MYODOCOPA.

CYPRIDINIDÆ.

- *Philomedes*, Liljeborg.
  - *assimilis*, G. S. Brady.
- *Asterope*, Philippi.
  - *australis*, G. S. Brady.
  - *oculata*, G. S. Brady.

HALOCYPRIDÆ.

- *Halocypris*, Dana.
  - *globosa*, Claus.
- *Conchœcia*, Dana.
  - *spinirostris*, Claus.
  - *procera*, G. W. Müller.
  - *elegans*, G. O. Sars.
- *Euconchœcia*, G. W. Müller.
  - *chierchiæ*, G. W. Müller.

COPEPODA.

Tribe *CALANOIDA*, G. O. Sars.*

Fam. CALANIDÆ.

Genus *Calanus*, Leach, 1816.

Calanus minor (Claus).

1863, *Cetochilus minor*, Claus, *Die freilebenden Copepoden*, p. 172.
1893, *Calanus minor*, Giesb., *F. Fl. Neapel*, vol. xix. p. 90, pls. vi., vii., viii.

This species was observed in samples of plankton from twenty-one stations, ranging from Stations 7, 8, and 10 in the North Atlantic, 26° 23′ N., 20° 20′ W., to Stations 60, 62, and 64 in the South, 6° 30′ S., 34° 25′ W.

C. minor appears to be one of the more widely distributed species; its distribution, according to GIESBRECHT, extends from the Mediterranean to the Atlantic, Pacific, and Indian Oceans, between lat. 34° N. and 36° S.

Calanus tenuicornis, Dana.

1849, *Calanus tenuicornis*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 15.

The only sample in which this species occurred was from Station 15 in 20° 34′ N., 23° 12′ W.

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* The arrangement followed for the Calanoida is that of G. O. SARS' *Crustacea of Norway*, vol. iv.

Calanus acutus, Giesbrecht.

1902, *Calanus acutus*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 17, pl. i.

This species occurred in two of the *Scotia* gatherings, in one from 200 fathoms collected in 69° 22′ S., 26° 36′ W., Station 273, and in another from 500 fathoms collected in lat. 68° 40′ S., long. 30° 18 W., Station 280.

Calanus propinquus, G. S. Brady.

1883, *Calanus propinquus*, Brady, *Report Voy. "Challenger,"* vol. viii. p. 34, pl. ii.
1892, ,, ,, Geisb., *F. Fl. Neapel*, vol. xix. p. 91, pl. vii. figs. 31, 34 *et seq.*

C. propinquus was met with very sparingly in a surface sample collected 28th November 1903 in 59° 43′ S., 48° 10′ W., Station 337*b*. The distribution of this species extends to the Atlantic, Pacific, and Indian Oceans, between lat. 55° N. and 65° S. (GIESBRECHT).

Genus *Calanoides*, G. S. Brady, 1883.

Calanoides brevicornis (Lubbock).

1856, *Calanus brevicornis*, Lubb., *Trans. Entom. Soc. Lond.* (N.S.), vol. iv. p. 11, pl. 3.
1892, ,, ,, Giesb., *F. Fl. Neapel*, vol. xix. p. 90, pl. vi. figs 7, 9, 18 *et seq.*
1894, ,, *frontalus*, F. Dahl, *Verh. d. zool. Gesellschaft*, p. 76.
1907, ,, *brevicornis*, G. O. Sars, *Bull. de l'Institut Océanographique*, No. 101, p. 4.
1909, *Calanoides* ,, A. Scott, "*Siboga*" *Exped.*, Monogr. xxixA, "Copepoda," p. 10.
1910, *Calanus* ,, Stebbing, *Annals of the S. African Museum*, vol. iv. pt. iv. p. 520.

A few specimens were obtained in a surface tow-net gathering collected 5th May 1904 off Cape Peninsula, 34° 21′ S., 18° 29′ E., Station 477. This species is easily recognised by the slightly crested forehead; it appears to be widely distributed in the South Atlantic and Indian Oceans. The fifth pair of thoracic legs of the male of the species recorded here and of *Calanoides patagoniensis*, Brady, differ distinctly from those of the typical *Calanus*.

Genus *Megacalanus*, Wolfenden, 1904.*

Megacalanus gracilis (Dana).

1849, *Calanus gracilis*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 18.

This species occurred very sparingly at Stations 11, 15, 18, and 29, 23° 50′ N., 21° 34′ W., to 12° 31′ N., 25° 09′ W., in the North Atlantic, and at Station 56 in the South Atlantic, 0° 42′ S., 31° 20′ W.

Megacalanus robustior (Giesbrecht).

1888, *Calanus robustior*, Giesb., *Atti Acc. Lincei Rend.*, ser. iv., vol. iv., sem. 2, p. 332.
1892, ,, ,, *idem*, *F. Fl. Neapel*, vol. xix. p. 91, pl. vii. figs. 15, 19 *et seq.*

Only a few specimens were obtained; they occurred in a gathering from Station 11, 23° 50′ N., 21° 34′ W., in the North Atlantic, and in two others, from Station 59, 2° 30′ S., 32° 42′ W., and Station 62, 4° 15′ S., 33° 38′ W., in the South Atlantic.

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* See note on this genus in the *Copepoda of the "Siboga" Expedition*, by ANDREW SCOTT (1909), p. 10 *et seq.*

Genus *Undinula*, A. Scott, 1909.

Syn. *Undina Dana* (name preoccupied).

Undinula vulgaris (Dana).

1849, *Undina vulgaris*, Dana, *op. cit.*, vol. ii. p. 18.
1892, *Calanus* ,, Giesb., *F. Fl. Neapel*, vol. xix. p. 92, pl. vi. fig. 11 ; pl. vii. fig. 2 *et seq.*

This species was observed in surface tow-net gatherings from a considerable number of stations, extending from Station 8, in 26° 12′ N., 20° 25′ W., to Station 82, in 20° 40′ S., 38° 20′ W. Both males and females were obtained. The structure of the fifth pair of thoracic legs in the male of this and the following species is so remarkable and so entirely different from those of the typical *Calanus*, that, as indicated by G. O. Sars, the position of these two species in the genus *Calanus* can scarcely be maintained. Dana ascribed the species named above to the genus *Undina*, but unfortunately that name was already occupied by Gould and also by Munster, and a modified form of the name was therefore adopted for the genus by my son in his Report on the Copepoda of the *Siboga* Expedition.

Undinula darwinii (Lubbock).

1860, *Undina darwinii*, Lubbock, *Trans. Linn. Soc. Lond.*, vol. xxiii. p. 7, pl. xxix.
1892, *Calanus* ,, Giesb., *F. Fl. Neapel*, vol. xix. p. 91, pl. vi. fig. 5 *et seq.*
1909, *Undinula* ,, A. Scott, "*Siboga*" *Expeditie*, "Copepoda," p. 17.

Several specimens, chiefly females, were obtained in a surface tow-net gathering collected 4th May 1904 in 34° 43′ S., 17° 15′ E., Station 476. This species is a true *Undinula*.

Fam. EUCALANIDÆ.

Genus *Eucalanus*, Dana, 1852.

Eucalanus attenuatus, Dana.

1849, *Calanus attenuatus*, Dana, *op. cit.*, vol. ii. p. 18.

This species occurred in samples from only five stations, all in the North Atlantic, viz., Stations 11, 12, 14, 20 and 26, 23° 50′ N., 21° 34′ W., to 14° 33′ N., 25° 9′ W.

Eucalanus crassus, Giesbrecht.

1888, *Eucalanus crassus*, Giesb., *Atti Acc. Lincei Rend.*, ser. 4, vol. iv. p. 333.
1892, ,, ,, *idem*, *F. Fl. Neapel*, vol. xix. p. 132, pl. iv. fig. 9 *et seq.*

This *Eucalanus* was obtained sparingly in two surface gatherings—one collected at Station 19, in the North Atlantic, 19° 12′ N., 24° 08′ W., the other at Station 68, in the South Atlantic—Pernambuco Lighthouse, bearing 7° 42′ S., 34° 32′ W.

Eucalanus subtenuis, Giesbrecht.

1888, *Eucalanus subtenuis*, Giesb., *op. cit.*, p. 33.
1892, ,, ,, *idem*, *F. Fl. Neapel*, vol. xix. p. 132, pls. xi. and xxxv.

A few specimens were obtained in samples from Stations 26, 27, and 59, 14° 33′ N., 25° 09′ W., to 2° 30′ S., 32° 42′ W.

Genus *Rhincalanus*, Dana, 1852.

Rhincalanus gigas, G. S. Brady.

1883, *Rhincalanus gigas*, Brady, *Report Voy.* "*Challenger*," vol. viii. p. 42, pl. viii. figs. 1–11.
1888, ,, *nasutus*, Giesb., *op. cit.*, p. 334.
1902, ,, *grandis*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 18, pl. i.
1909, ,, *gigas*, A. Scott, "*Siboga*" *Expeditie*, Monogr. xxixA, "Copepoda," p. 24.

This species was obtained in two gatherings—one from 200 fathoms, collected 28th February 1903 in 69° 22′ S., 26° 36′ W., Station 273; the other from 500 fathoms, collected 2nd March, also 1903, in 68° 40′ S., 30° 18′ W., Station 280. Several specimens were obtained, large and small; the larger measured fully 8 mm. in length, while the smaller were similar to *R. nasutus*.

A careful examination of these *Scotia* specimens leaves scarcely any doubt in my mind that they all belong to the one species—*Rhincalanus gigas* of Brady, the only apparent difference between the largest and the smallest specimens being the difference in their size. Brady's specimens ranged from 8·5 to 10 mm., while the largest of the *Scotia* specimens measured fully 8 mm., and ranged from that to specimens no bigger than those found in the North Sea. I am therefore unable to regard *Rhincalanus nasutus* as anything more than a small variety of *R. gigas*, while *R. grandis* is a finer and somewhat larger form of the same species.

Rhincalanus cornutus, Dana.

1849, *Calanus cornutus*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 19.
1852, *Rhincalanus cornutus*, Dana, *U.S. Explor. Exped.*, vol. xiii., II., p. 1083, pl. lxxvi.

Tolerably frequent in two surface gatherings collected 5th May 1904, Station 477, off Cape Peninsula (34° 21′ S., 18° 29′ E.), South Africa.

Genus *Mecynocera*, I. C. Thompson, 1888.

Mecynocera clausi, I. C. Thompson.

1888, *Mecynocera clausi*, I. C. Thompson, *Journ. Linn. Soc.*, "Zool.," vol. xx. p. 150, pl. xi.

Mecynocera was observed in gatherings from Stations 7, 10, 12, 13, 15, and 28, all in the North Atlantic, between 26° 23′ N., 20° 20′ W., and 13° 7′ N., 25° 9′ W. I. C. Thompson collected his specimens at the Canary Islands, nearly in the same latitude as Station 7, 26° 23′ N., 20° 20′ W.

Fam. Paracalanidæ.

Genus *Paracalanus*, Boeck, 1864.

Paracalanus aculeatus, Giesbrecht.

1888, *Paracalanus aculeatus*, Giesb., *op. cit.*, p. 333.

This *Paracalanus* was met with at eight stations in the North, and four in the South Atlantic, ranging from Stations 26 to 66, 14° 33′ N., 25° 9′ W., to 7° 9′ S., 34° 30′ W.

Genus *Acrocalanus*, Giesbrecht, 1888.

Acrocalanus longicornis, Giesbrecht.

1888, *Acrocalanus longicornis*, Giesb., *op. cit.*, p. 332.

A. longicornis occurred sparingly in the twenty-one samples collected between Stations 17 in the North and 95 in the South Atlantic, 20° 18′ N., 23° 22′ W., to 32° 15′ S., 47° 30′ W.

Genus *Calocalanus*, Giesbrecht, 1888.

Calocalanus pavo (Dana).

1849, *Calanus pavo*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 13.

This *Calanoid* was observed in gatherings from twenty-two stations, ranging from 7 to 94, 26° 23′ N., 20° 20′ W., to 30° 25′ S., 45° 45′ W., but was not very common in any of them.

Calocalanus plumulosus (Claus).

1863, *Calanus plumulosus*, Claus, *Die freilebenden Copepoden*, p. 174, pl. xxvi. figs. 15, 16.

The only gathering in which *C. plumulosus* was observed was collected at Station 25 in 15° 15′ N., 25° 9′ W.

Genus *Clausocalanus*, Giesbrecht, 1888.

Clausocalanus arcuicornis (Dana).

1849, *Calanus arcuicornis*, Dana, *op. cit.*, p. 52.

This was one of the more common species in the *Scotia* collections. It was observed in gatherings of plankton from thirty-one stations, extending from Station 7 in the North, to Station 112 in the South Atlantic, 26° 23′ N., 20° 20′ W., to 46° 03′ S., 56° 30′ W.

Clausocalanus furcatus (G. S. Brady).

1883, *Drepanopus furcatus*, Brady, *Report* "*Chall.*," "Copep.," p. 77, pl. iv. figs. 1 and 2, pl. xxiv. figs. 12–15.

In the *Scotia* collections this species appeared to be much rarer than the last. It was observed in gatherings from only four stations, viz., 12, 13, 59, and 90, 22° 19′ N., 22° 07′ W., to 26° 50′ S., 42° 20′ W.

Fam. EUCHÆTIDÆ.

Genus *Euchæta*, Philippi, 1843.

Euchæta marina (Prestandrea).

1833, *Cyclops marina*, Prestandrea, *Effemeridi Sci. lett. Sicilia*, Palermo, vol. vi. p. 12.

The only species of *Euchæta* observed in the *Scotia* collections is the one named above—a species which appears to be widely distributed. It occurred more or less sparingly in gatherings from twenty-one stations, extending from Station 7 to Station 94, 26° 23′ N., 20° 20′ W., to 30° 25′ S., 45° 45′ W.

Fam. SCOLECITHRICIDÆ.

Genus *Scolecithrix*, G. S. Brady, 1883.

Scolecithrix danæ (Lubbock).

1856, *Undina danæ*, Lubbock, *Trans. Entom. Soc. Lond.*, vol. iv. p. 15, pl. ix.

This, which is one of the only two representatives of the genus *Scolecithrix* observed, occurred in gatherings from eighteen stations, extending from Station 7 in the North Atlantic to Station 65 in the South, 26° 23′ N., 20° 20′ W., to 6° 52′ S., 34° 32′ W.

Scolecithrix glacialis, Giesbrecht.

1902, *Scolecithrix glacialis*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 25, pl. iv.

One or two specimens of this southern form occurred in two gatherings, one of which was collected at 200 fathoms on 28th February 1903 in lat. 69° 22° S., long. 26° 36′ W., Station 273; the other at 500 fathoms on 2nd March in 68° 40′ S., 30° 18′ W., Station 280.

Genus *Racovitzanus*, Giesbrecht, 1902.

Racovitzanus antarcticus, Giesbrecht.

1902, *Racovitzanus antarcticus*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 26, pl. iv. figs. 8–13, pl. v. figs. 1–5.

A single specimen was obtained in a sample from 200 fathoms, collected on 28th February 1903 in lat. 69° 22′ S., long. 26° 36′ W., Station 273.

The *Belgica* obtained this species at a depth of 500 metres in 70° 9′ S., 82° 35′ W. (*Belgica* Station 701). (*Vide* Dr GIESBRECHT's *Copepoden of the "Belgica."*)

Fam. CENTROPAGIDÆ.

Genus *Centropages*, Kröyer, 1848–1849.

Centropages furcatus (Dana).

1849, *Catopia furcata*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 25.
1883, *Centropages furcatus*, Brady, *Report Voyage of the "Challenger,"* vol. viii. p. 83, pl. xxviii.
1892, „ „ Giesb., *F. Fl. Neapel*, vol. xix. p. 304, pls. xvii., xviii., and xxxviii.

The only gatherings in which this species was obtained were collected in the South Atlantic at Station 64, 6° 30′ S., 34° 25′ W., and Station 68A, 8° 00′ S., 34° 34′ W., Pernambuco, bearing 12 miles W.

Centropages violaceus (Claus).

1863, *Ichthyophorba violacea*, Claus, *Die freilebenden Copepoden*, p. 199, pl. xxxv.
1892, *Centropages violaceus*, Giesb., *F. Fl. Neapel*, vol. xix. p. 304, pl. iv. fig. 5 *et seq.*

This species occurred in gatherings from a number of stations both in the North and South Atlantic, from Station 7 in 26° 23′ N., 20° 20′ W., to Station 90 in 26° 50′ S., 42° 20′ W.

Centropages brachiatus (Dana).

1849, *Pontella brachiata*, Dana, *Proc. Amer. Acad.*, vol. ii. p. 27.
1852, *Calanopia brachiata*, Dana, *U.S. Explor. Exped.*, vol. xiii., II., p. 1133, pl. lxxix.
1892, *Centropages brachiatus*, Giesb., *F. Fl. Neapel*, vol. xix. p. 304, pl. xvii. figs. 26, 37 *et seq.*
1893, „ „ T. Scott, *Trans. Linn. Soc. Lond.*, ser. ii., "Zool.," vol. vi. p. 77.

Several specimens were obtained in surface tow-net gatherings collected on the 4th and 5th of May 1904 off Cape Peninsula, South Africa; Station 476, 34° 43′ S., 17° 15′ E., and Station 477, 34° 21′ S., 18° 29′ E.

Centropages calaninus (Dana).

1849, *Cyclopsina calanina*, Dana, *op. cit.*, vol. ii. p. 25.
1852, *Hemicalanus calaninus*, Dana, *U.S. Explor. Exped.*, vol. xiii., II., pp. 1105, 1106, pl. lxxviii.
1892, *Centropages* „ Giesb., *F. Fl. Neapel*, vol. xix. p. 305, pl. xvii. fig. 27 *et seq.*

The only sample in which this species was obtained was a surface gathering collected at Station 90 in 26° 50′ S., 42° 20′ W. Only one or two specimens were observed.

Centropages typicus, Kröyer.

1848, *Centropages typicus*, Kröyer, *Naturh. Tidsskr.* (N.S.), vol. ii. p. 588, pl. vi.
1863, *Ichthyophorba denticornis*, Claus, *Die freilebenden Copepoden*, p. 199, pl. xxxv.
1864, *Centropages typicus*, Boeck, *Forhandl. Videnskabs-Selsk. Christiania*, p. 19.
1892, „ „ Giesb., *F. Fl. Neapel*, vol. xix. p. 303, pls. ii., iv., xvii. fig. 48 *et seq.*

This species was observed in only one plankton sample—a gathering collected at Station 27 in 13° 38′ N., 25° 9′ W. The distribution of this species extends to the Mediterranean; and in the North Atlantic between 36° N. and 62° N. (GIESBRECHT).

Fam. TEMORIDÆ.

Genus *Temora*, W. Baird, 1850.

Temora stylifera (Dana).

1849, *Calanus stylifer*, Dana, *op. cit.*, vol. i. p. 12.
1856, *Diaptomus dubius*, Lubbock, *Trans. Entom. Soc. Lond.* (N.S.), vol. iv. p. 21.
1863, *Temora armata*, Claus, *op. cit.*, p. 195, pl. xxxiv.
1892, „ *stylifera*, Giesb., *F. Fl. Neapel*, vol. xix. p. 328, pl. v. fig. 2 *et seq.*

This species was of moderately frequent occurrence, and was observed in samples from Stations 18, 19, 26, 30, 36, 67, 68, 79, 83, 85, 86, 90, and 93, 19° 59′ N., 23° 34′ W., to 30° 05′ S., 45° 28′ W.

Temora turbinata (Dana).

1849, *Calanus turbinatus*, Dana, *op. cit.*, vol. i. p. 12.
1892, *Temora turbinata*, Giesb., *op. cit.*, p. 329, pl. xvii. fig. 14 *et seq.*

The only two samples in which this species was observed were collected at Station 12, 22° 19′ N., 22° 07′ W., and Station 14, 21° 28′ N., 22° 40′ W., both in the North Atlantic.

Fam. METRIDIIDÆ.

Genus *Metridia*, Boeck, 1864.

Metridia lucens, Boeck.

1865, *Metridia lucens*, Boeck, *Vid. Selsk. Vorhandl.*, 1864, p. 14.
1892, „ *hibernica*, Giesb., *op. cit.*, p. 340, pl. xxxii. fig. 11 *et seq.*
1904, „ *lucens*, Cleve, *Invest. S. Africa*, vol. iii. p. 192.

A number of specimens were obtained in one or two samples collected on the 4th and 5th of May 1904 off Cape Peninsula, South Africa, Station 476, 34° 43′ S., 17° 15′ E., and Station 477, 34° 21′ S., 18° 29′ E. The Rev. T. R. R. STEBBING records the species as "abundant south and west of Cape Colony" (*Annals of the S. African Museum*, vol. vi. pt. iv. p. 535, 1910).

Metridia gerlachei, Giesbrecht.

1902, *Metridia gerlachei*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 27, pl. v.

This species was obtained in two gatherings, in one from 200 fathoms collected on 28th February 1903 in 69° 22′ S., 26° 36′ W., Station 273; and the other from 500 fathoms collected on 2nd March in 68° 40′ S., 30° 18′ W., Station 280. The distribution of *Metridia gerlachei* is apparently limited more or less to deep water, for although it was obtained at a number of stations by the Belgian Antarctic Expedition of 1897–1899, none of the samples in which it occurred were surface gatherings, but were from depths ranging from 100 to 500 metres.

Genus *Pleuromamma*, Giesbrecht, 1898.

Pleuromamma abdominalis (Lubbock).

1856, *Diaptomus abdominalis*, Lubbock, *Trans. Entom. Soc. Lond.* (N.S.), vol. iv. p. 22, pl. x.

The only gatherings in which this species occurred were collected at Stations 26 and 56, the one in 14° 33′ N., 25° 09′ W., Station 26, and the other in lat. 0° 42′ S., long. 31° 20′ W., Station 56; very few specimens were observed.

Pleuromamma gracilis (Claus). (Pl. XIII. fig. 7.)

1863, *Pleuromma gracilis*, Claus, *Die freilebenden Copepoden*, p. 197, Taf. 5.

This species was only observed in gatherings collected at Stations 14, 18, 39; all in the North Atlantic, 21° 28′ N., 22° 40′ W., to 6° 43′ N., 25° 48′ W.

Pleuromamma gracilis, var. *esterlyi*, nov. (Pl. XIII. figs. 8-10.)

1905, *Pleuromamma gracilis*, Esterly, "Copep. of the San Diego Region," *Univ. of California Publications*, vol. ii. p. 175, text-fig. C.

C. O. Esterly, in the work referred to above, describes and partly figures a form of this species which differs from what Giesbrecht appears to consider as the typical *Pleuromamma gracilis*—especially in the structure of the fifth pair of thoracic feet in the female. Dr Giesbrecht * shows the female fifth pair to consist each of a single ramus provided with three short and tolerably stout teeth, the inner one being slightly the larger; and this agrees fairly well with the specimens of *P. gracilis* in the *Scotia* collections, and with Dr Claus' original description, where, referring to the fifth pair, he says, "Der letzte Fuss des Weibchens bildet einen schmalen, undeutlich gegliederten Stab und endit mit drei kurzen Zinken." † In the form recorded by Esterly from the San Diego region—a form which is also represented in the *Scotia* collections—the rami of the fifth pair of thoracic legs in the female are distinctly two-jointed and armed at the apex with three tolerably long and spiniform teeth, the middle one being the longest (see fig. 9, Pl. XIII.). As there does not appear to be otherwise any marked difference between this form and *P. gracilis*, and in the absence of a male, I am inclined to regard this form as no more than a fairly distinct variety of *Pleuromamma gracilis*.

Fam. Lucicutidæ.

Genus *Lucicutia*, Giesbrecht, 1898.

Lucicutia flavicornis (Claus).

1863, *Leuckartia flavicornis*, Claus, *Die freilebenden Copepoden*, p. 183, pl. xxxii. figs. 1–7.
1892, ,, ,, Giesb., *F. Fl. Neapel*, vol. xix. p. 358, pls. v., xix., and xxxviii.
1898, *Lucicutia* ,, Giesbrecht & Schmeil, *Das Tierreich*, vol. vi. p. 3.
1904, ,, ,, Cleve, *Mar. Invest. S. Africa*, vol. iii. p. 192.

The only samples in which this species was observed were collected at Stations 11, 36, and 49, in the North Atlantic, 23° 50′ N., 21° 34′ W., to 1° 53′ N., 27° 26′ W.

Fam. Heterorhabdidæ.

Genus *Heterorhabdus*, Giesbrecht, 1898.

Heterorhabdus papilliger (Claus).

1863, *Heterochæta papilligera*, Claus, *op. cit.*, p. 182, pl. xxxii.
1892, ,, *papilliger*, Giesb., *op. cit.*, p. 372, pls. xx. and xxxix.
1898, *Heterorhabdus* ,, Giesbrecht & Schmeil, *Das Tierreich*, vol. vi. p. 114.
1901, *Heterochæta papilligera*, Cleve, "Plankton from the Indian Ocean and the Malay Archipelago," *Kongl. Sv. Vet.-Akad. Handl.*, Band xxxv., No. 5, p. 7.

This species, which appeared to be moderately rare, was only obtained in a single gathering collected at Station 15, 20° 34′ N., 23° 12′ W.

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* Cf. *Fauna u. Flora des Golfes von Neapel.*

† *Die freilebenden Copepoden*, p. 197 (1863).

Heterorhabdus austrinus, Giesbrecht.

1902, *Heterorhabdus austrinus*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 28, pl. vi.

H. austrinus occurred in gatherings from 200 and 500 fathoms. Only one or two specimens were obtained. These gatherings were collected on 2nd March 1903; Station 280, 68° 40′ S., 30° 18′ W.

Fam. HALOPTILIDÆ.

Genus *Haloptilus*, Giesbrecht, 1898.

Haloptilus acutifrons, Giesbrecht.

1892, *Hemicalanus acutifrons*, Giesb., *F. Fl. Neapel*, vol. xix. p. 384, pl. iii. fig. 11, pl. xxvii. fig. 12, pl. xlii. figs. 12 and 20.
1898, *Haloptilus acutifrons*, Giesb. & Schmeil, *Das Tierreich*, vol. vi. p. 117.

A single specimen of this *Haloptilus* was obtained in each of two gatherings, in one from 200 fathoms, the other from 500 fathoms, collected on 2nd March 1903 in 68° 40′ S., 30° 18′ W., Station 280. These specimens are more than twice the size of those recorded by Dr GIESBRECHT, and on that account were considered at first as belonging to a different species. A careful examination of them, however, did not reveal any difference sufficiently important to separate them from *H. acutifrons.*

Fam. CANDACIIDÆ.

Genus *Candacia*, Dana, 1846.

Candacia pachydactyla, Dana.

1849, *Candace pachydactyla*, Dana, *Proc. Amer. Acad. Sci.*, vol. ii. p. 23.
1883, ,, ,, Brady, *Report Voyage of the "Challenger,"* vol. viii. p. 68, pl. xxxi. figs. 2–9.
1898, *Candacia pachydactyla*, Giesb. & Schmeil, *op. cit.*, p. 128.
1904, ,, ,, Cleve, *Mar. Invest. South Africa*, vol. iii. p. 187.

This was a tolerably common form in the *Scotia* plankton collections, and appeared to be widely distributed. It was observed in samples collected at twenty-eight different stations, extending from Station 7 in 26° 23′ N., 20° 20′ W., to Station 95 in 32° 15′ S., 47° 30′ W.

Candacia curta, Dana.

1849, *Candace curta*, Dana, *op. cit.*, vol. ii. p. 33.
1892, ,, ,, Giesb., *F. Fl. Neapel*, vol. xix. p. 424, pls. xxi., xxii., and xxxix.
1893, ,, *intermedia*, T. Scott, *Trans. Linn. Soc. Lond.*, "Zool.," ser. 3, vol. vi. p. 61, pl. iv. figs. 30–37.
1898, *Candacia curta*, Giesb. & Schmeil, *Das Tierreich*, vol. vi. p. 128.

This *Candacia* was obtained sparingly in gatherings from the following five stations, viz. 31, 32, 35, and 49 in the North Atlantic, 11° 10′ N., 25° 20′ W., to 1° 53′ N., 27° 26′ W., and Station 59 in 2° 30′ S., 32° 42′ W. This species is found in the Red Sea, and its distribution extends both to the Atlantic and Pacific Oceans.

Candacia bipinnata, Giesbrecht.

1889, *Candace bipinnata*, Giesb., *Atti Acc. Lincei Rend.*, ser. 4, vol. v. p. 815.
1892, „ „ *idem*, *F. Fl. Neapel*, vol. xix. p. 424, pl. xxii. fig. 20 *et seq.*
1898, *Candacia* „ Giesb. & Schmeil, *Das Tierreich*, vol. vi. p. 129.
1904, „ „ Cleve, *Mar. Invest. S. Africa*, vol. iii. p. 186.

A few specimens were obtained in a surface gathering collected 5th May 1904 off Cape Peninsula, South Africa, Station 477, 34° 21′ S., 18° 29′ E.

Candacia æthiopica, Dana.

1849, *Candace æthiopica*, Dana, *op. cit.*, vol. ii. p. 23.

The only gathering in which this species occurred was collected at Station 12 in 22° 19′ N., 22° 07′ W.

Candacia bispinosa, Claus.

1863, *Candace bispinosa*, Claus, *Die freilebenden Copepoden*, p. 191, Taf. 27, 28.

This species occurred sparingly in gatherings from the following seven Stations: 12, 14, 15, 72, 83, 85, and 86, 22° 19′ N., 22° 07′ W., to 24° 26′ S., 40° 25′ W.

Candacia simplex, Giesbrecht.

1889, *Candace simplex*, Giesb., *op. cit.*, ser. 5, vol. v. sem. 1, p. 815, and *Fauna u. Flora des Golfes von Neapel*, vol. xix ("Copep."), p. 424, pl. xxi. figs. 10, 30, 31 *et seq.*

This species was tolerably rare in gatherings from Stations 11, 59, and 83, 23° 50′ N., 21° 34′ W., to 22° 32′ S., 39° 22′ W.

Candacia longimana, Claus.

1863, *Candace longimana*, Claus, *op. cit.*, p. 190, Taf. 27 and 33.

A single specimen of this *Candacia* was obtained in a gathering from Station 49, 1° 53′ N., 27° 26′ W.

Fam. PONTELLIDÆ.

Genus *Calanopia*, Dana, 1852.

Calanopia americana, Dahl. (Pl. XIII. figs. 1–6.)

1894, *Calanopia americana*, Dahl, *Berichte naturf. Gesells. Freiburg* (N.S.), vol. viii. p. 21, Taf. 1, figs. 23–26.

In this species the inner ramus of the first four pairs of thoracic legs in the female are two-jointed. The female fifth pair are simple, and consist each of a single two-jointed ramus; the proximal joint is moderately stout, but the end one is narrow and rather longer than the other, and terminates in a tolerably long spine, and there are also two short spines on the outer and one on the inner margin (fig. 4).

The male differs from the female by the peculiar structure of the right antennule, the fifth and sixth joints of which are produced exteriorly into angular and gibbous expansions. The seventh joint is elongated and slender, while the base of the next one extends inwards into a horn-like projection nearly at right angles to the joint, but curved slightly forward and having its inner edge finely serrated. The remaining joints are slender and moderately elongated, except the last one, which is short; the articulations between the fifth and sixth and the eighth and ninth joints are hinged (fig. 1).

The fifth pair of thoracic legs in the male are asymmetrical, that on the left side is long and slender and terminates in a claw-like spine, while the basal part of the proximal joint expands anteriorly into a short angular process. The other foot is also elongated, but the end joints are dilated and form a thumb-like arrangement, as shown in the drawing (fig. 5).

Habitat.—This species was obtained in gatherings from Stations 64, 65, 67, and 93, 6° 30′ S., 34° 25′ W., to 30° 05′ S., 45° 28′ W.

Calanopia americana was obtained by Dr DAHL in a collection of plankton from the mouth of the river Tocantins, on the north-west coast of South America, where the water was doubtless more or less brackish. Its occurrence in the *Scotia* collections, besides extending the distribution of the species considerably, is interesting, from its having been found in the open sea.

Genus *Labidocera*, Lubbock, 1853.

Labidocera nerii (Kröyer).

1848, *Pontia nerii*, Kröyer, *Naturh. Tidsskr.* (N.S.), vol. ii. p. 579, Taf. 6.

This was a tolerably common species in the *Scotia* collections. It occurred in no fewer than twenty-eight gatherings, extending from Station 7, 26° 23′ N., 20° 20′ W., in the North Atlantic, to 95, 32° 15′ S., 47° 30′ W., in the South Atlantic, occurring at nearly regular intervals.

Labidocera acutifrons (Dana).

1849, *Pontella acutifrons*, Dana, *op. cit.*, vol. ii. p. 30.

The only gatherings in which this species was obtained were collected at Station 14, 21° 28′ N., 22° 40′ W., and Station 18, 19° 59′ N., 23° 34′ W.

Genus *Pontella*, Dana, 1849.

Pontella atlantica (M.-Edw.).

1840, *Pontia atlantica*, M.-Edw., *Hist. Nat. Crust.*, vol. viii. p. 420, Taf. 39.

This species occurred in gatherings from Stations 7, 35, and 41, 26° 23′ N., 20° 20′ W. to 5° 40′ N., 26° 4′ W., but only a few specimens were observed.

Pontella securifer, G. S. Brady.

1883, *Pontella securifer*, Brady, *Report Voyage of the "Challenger,"* vol. viii. ("Copepoda"), p. 96, pl. xlv.

Gatherings collected at Stations 41, 82, and 83 yielded a few specimens of this *Pontella*, 5° 40′ N., 26° 4′ W., to 22° 32′ S., 39° 22′ W.

Pontella spinipes, Giesbrecht.

1889, *Pontella spinipes*, Giesb., *Atti. Acc. Lincei Rend.*, ser. 4, vol. v. sem. 2, p. 28.

This species was obtained in gatherings collected at Stations 14, 44, and 82, 21° 28′ N., 22° 40′ W., to 20° 40′ S., 38° 20′ W.

Genus *Pontellina*, Dana, 1852.

Pontellina plumata, Dana.

1849, *Pontella plumata*, Dana, *op. cit.*, vol. ii. p. 27.
1852, *Pontellina plumata*, Dana, *U.S. Explor. Exped.*, vol. xiii. (ii.), p. 1135, pl. lxxix.

This moderately common species occurred in gatherings from eighteen stations, extending from Station 14 to 93, 21° 28′ N., 22° 40′ W., to 30° 05′ S., 45° 28′ W.

Genus *Pontellopsis*, G. S. Brady, 1883.

Pontellopsis regalis (Dana).

1849, *Pontella regalis*, Dana, *op. cit.*, vol. ii. p. 31.

This species occurred sparingly in gatherings from Stations 11, 35, 49, 54, 59, and 68, 23° 50′ N., 21° 34′ W., to Station 68A, 8° 0′ S., 34° 34′ W., Pernambuco bearing 12 miles W.

Pontellopsis perspicax (Dana).

1849, *Pontella perspicax*, Dana, *op. cit.*, vol. ii. p. 32.

The gatherings in which this species was observed were collected at Stations 27, 30, 35, 44, and 49, all in the North Atlantic, 13° 38′ N., 25° 9′ W., to 1° 53′ N., 27° 26′ W.

Pontellopsis brevis (Giesbrecht).

1889, *Monops brevis*, Giesb., *op. cit.*, ser. 4, vol. v. sem. 2, p. 28.

The only gathering in which this species occurred was collected at Station 67, in 7° 20′ S., 34° 38′ W.

Pontellopsis villosa, G. S. Brady.

1883, *Pontellopsis villosa*, Brady, *Report Voyage of the "Challenger,"* vol. viii. ("Copepoda"), p. 86, pls. xxxiv and xxxv.

This, which was a tolerably rare species in the *Scotia* collections, was only observed in a gathering from Station 8 in 26° 12′ N., 20° 25′ W.

Fam. ACARTIIDÆ.

Genus *Acartia*, Dana, 1846.

Acartia negligens, Dana.

1849, *Acartia negligens*, Dana, *op. cit.*, vol. ii. p. 26.

This species was observed in gatherings collected at Stations 7, 11, 19, and 95, 26° 23′ N., 20° 20′ W., to 32° 15′ S., 47° 30′ W.

Acartia danæ, Giesbrecht.

1889, *Acartia danæ*, Giesb., *op. cit.*, ser. 4, vol. v. sem. 2, p. 26.

This occurred in gatherings from eleven stations, extending from Station 11 to Station 102, 23° 50′ N., 21° 34′ W., to 36° 31′ S., 51° 56′ W.

Tribe *HARPACTICOIDA*, G. O. Sars.*

Fam. CERVINIIDÆ.

Genus *Pseudozosime*, new genus.

Generic characters: Female.—In the female the body is tolerably robust, and has a general resemblance to *Zosime*, Boeck, except that the abdomen is not so clearly defined from the cephalothorax; genital segment moderately large, with a distinct transverse suture. Anterior antennæ (antennules) short, stout, and composed of about five joints. Second antennæ and mouth organs nearly as in *Zosime*. The inner ramus of all the four pairs of swimming legs is composed of two joints, and the outer of three joints. The fifth pair are of moderate size; the inner portion of the basal joint is somewhat expanded, while the second joint is comparatively small.

Remarks.—*Pseudozosime* differs from the other genera nearly related to it by having the inner ramus of all the four pairs of thoracic legs biarticulated, and by the fifth pair being comparatively larger and more compact.

Pseudozosime browni, new species. (Pl. VIII. figs. 9–19.)

Female.—The body of the female tolerably stout, narrow, and elongated, bluntly rounded anteriorly, and tapering slightly towards the posterior end; rostrum prominent. Length of the specimen represented by the drawing 0·95 mm.

Antennules short, stout, composed of about five joints, and densely setiferous. Antennæ with the outer ramus triarticulated, and otherwise nearly as in *Zosime typica*, Boeck. Mouth organs also somewhat similar to those in that species.

The first four pairs of thoracic legs are moderately stout, and the inner ramus is composed of two and the outer of three joints. In the first pair the inner ramus reaches to the end of the three-jointed outer one, and the joints are nearly of equal length; the

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* The arrangement followed for the Harpacticoida is that of G. O. SARS, *Crustacea of Norway*, vol. v.

outer margins of both rami are fringed with minute bristles, but in the outer ramus, the spinules at the outer distal angles of the first and second joints, and also those on the third joint, are tolerably stout and elongated. In the second and third pairs the inner ramus is rather shorter than the outer, and the end joint is about twice as long as the proximal one. In the fourth pair the inner ramus is considerably shorter than the outer one, and scarcely reaches to the end of its middle joint. The fifth pair are of moderate size; the inner portion of the basal joint is somewhat expanded, and provided with four setæ—two on the inner margin and two at the apex; the second joint is smaller, and furnished with three setæ at the distal end; all the setæ are elongated. Caudal rami short, and about equal in length to the last abdominal segment.

Habitat.—South Orkney Islands; collected in June 1903, 60° 43′ 42″ S., 44° 38′ 33″ W., Station 325. Only one specimen—a female—was observed in some siftings from dredged material. Named in compliment to Dr R. N. RUDMOSE BROWN, the *Scotia* naturalist, who was in charge of tow-netting, and who in consequence was the collector of the whole material dealt with in this monograph.

Fam. ECTINOSOMIDÆ.

Genus *Ectinosoma*, Boeck, 1864.

Ectinosoma antarcticum Giesbrecht. (Pl. II. figs. 10–13.)

1902, *Ectinosoma antarcticum*, Giesb., *Expéd. Antarct. Belge*, "Copepoden," p. 31, Taf. 12.

One or two specimens (females) of an *Ectinosoma* apparently belonging to this species were obtained in one of the small gatherings of dredged material collected by the *Scotia* among the South Orkney Islands, Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W., and in these specimens the structure of the various appendages agrees very well with the description of the species given by Dr GIESBRECHT. In the genus *Ectinosoma*, the form and armature of the fifth pair of thoracic legs are usually regarded as furnishing important specific characters, and in these *Scotia* specimens, the fifth pair of legs are identical with those of *Ectinosoma antarcticum*, as shown by Dr GIESBRECHT's figures, and also by our drawings on Pl. II. fig. 14.

Genus *Bradya*, Boeck, 1872.

Bradya proxima, new species. (Pl. II. figs. 1–9.)

Female.—Body moderately robust. Antennules short and stout. Antennæ with the outer ramus well developed, and reaching to the end of the inner ramus. Mandibles, maxillæ, and maxillipeds similar to those in *Bradya typica*, Boeck.

In the first four pairs of thoracic legs both rami are of moderate length, and the joints are somewhat broad and flattened, and the marginal spines of the outer ramus are also elongated and slender. In the fifth pair there is a considerable space between the one and the other, as in *Bradya typica*; the inner lobe of the basal joint is furnished with two long, slender setæ—the inner being rather the longer one; the second joint is small, and carries three setæ at its apex; the two inner setæ are elongated and subequal, but the other is short. The appendicular bristle is slender, and scarcely reaches to the end of the short apical seta. Caudal rami very short.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903: Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Apparently rare.

Remarks.—The form described above is nearly allied to *Bradya typica*, Boeck, but differs in the armature of the last pair of thoracic legs, and in one or two other structural details.

Genus *Microsetella*, Brady & Robertson, 1873.

Microsetella norvegica (Boeck).

1864, *Setella norvegica*, Boeck, *Selskab. Forhandl. Christiania* (1864), p. 281.

This small *Harpactid* was observed in gatherings from only a few stations, viz. 37, 62, 93, 94, and 106, 7° 50′ N., 25° 31′ W., to 39° 01′ S., 53° 40′ W.

Microsetella rosea (Dana).

1847, *Harpacticus roseus*, Dana, *Proc. Amer. Acad.*, Boston, vol. i. p. 153.

This species appeared to be rather more common than the last, being present in gatherings from about fifteen stations, and with a distribution extending from Stations 7, 10, and 12 in the North Atlantic, 26° 23′ N., 20° 20′ W., to 22° 19′ N., 22° 07′ W., to Station 88 in 26° 25′ S., 42° 00′ W.

Fam. MACROSETELLIDÆ.

Macrosetella, A. Scott, 1909.

Syn. *Setella*, Dana (but this name is preoccupied).

Macrosetella gracilis (Dana).

1846, *Setella gracilis*, Dana, *Amer. Journ. Sci.* (2), vol. i. p. 227.

This species occurred in gatherings from twenty-five stations, and appeared to be distributed over nearly the whole area traversed by the *Scotia*. The northerly Stations comprised 7, 10, 12, 14 in the North Atlantic, while Stations 93, 94, and 95 were the most southerly; 26° 23′ N., 20° 20′ W., to 32° 15′ S., 47° 30′ W.

Genus *Miracia*, Dana.

Miracia efferata, Dana, 1846.

1846, *Miracia efferata*, Dana, *Amer. Journ. Sci.* (2), vol. i. p. 230.

This was also observed in gatherings from twenty-five stations, and its distribution was somewhat similar to that of *Setella*.

Fam. EUTERPINIDÆ.

Genus *Euterpina*, Norman, 1903.

Syn. *Euterpe*, Claus, 1863 (name preoccupied).

Euterpina acutifrons (Dana).

1847, *Harpacticus acutifrons*, Dana, *Proc. Amer. Acad.*, Boston, vol. i. p. 153.

The only gathering in which this species occurred was from Station 65 in 6° 52′ S., 34° 32′ W.

Fam. CLYTEMNESTRIDÆ.

Genus *Clytemnestra*, Dana, 1847.

Clytemnestra scutellata, Dana. (Pl. XIII. figs. 11 and 12.)

1847, *Clytemnestra scutellata*, Dana, *Proc. Amer. Acad.*, Boston, vol. i. p. 154.

This species was observed rather sparingly at Stations 14, 32, 33, and 39, 21° 28′ N., 22° 40′ W., to 6° 43′ N., 25° 48′ W., all in the North Atlantic. This species may be distinguished from *Clytemnestra rostrata* (Brady) by the different structure of the antennules and caudal rami. Fig. 11, Pl. XIII., shows the end-joints of one of the antennules, and the caudal rami are represented by fig. 12.

Fam. HARPACTICIDÆ.

Genus *Harpacticus*, M.-Edw., 1838.

Harpacticus fucicolus, new species. (Pl. VIII. figs. 20–24.)

Female.—In its general appearance the female of this species is somewhat similar to *Harpacticus gracilis* (Claus).

The antennules are moderately slender and composed of nine joints; the first four are of moderate size and subequal, but the third is rather longer than any of the other three; the remaining five joints are small, and together are scarcely equal to one-fourth of the total length—the penultimate joint is the smallest. Antennæ small, the outer ramus short and composed of two joints. Mandibles and other mouth organs nearly as in *Harpacticus gracilis.*

First pair of thoracic legs slender; the outer ramus is considerably elongated, but the inner one reaches only to about the end of the first joint of the outer ramus; the armature of both rami is rather feeble. The next three pairs are somewhat similar to those in *Harpacticus gracilis.*

In the fifth pair, the inner portion of the basal joint is not much produced; it is provided with four setæ; one springs from the inner margin and three from the broadly rounded apex; the outer margin of the second joint is nearly parallel with the inner, and near the extremity of the joint both margins converge to the angular apex; four setæ spring from the lower end of the outer margin and apex of this joint, and one from the lower end of the inner margin; all the setæ are moderately slender. Caudal rami very short.

Habitat.—Obtained on floating seaweed collected in the North Atlantic on 29th June 1904, between Cape Verde Islands and the Azores, Station 537, 29° 54′ N., 34° 10′ W.

Remarks.—The form described above has a close resemblance to *Harpacticus gracilis*, Claus, and it may ultimately have to be ascribed to that species. Meanwhile, as no male specimens have been observed, and as there are one or two slight differences between the two forms, as, for example, in the structure of the antennules and of the fifth pair of thoracic legs, it is perhaps better that the specimens from the *Scotia's* collections should be recorded under a distinct name.

Harpacticus piriei, new species. (Pl. V. fig. 15; Pl. XI. figs. 18–25.)

Female.—Body moderately stout, somewhat resembling *Harpacticus chelifer*, O. F. Müller, in its general form. Length about 0·85 mm.

Antennules composed of nine joints; the first four tolerably stout and elongated, the others small, so that, together, they are scarcely equal to a fourth of the entire length of the antennule (fig. 18, Pl. XI.). Antennæ and mouth appendages nearly as in *Harpacticus chelifer*.

The first pair of thoracic legs are tolerably slender, and somewhat similar to the species mentioned; the other three pairs are also somewhat similar to those in the same species, except that in the second pair the inner ramus is nearly as long as the outer one.

The fifth pair has the basal joint broad and its inner portion only slightly produced, and provided with four setæ of unequal lengths on its distal margin, the second seta from the outside being much longer than the others. The second joint is subtriangular in outline, the greatest width, which is near the proximal end, being about equal to half the length; the inner margin is nearly straight, but the outer is rounded and curves obliquely to the distal extremity: this joint is provided with six setæ of unequal lengths—two, having a considerable space between them, on the lower half of the outer margin, two close together at the apex, and two at the distal end of inner margin—the second seta from the inside being very small (fig. 15, Pl. V.).

The caudal rami in this species are very short.

Habitat.—Scotia Bay, South Orkneys, in siftings from some dredged material collected in 9 to 10 fathoms, in April 1903, Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species, though it resembles *Harpacticus chelifer* in some respects, differs distinctly in the form and armature of the fifth pair of thoracic legs, and also in the structure of the antennules. Named in compliment to Dr J. H. HARVEY PIRIE, one of the *Scotia* naturalists.

Fam. Peltidiidæ.

Genus *Alteutha*, Baird, 1845.

Alteutha austrina, new species. (Pl. X. figs. 9–15.)

Female.—Body depressed, expanded laterally, and having a general resemblance to *Alteutha depressa*, Baird. Length of the specimen represented by the drawing (fig. 9), 0·92 mm.

Antennules composed of nine joints; the second joint, which is the longest, is about equal to the third and fourth joints combined; the seventh and eighth, which are about equal in size, are smaller than any of the others (fig. 10). Second maxillipeds small, with the end joint short, and armed with a moderately stout terminal claw.

The outer ramus of the first pair of thoracic legs is considerably longer and stouter than the inner, and both rami are three-jointed—the joints of the outer ramus are subequal in length. The next three pairs are slender and similar to those in *Alteutha depressa.*

The fifth pair also resemble those of the same species: they consist of thin and moderately narrow and elongated plates with a subcentral and longitudinal hyaline band, as indicated in the drawing (fig. 14); each foot is two-jointed, but the articulation between the joints is sometimes not very clearly defined. The basal joint is short and carries a moderately stout spine on its outer distal angle; there is also a stout spine and a few small spinules at the extremity of the second joint, and the inner margin of this joint is obscurely crenulated, as shown in the figure (fig. 14).

Caudal rami short, moderately broad, and furnished each with one long and three (or four) short terminal bristles (fig. 15).

Habitat.—Scotia Bay, South Orkneys, obtained in siftings from some dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″. W.

Though this species resembles in some respects Dr Baird's *Alteutha depressa*, it differs from it in some important details, as indicated in the description given above.

Alteutha dubia, new species. (Pl. X. figs. 1–8.)

Female.—Body depressed, expanded laterally, as in *Alteutha depressa*, Baird; rostrum prominent. Length, 1·4 mm.

Antennules composed of nine joints; the second is considerably longer than any of the others; the seventh and eighth are small and subequal, and the end joint is about as long as the two preceding ones combined (fig. 2). Antennæ slender; outer ramus small and biarticulate.

Second maxillipeds elongated, end joint ovate, and armed with a moderately short and stout terminal claw (fig. 4).

The swimming legs are moderately slender, and both rami are three-jointed; the inner ramus of the first pair is considerably shorter than the outer one, and the end joint is rather narrower than the first or second (fig. 5).

Fifth pair lamelliform, tolerably broad, and composed of two joints; the first joint is produced anteriorly into a narrow appendage bearing two apical and marginal setæ; the second joint is provided with five or six slender bristles on the distal half of the outer margin and apex (fig. 7).

Caudal rami short, ovate; a tolerably stout spine springs from a notch near the middle of the outer margin, and there are also one elongate and three short setæ round the distal end of each ramus (fig. 8).

Habitat.—Scotia Bay, South Orkneys, obtained in siftings from some dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The species described above may be distinguished by the peculiar structure of the fifth pair of thoracic legs, as well as by the form and armature of the caudal rami.

Genus *Paralteutha*, new genus.

Definition.—Similar to *Alteutha*, Baird, in its general form and in its cephalothoracic appendages, except that the inner ramus of the first pair of swimming feet consists of two instead of three joints; and the lateral margins of the second joint of the fifth pair are parallel, or nearly so, while the distal extremity of the joint is obliquely truncated.

Paralteutha typica, new species. (Pl. X. figs. 16–25.)

Female.—Body depressed, expanded laterally, as in *Alteutha depressa*, Baird. Length of the specimen represented by the drawing (fig. 16), 1·6 mm.

Antennules nine-jointed, as in *Alteutha depressa.* Outer ramus of the antennæ small and biarticulate, but the end joint is very minute.

Mandibles with the masticatory end narrow and truncated, biting edge obscurely dentate. Second maxillipeds elongated, each provided with a tolerably large and powerfully clawed hand (fig. 20).

First pair of thoracic legs elongated and moderately stout, inner ramus not much shorter than the outer, and composed of two subequal joints (fig. 21). The next three pairs long and slender, and furnished with long slender marginal spines (fig. 22).

Fifth pair stout, two-jointed; the first joint is short, but the second is tolerably elongated, and about four times as long as broad; its margins are nearly parallel, and its distal extremity truncated and armed with three stout spines, the inner one being the largest. There are also two short spines on the inner margin, one near the middle of the joint, the other near its distal end. The first joint is also provided with a few long setæ, as shown in the drawing (fig. 24).

Caudal rami short and subquadrangular in outline. A short, stout spine springs from a notch on the outer margin of each ramus, and there are also a few small apical spines.

The male does not differ much from the female, except in the structure of the antennules and of the fifth pair of thoracic legs. The antennules are so modified that they form effective grasping organs. In the fifth pair of legs, the joints are nearly of equal length and their armature is also slightly different (fig. 25).

Habitat.—Scotia Bay, South Orkneys, obtained in siftings from dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species appears to hold an intermediate place between *Alteutha* and *Peltidium.* It resembles the first in its general appearance, and also to some extent in the structure of several of its appendages. On the other hand, the structure of the first pair of thoracic legs is somewhat similar to that of the same pair of legs in *Peltidium.*

Fam. PORCELLIDIIDÆ.

Genus *Porcellidium*, Claus, 1860.

Porcellidium affine, Quidor. (Pl. IV. figs. 5–13.)

1906, *Porcellidium affinis*, Quidor, *Expéd. Antarct. Française*, 1903–1905, "Copepodes," p. 4, pl. i. figs. 1–19.

Female. — The female of this species has a general resemblance to that of *Porcellidium ravanæ*, Thompson & Scott, described in Supplementary Report VII. of the Report on the Ceylon Pearl-Oyster Fisheries, by Professor HERDMAN. It differs, however, in the form of the first abdominal segment, as well as in the structure of the antennules; it is also somewhat larger than that species, being about 1 mm. in length.

The antennules are composed of seven unequal joints; the first three are large, their combined lengths being equal to about two-thirds of the entire length of the antennule. The remaining joints are small, but the fourth and sixth are rather longer than the others (fig. 7). The antenna (fig. 8) has the outer ramus articulated to the end of the first joint of the inner one, and is composed of a single moderately long joint. The mouth appendages and swimming feet are similar to those in *Porcellidium ravanæ.* The first pair of swimming feet are short, and the first joint of the inner ramus is a broad angular plate widest near the proximal end, but becoming narrower distally; the end joint, which is very small, is provided with two stout claw-like spines of tolerable length, which usually extend outwardly at about a right angle to the leg; in the outer ramus the first joint is moderately expanded, but the second and third are smaller. The spiniform setæ on the outer margin are all dilated at the base and plumose, but the two at the end are tolerably long and slender. A stout seta also springs from the inner distal angle of the second joint. The claw-like spines on the end joint of the inner ramus are each furnished on the lower edge with a fringe of close-set delicate filaments (fig. 9).

The next three pairs have both rami three-jointed, and moderately elongated and slender.

The fifth pair are somewhat similar to those in *Porcellidium ravanæ*, both in their general outline and in having their extremity bluntly rounded (fig. 10).

The abdomen and caudal rami also resemble the same parts in *P. ravanæ*, but in that species the caudal rami do not reach to the end of the fifth pair of feet, whereas in the present form the caudal rami reach somewhat beyond these appendages. They are also more bluntly rounded at the end, and the terminal and marginal spines are somewhat differently arranged, as shown in the drawing (fig. 12).

Male.—The male, as is usual, is smaller than the female; the antennules are modified for grasping; the fifth pair of feet are different in form and armature, and the abdomen and caudal rami are shorter (see figs. 12 and 13).

The fifth pair of feet are small, and narrow at the proximal end, but they become wider distally; the extremity is obliquely truncated and fringed with about six short setiferous spines (fig. 11). Caudal rami are very short, and have the squarely truncated ends furnished with a few marginal setæ (fig. 13).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species, as already stated, has some resemblance to *Porcellidium ravanæ*, Thompson & A. Scott, but differs in several anatomical details, as, for example, in the structure of the female antennules, as well as in the form and armature of the caudal segments. It also resembles in some respects the *Porcellidium wolfendeni* described by G. S. Brady.*

Genus *Tisbe*, Lilljeborg,† 1853.

Tisbe austrina, new species. (Pl. III. figs. 26–30.)

Female.—This species, in its general appearance, is somewhat like *Tisbe minor* (T. Scott), but is rather more slender. Length about 0·6 mm.

Antennules composed of eight joints; the second and third joints are subequal and of moderate size; the fourth is fully half as long as the third; the fifth and sixth, which are subequal, are together about as long as the fourth, but the seventh is very small; the end joint was incomplete, but appeared to be about as long as the fourth joint. The antennæ are small, and the outer ramus reaches only to the end of the second joint of the inner ramus. Mouth organs somewhat similar to those in *Tisbe minor*, but the second maxillipedes are moderately stout. All the four pairs of swimming legs are also somewhat similar to those in the species mentioned.

In the fifth pair, the inner portion of the basal joint ends in a blunt pointed apex, which bears two setæ, one being moderately stout and elongated, and the other small;

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* *Deutsche Südpolar Exped.*, 1901–1903: "Über die Copepoden der Stämme Harpacticoida," *et seq.*, p. 556 (1910). Separate reprint.

† "The name *Idya* having been previously given by Blainville to a genus of Acalephæ," was changed by G. O. Sars to *Idyæa*: see *Rept. of Second Norwegian Arctic Exped. in the "Fram,"* 1898–1902, No. 18; *Crustacea*, by G. O. Sars, p. 21 (1909). Rev. T. R. R. Stebbing, in *Annals of the South African Museum*, vol. vi. p. 544 (1910), restores Lilljeborg's name, *Tisbe*.

the second joint is of a broadly ovate form, its greatest width being equal to about half the length, and it carries four (or five) short setæ round the lower part of the outer margin and apex, as shown in the drawing (fig. 30).

Caudal rami short.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. No males observed.

Remarks.—As already stated, this species has a somewhat close resemblance to *Tisbe minor* (T. Scott), first described in the *Annals of Scottish Natural History* in October 1896, from specimens obtained in the Firth of Clyde. The same species has also been recorded from Norway by Professor G. O. Sars, and it was one of the Harpactids discovered by Dr Bruce in Franz Josef Land. But the Antarctic form, though closely resembling the northern species referred to, may be readily distinguished from it by the broadly ovate form of the second joint of the last pair of thoracic legs.

The genus *Tisbe*, as Professor G. O. Sars remarks, "seems to be represented in all parts of the oceans," and he has "even found one or two species of this genus in the Caspian Sea."* Dr Giesbrecht obtained two species belonging to the *Idyæa* in the collections brought home from the Antarctic by the *Belgica* in 1899;† both these species, however, differ in several respects from those observed in the material collected by the *Scotia*; and they differ especially in the structure of the first and fifth pairs of thoracic legs. I am also unable to identify the *Scotia* species with either of those recorded by Dr Brady in his account of the Copepoda-Harpacticoida of the *Deutsche Südpolar Expedition*, pp. 560, 561.‡

Tisbe gracilipes, new species. (Pl. I. figs. 23–29.)

Female.—The female of this species is somewhat like that of *Tisbe gracilis* (T. Scott) in its general form, being elongated and rather slender.

The antennules are tolerably elongated; the second joint is rather longer than the third, which, in its turn, is about one and a half times the length of the fourth joint. The three following joints are small, while the end one is equal to the two preceding joints combined (fig. 23).

Antennæ moderately slender, the outer ramus four-jointed and rather longer than the penultimate joint of the inner ramus (fig. 24). The mandibles and other mouth organs are somewhat similar to those in *Tisbe gracilis*.

The thoracic legs are also somewhat similar to those in the species mentioned, but in the first pair, the second joint of the inner ramus is proportionally more elongated, being fully one and a half times the length of the first joint. The outer ramus scarcely reaches to the end of the first joint of the inner one (fig. 26). In the fourth pair, the

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* *Crustacea of Norway*, vol. v. p. 88 (1905).

† *Resultats du Voyage du s.y. "Belgica," "Copepoda,"* von Dr W. Giesbrecht, p. 38 (1902).

‡ *Deutsche Südpolar Exped.*, 1901–1903: "Über die Copepoden der Stämme Harpacticoida, Cyclopoida," etc. (1910).

end joint of the outer ramus is about twice as long as the preceding joint. It is also moderately narrow, and furnished with two rather stout marginal spines and two at the apex, the inner apical spine being nearly as long as the joint to which it is articulated (fig. 27).

The fifth pair are somewhat like the same pair in *Tisbe gracilis*; the second joint, however, differs in being rather wider in proportion to its length. The seta on its inner margin is also articulated nearer the middle of the joint, and the whole of the inner aspect of the joint is covered with minute hairs (fig. 28).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Rare.

Remarks.—This form resembles *Idyæa gracilis*, and might be considered as only a variety of that species, but the inner ramus of the first pair of swimming legs is proportionally and distinctly more elongated, and the second joint of the fifth pair is also more broadly ovate. Because of these differences and one or two others alluded to in the description, the species ought, I think, to be considered distinct.

Genus *Psamathe*, Philippi, 1840.

Psamathe longicauda, Philippi. (Pl. V. figs. 16–22.)

1840, *Psamathe longicauda*, Philippi, *Archiv f. Naturgesch.* (1840), p. 89, pl. iv. fig. 1.
1866, *Scutellidium tisboides*, Claus, *Die Copepoden fauna von Nizza*, p. 21, pl. iv. figs. 8–15.
1880, „ „ Brady, *Monogr. Brit. Copep.*, vol. ii. p. 175, pl. lxviii. figs. 1–10.
1905, *Psamathe longicauda*, G. O. Sars, *Crustacea of Norway*, vol. v. p. 83, pl. xlix.

A single specimen of this Harpactid was obtained in a plankton gathering collected at Station 27 in 13° 38′ N., 25° 09′ W.

The body in this species is considerably flattened, and there is a distinct break between the anterior and the posterior portions, best seen when viewed from above, the former being expanded, while the latter is narrow (see fig. 16).

The antennules are composed of nine joints; the first three are elongated and moderately stout, and are together about twice the entire length of the remaining six joints: the end joint is slender and rather longer than the three preceding joints combined (fig. 17).

Antennæ with the outer ramus four-jointed and not more than half the length of the inner one; it is also articulated to the outer distal angle of the second basal joint (fig. 18).

Maxillipeds moderately stout; first pair smaller than the second and armed with two claw-like terminal spines (fig. 19). Second maxillipeds robust; the basal joint is provided with a stout plumose seta on its inner distal angle, and the end joint with three stout terminal claws and a small plumose bristle (fig. 20).

The first pair of thoracic legs are moderately stout, and both rami are composed of three joints, but the end joints are extremely small and bear peculiar recurved terminal spines, as shown in the drawing (fig. 21); the outer ramus is considerably shorter than the inner, and the spiniform seta at the outer angle of the second basal joint is remarkably stout. The next three pairs have both rami also three-jointed, and are of normal form.

In the fifth pair, which were somewhat imperfect, the basal joint was bilobed and moderately expanded; the end joint, which is of a narrow ovate outline, is about three times longer than broad, but, being imperfect, its dimensions could not be accurately made out (see fig. 22).

The specimen—a female—represented by the drawing (fig. 16) measured 0·88 mm. in length. It agrees so closely in size and form and in the structure of its various appendages with the description and drawing of *Psamathe longicauda* given by G. O. SARS in the work referred to above, that I have no hesitation in ascribing it to the same species.

The distribution of *Psamathe longicauda* is apparently extensive, for in addition to the Mediterranean records by PHILIPPI and CLAUS, it also belongs to the Copepod fauna of Britain and Norway. It has also been reported from Franz Josef Land as well as from the Black Sea. Its occurrence at the *Scotia* Station 27 extends its distribution to the south of the Cape Verde Islands.

Psamathe fucicola, new species. (Pl. VI. figs. 12–19.)

Female.—The female of this species has a general resemblance to *Psamathe longicauda*, Philippi, but is rather smaller. The length of the specimen represented by the drawings is 0·75 mm.

Antennules moderately stout and composed of nine joints; second joint tolerably large, and fully one and a half times longer than the next; the fifth, sixth, and seventh very small; the last two joints are slender, but rather longer than those immediately preceding (fig. 12).

The antennæ, mouth organs, and swimming feet are nearly as in *Psamathe longicauda.*

In the fifth pair the second joint is about three times longer than broad; both the lateral margins are fringed with minute bristles; a small spiniform seta also springs from near the distal end of the inner margin, and another from the apex of the joint (fig. 18). The caudal rami are short and broad (fig. 19.)

Habitat.—Found on floating seaweed—"Gulf-weed"—collected between the Cape Verde Islands and the Azores in June 1904; Station 538, 32° 11′ N., 34° 10′ W.

Remarks.—The Harpactid recorded above has a close resemblance to *Psamathe longicauda,* Philippi, and may be mistaken for that species. It is, however, rather smaller; the proportional lengths of the joints of the antennules are somewhat different; the thoracic legs are rather more slender, and the armature of the fifth pair, especially, differs distinctly from the species referred to.

Genus *Machairopus*, G. S. Brady, 1883.

Machairopus australis, new species. (Pl. VI. figs. 20–28.)

Female.—Body depressed, anterior portion considerably expanded. Length about 1·1 mm.

Antennules elongated and slender and composed of nine articulations; the second and third joints, which are nearly of equal length, are longer than any of the others; the fifth and sixth are also subequal, but very small, while the end joint is narrow and rather longer than the one immediately preceding. Antennæ and mouth organs somewhat similar to those in *Machairopus idyoides*, Brady.

First pair of thoracic legs stout; outer ramus much shorter than the inner one; while the first joint of the inner ramus is considerably longer than the second, as shown by the drawing (fig. 25). The next three pairs are slender.

Fifth pair lamelliform; proximal joint small; end joint elongate ovate, widest anteriorly, the greatest width equal to rather more than one-third of the length; both lateral margins fringed with minute bristles; this joint is also furnished with three apical setæ, the innermost being very short, while the other two are moderately elongated.

Caudal rami short, about as long as the last abdominal segment.

Habitat.—Scotia Bay, South Orkneys; obtained in siftings from some dredged material collected in April 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Machairopus major, new species. (Pl. IV. figs. 14–24.)

Female.—Resembling the species last described, but larger. Length, 1·5 mm.

Antennules composed of nine joints; second and third joints moderately stout, subequal in length and longer than any of the others, the two combined being equal to the entire length of the following six joints; end joint longer than the preceding one (fig. 15).

Mandibles elongated and narrow, the masticatory end obliquely truncate; mandible pulp small and two-branched. First maxillipeds somewhat slender, but the second pair are moderately stout.

All the four pairs of swimming legs are tolerably stout; in the first pair, the outer ramus scarcely reaches to the end of the first joint of the inner ramus; the first and second joints of the inner ramus are nearly of equal length. In the next three pairs, the inner ramus is rather longer than the outer, and the marginal spines of the outer ramus are short and stout. In the fifth pair, the second joint is broadly foliaceous, somewhat ovate in outline and widest near the proximal end, the greatest width being equal to about half the length; a slender seta springs from a notch near the middle of the outer margin, and there are also about four slender and moderately elongated setæ on the bluntly rounded apex of the joint (fig. 23).

Caudal rami short.

Habitat.—South Orkney Islands; collected in April 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species differs from the last in the proportional lengths of some of the joints of the antennules, and in the form and armature of the last pair of thoracic legs. The other thoracic legs are also stouter.

One obvious character by which *Machairopus* may be distinguished from *Psamathe* is found in the armature of the outer branches of the first pair of thoracic legs. In *Psamathe* the terminal spines of both rami are somewhat similar, while in *Machairopus*, only the terminal spines of the outer ramus have their upper margins setiferous, as shown in the drawings.

Fam. THALESTRIDÆ.

Genus *Parathalestris*, G. O. Sars, 1905.

Parathalestris clausi (Norman). (Pl. II. figs. 15–18.)

1869, *Thalestris clausi*, Norman, *Brit. Assoc. Report* (1868), p. 297.
1880, „ „ Brady, *Monogr. Brit. Copep.*, vol. ii. p. 128, pl. lxii. figs. 1–12.
1905, *Parathalestris clausi*, G. O. Sars, *Crust. of Norw.*, vol. v. p. 111, pls. lxv., lxvi.

A single specimen—a male—which undoubtedly belongs to this species, was obtained in a tow-net gathering collected by the *Scotia* at Station 62 on 13th December 1902; Station 61, 4° 15′ S., 33° 38′ W.; earlier on this date, the vessel passed Rocas Light, bearing WSW. about 30 miles, off the north-east coast of South America.

From what is known concerning the distribution of this species, its occurrence so far south appears to be somewhat unusual; its presence in this gathering may have therefore been accidental. It is moderately common round the British and Norwegian coasts, and Dr Canu records it from the French coast.

Parathalestris coatsi, new species. (Pl. III. figs. 7–16.)

Female.—Body depressed and somewhat expanded; thorax and abdomen not clearly defined; forehead broadly rounded, rostrum small, caudal rami short. Length of specimen represented by the drawing about 1 mm.

Antennules composed of nine joints; the first four are tolerably large, but the remaining five are small, their entire length being shorter than the second and third combined. Antennæ moderately stout, the outer ramus two- (or indistinctly three-) jointed.

The mandibles are moderately stout and provided with a small two-branched palp (fig. 10). Second maxillipeds stout; end joint short and armed with a strong and curved terminal claw which is furnished with a few minute spines on its inner edge; the end joint, to which the claw is articulated, has also a few minute spines on the margin on which the claw impinges (fig. 11).

The first pair of thoracic legs are stout and of moderate length; their outer ramus is armed with elongated and tolerably stout terminal claws, and the setæ on its outer margin and apex are also elongated; the first joint of the inner ramus reaches to near the end of the second joint of the outer one; the end joints are small and the apical claws elongated; there is also a fringe of minute spines along the outer margin in both rami (fig. 12). The second, third, and fourth pairs are nearly as in *Parathalestris clausi* (Norman).

The fifth pair are broadly foliaceous, and both segments are furnished with several spines, all of which are tolerably stout, except the one at the outer distal angle of the inner segment, and the apical one on the outer segment, as shown in the figure (fig. 15).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Only a few specimens were observed; they were in some material washed from zoophytes brought in the trawl-net or dredge.

This species is named in honour of the late Mr James Coats, junior, and of Major Andrew Coats, D.S.O., who were the two chief subscribers to the Expedition. Major Coats is also a member of the Scotia Committee.

Parathalestris affinis, new species. (Pl. III. figs. 17–25.)

Female.—In its general appearance, and also in the structure of some of its appendages, the female of this species is not unlike that of *Parathalestris jacksoni* (T. Scott), recorded from Franz Josef Land, except that the caudal rami are short. The body is elongated, tolerably stout, and tapers slightly towards the posterior end, and the integument is strongly chitinous. Head rounded and furnished with a small rostrum. Caudal rami short, their length about equal to that of the last segment of the abdomen (fig. 17). Length of the specimen represented by the figure about 1·5 mm.

Antennules short, and composed of nine articulations; the first four joints are moderately large, and the upper distal portion of the fourth joint extends forward to near the middle of the next one and carries a tolerably long and stout sensory filament; the sixth joint is rather longer than the preceding one, while the seventh and eighth, which are subequal, are shorter than any of the others; the end joint is about one and a half times the length of that which precedes it; all the joints except the first are moderately setiferous (fig. 18). Antennæ with the outer ramus small and biarticulate.

Mandibles slender and becoming attenuated towards the distal end. Maxillæ strongly developed, the truncated masticatory part armed with several spiniform setæ and extending rather beyond the supplementary lobes (fig. 21).

Maxillipeds small; the second pair short, but with the end joint dilated and armed with a short and rather stout and curved terminal claw (fig. 23).

The first pair of thoracic legs have the inner ramus rather shorter than the outer, and provided with long, terminal, claw-like spines; the end joint of the outer ramus is also armed with several claw-like spines somewhat similar to those of the inner ramus, and an elongated seta springs from its inner distal angle; the second joint of the same ramus has also its outer margin fringed with minute teeth as far forward as the spine, which spring from near its distal end, while the inner margin of the same joint and the outer margin of the inner ramus are both fringed with delicate hairs, as shown in the drawing (fig. 24). Another feature here is the presence of three small teeth on the transverse end of the first joint of the outer ramus (see fig. 24).

The next three pairs are somewhat similar in structure to the same appendages in *Parathalestris jacksoni* (T. Scott).

The fifth pair are tolerably large and foliaceous; the outer segment, which is broadly ovate in form, is provided with six setæ; five of them spring from the distal half of the outer margin and apex, and one from the lower part of the inner margin; the uppermost three on the outer margin are moderately stout and widely apart, while the two at the apex are slender and close together. The inner portion of the basal joint is shorter than the outer, and is somewhat triangular in outline, being broad at the proximal end, and tapering from thence to the rounded extremity; five setæ spring from the distal end of this inner segment; the three on the inner aspect are moderately stout and placed widely apart; the other two spring from the lower half of the outer margin and are close together; they are smaller than the others (fig. 25).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Only one or two specimens were observed.

Remarks.—The species now described is in its several appendages not unlike the northern form mentioned above, the fifth pair of thoracic legs being remarkably similar; there are, however, a few differences of more or less importance between them —the species referred to being, for example, distinctly larger, and the caudal rami entirely different.

Genus *Idomene*, Philippi, 1843.

Idomene forficata, Philippi. (Pl. III. figs. 1–6; Pl. IV. fig. 1; Pl. IX. fig. 29.)

1843, *Idomene forficata*, Philippi, *Archiv f. Naturgeschichte*, p. 65, pl. iii. fig. 4.
1880, *Dactylopus flavus*, Brady, *Monogr. Brit. Copep.*, vol. ii. p. 116, pl. lvi. figs. 1–11.
1906, *Idomene forficata*, G. O. Sars, *Crust. of Norway*, vol. v. p. 134, pl. lxxxii.

Female.—Body somewhat depressed, expanded in front, but becoming narrower towards the distal end. Length, ·57 mm.

Antennules short and composed of seven joints; the first four joints are tolerably large, but the others are smaller, the penultimate joint being rather shorter than the preceding one, and about half as long as the next. Antennæ with the outer ramus small and biarticulate.

The second maxillipeds are of moderate size; a stout seta springs from the end of the first joint, while the second is armed with a long slender claw, and a small bristle also springs from near the distal end of its inner margin.

The four pairs of swimming feet have both rami three-jointed. The first pair are stout, and the second basal joint is furnished with a stout seta on both the outer and inner margins; the first and second joints of the outer ramus are tolerably large, but the end one is only about half the length of the preceding joint; inner ramus considerably longer than the outer, and the first joint, which is as long as the entire outer ramus, is widest near the proximal end, but becomes narrower distally; the greatest width is equal to about two-fifths of the length; second and third joints are small; the last is provided with one or two apical setæ, and a moderately stout appendage which terminates in a small hook-like process (fig. 4). The fourth pair are small, and the inner ramus is shorter than the outer one; both rami are furnished with moderately long and slender marginal setæ, and the terminal setæ are also considerably elongated.

Fifth pair small; basal joint not greatly produced interiorly, the interior part broadly rounded and provided with five elongated setæ; the space between the outermost seta and the next one is rather greater than that between the others; second joint subtriangular, and furnished with one seta on the inner margin, two setæ on the outer, and two at the apex (see fig. 29, Pl. IX.).

The male does not differ greatly from the female, but the basal joint of the fifth pair of thoracic legs is only slightly produced interiorly, and bears two instead of five setæ, while the second joint has three instead of two setæ on its outer margin (fig. 6, Pl. III.).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This Antarctic *Idomene* so closely resembles the form described by Philippi from the Mediterranean that I have scarcely any hesitation in referring it to the same species. The only difference of any importance is the small hook-like process at the end of the inner ramus of the first pair of thoracic legs. The occurrence of this species in the Antarctic collections made by the s.y. *Scotia* is of considerable importance. The distribution of *Idomene* extends to the British and Norwegian coasts.

Genus *Dactylopusia*, Norman, 1903.

Dactylopusia frigida, new species. (Pl. II. figs. 19–25.)

Female.—Body moderately stout, and somewhat similar to *Dactylopusia neglecta*, G. O. Sars, in its general appearance. Length, 0·85 mm.

Antennules moderately short and composed of nine joints; the first four are stout and subequal; the sixth is about equal to the fourth, and rather longer than the preceding joint; the seventh and eighth joints are very short, but the terminal joint is about equal in length to the fifth. Antennæ small; outer ramus moderately elongated and composed of three joints, but the middle joint is very small.

Second maxillipeds with the end joint oblong and furnished with a tolerably long slender claw.

In the first pair of thoracic legs the inner ramus is moderately elongated and narrow, but the outer is short and only reaches to a little beyond the middle one; the second joint is nearly twice as long as the first, and the end one is very small. The next three pairs are tolerably stout; in the fourth pair the short inner ramus is somewhat triangular in its general outline, and both the inner and outer margins taper to the narrow distal extremity.

In the fifth pair, the inner portion of the basal joint, which is moderately produced, is transversely truncated, and furnished with about five apical setæ; the second joint is broadly ovate and is provided with six setæ; the three setæ on the inner margin, and one near the end of the outer margin, are tolerably stout, but the other two are somewhat slender. Caudal rami very short.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Dactylopusia ferrieri, new species. (Pl. XII. figs. 14–22.)

Female.—Body tolerably stout and elongated; rostrum short; abdomen somewhat reflexed; caudal rami short (fig. 14). Length about 1 mm.

Antennules short, scarcely reaching to the end of the first cephalothoracic segment, and apparently composed of seven joints, but the articulation between the fifth and sixth joints is not very clearly defined; the first and second joints are moderately robust; the third is narrower than the second, and equal to about one and a half times its length; the other joints are small and subequal, except the sixth, which is scarcely half the length of the one that precedes it; the antennules are tolerably setiferous, and the third joint bears an extremely long sensory filament (fig. 15).

Antennæ, as in *Dactylopusia frigida.*

Maxillipeds small; the first pair are each armed with a stout terminal claw, and are also provided with two small marginal setiferous lobes, as shown in the figure (fig. 17); second pair narrow and elongated, and furnished with slender terminal claws that reach beyond the middle of the joints to which they are articulated (fig. 18).

The first pair of thoracic legs have both rami tolerably stout; the first joint of the inner ramus, which is elongated and reaches nearly to the extremity of the outer ramus, bears a moderately stout seta near the middle of the inner margin; the end joints are very small, and bear stout, terminal, claw-like spines, as shown in the figure (fig. 19); a stout setiferous spine springs from the outer margin of the first and second joints of the outer ramus, and the second joint has also a seta on the inner margin; the end joint of the outer ramus is very short and carries a tolerably stout setiferous spine on the outer margin; it is also furnished with two terminal claw-like spines and two slender and elongated setæ—the inner one being considerably longer than the other; both rami are fringed on their outer margins with small bristles, and stout setiferous spines spring from the distal end of both the outer and inner margins of the second basal joint (fig. 19).

The second, third, and fourth pairs are somewhat similar in structure to the same appendages in *Dactylopusia brevicornis* (Claus), except that the second joint of the inner ramus of the second pair is provided with two setæ on the inner margin, while the same joint in the third and fourth pairs bears only one seta. In the third pair, the end joint of the inner ramus carries three setæ on the inner margin, two at the apex and a tolerable stout spine at the outer distal angle; but in the fourth pair, the same end joint is furnished with only two setæ on the inner margin (see figs. 20 and 21).

In the fifth pair, which are comparatively small, the basal joint is moderately expanded interiorly and provided with five elongated and rather slender plumose setæ on the broadly rounded distal end; the second joint is small, oblong in form, and about twice as long as wide; the inner margin is nearly straight, but the outer is slightly rounded and fringed with minute setæ; it is also provided with six plumose setæ round the distal end, as shown in the drawing (fig. 22).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species has a slight resemblance to the *Dactylopusia antarctica* of Giesbrecht, from the Belgian Antarctic Expedition, but it differs distinctly from it in the structure of the antennules and of the fifth pair of thoracic legs. Named in compliment to Mr James G. Ferrier, a member of Committee and Secretary to the Expedition.

Dactylopusia perplexa, new species. (Pl. II. figs. 26–30; Pl. VI. figs. 1 and 2.)

Female.—Body moderately stout. Length, 0·8 mm.

Antennules short, robust, and composed of nine joints, the first four of which are moderately large, and the second, third, and fourth are each rather shorter than the preceding one; the next two joints and the last joint are nearly equal in size, and are each fully half as long as the fourth; the seventh and eighth are also nearly equal, but they are shorter than any of the others.

Antennæ stout; outer ramus three-jointed and of moderate length; mandibles with the distal end somewhat attenuated; mandible-palp small and two-branched.

The second maxillipeds are short and rather robust, and they are provided with short but moderately stout terminal claws.

The first pair of thoracic legs are short and stout, and the rami are nearly of equal length; the outer ramus, which is slightly shorter than the other, is armed with short, stout terminal claws; in the outer ramus, the middle joint is about twice as long as the preceding one, but the end joint is small and is provided with tolerably stout terminal claws. The next three pairs are all moderately stout, with short margin spines on the outer rami.

The fifth pair are short, and both segments are somewhat expanded; the inner portion of the basal segment, which reaches to about the middle of the second, bears five setæ on its broadly rounded end; the two inner setæ are short and tolerably stout; the two outer are more slender and are close together, but the middle one, which is also stout, is moderately elongated. The second segment is broadly ovate, the greatest width being equal to about three-fourths of the length; this segment is furnished with three short setæ on the lower half of the outer margin, one on the inner margin, and two at the apex; the apical setæ are slender, but the others are tolerably stout. Caudal rami short.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Genus *Pseudothalestris*, G. S. Brady, 1883.

Pseudothalestris intermedia, new species. (Pl. IX. figs. 1–4; Pl. XII. figs. 27–29.)

Female.—The female of this species is small, measuring only about 0·4 mm. (about $\frac{1}{60}$ of an inch), and has a general likeness to *Pseudothalestris pygmæa*, Scott.

The antennules are composed of seven joints; the second joint is tolerably large, but the next three are each shorter than the one that precedes it; the two end joints are small, and together are only about equal to the third, as shown in the formula, which gives approximately the proportional lengths of the various joints:

Numbers of the joints	1	2	3	4	5	6	7
Proportional lengths	7	8	7	3	2	3	4

In the first pair of thoracic legs, the two-jointed outer ramus is tolerably short, and the seta on the inner margin of the first joint of the inner ramus springs from slightly below the middle of the joint, instead of from near the proximal end.

The fifth pair of thoracic legs are small; the basal joint is moderately broad, and the produced inner portion is of a triangular form, and furnished with three setæ on the lower half of the inner margin, and with two on the outer margin near the apex: a distinct space also separates these two from the others; the second joint is small, and bears three setæ on the outer margin, one on the inner margin, and one at the apex—these setæ are all tolerably elongated, as shown in the drawing (fig. 5, Pl. XII.).

Male.—In the second pair of thoracic legs of the male, the second joint of the inner ramus is provided with five setæ—two on the inner margin, one near the proximal end of the outer margin, and two at the apex; and the innermost of the two apical setæ forms a stout and claw-like appendage, but the other four setæ mentioned are tolerably slender (see figs. 3 and 3A, Pl. IX.).

Fifth pair small; the inner portion of the basal joint moderately produced, and furnished with a short, stout seta on the inner margin, and with two at the apex, the outer being considerably smaller than the other (see fig. 4, Pl. IX.).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The species described above differs from *Pseudothalestris pygmæa*, Scott, and *Westwoodia minuta*, Claus (both of which it resembles to some extent), in the structure of the female antennules, in the armature of the inner ramus of the second pair of thoracic legs in the male, and in the form of the male and female fifth pair. There are also one or two other points of difference, but those referred to appear to be the most important.

Pseudothalestris assimilis, G. O. Sars, var. *antarctica*, nov. var. (Pl. IX. figs. 5–9.)

A single specimen—a male—closely resembling, if it be not identical with, the male of the species referred to, described by G. O. Sars in his *Crustacea of Norway*, vol. v. p. 141, was obtained in the same gathering with *P. intermedia*, collected in Scotia Bay, South Orkneys, Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. But though agreeing with some of the more important characters of that species, it differed in one or two minor points. In the first pair of thoracic legs the seta on the inner margin of the first of the inner ramus was situated nearer the proximal end of the joint.

The inner produced portion of the basal joint of the fifth pair is narrower, and the second joint is broader, and further, this joint is only provided with five instead of six setæ (see fig. 8). On account of these differences, I am inclined to regard this as a variety of the species it otherwise so closely resembles.

Fam. Diosaccidæ.

Genus *Diosaccus*, Boeck, 1872.

Diosaccus tenuicornis (Claus).

1863, *Dactylopus tenuicornis*, Claus, *Die freileb. Copep.*, p. 127, pl. xvi. figs. 17–23.
1880, *Diosaccus tenuicornis*, Brady, *Monogr. Brit. Copep.*, vol. ii. p. 68, pl. lix. figs. 12–16, pl. lx. figs. 14–18.
1906, *Diosaccus tenuicornis*, G. O. Sars, *Crust. of Norway*, vol. v. p. 146, pl. lxxxix. and xc.

A single specimen—a male—was obtained in a tow-net gathering from Station 85, collected on 22nd December 1902, 23° 8′ S., 39° 40′ W.

Genus *Amphiascus*, G. O. Sars, 1905.

Amphiascus fucicolus, new species. (Pl. IX. figs. 23–28.)

Female.—Somewhat like *Amphiascus similis* (Claus) in general appearance; rostrum prominent; abdomen strongly flexed. Length about 0·8 mm.

Antennules eight-jointed; first and second joints robust and subequal; the next two shorter and not so much dilated; the fifth and seventh joints are smaller than any of the others; the sixth is nearly as long as the fourth, while the last, which is narrow, is about equal in length to the third (fig. 23).

In the first pair of thoracic legs, the outer ramus is considerably shorter than the inner one, and the middle joint is about twice the length of the first (fig. 26). In the fourth pair, the outer ramus is rather longer than the inner one (fig. 27).

The fifth pair of legs are of moderate size and broadly foliaceous; the interior of the basal joint, which is only slightly produced, is provided with two short and three tolerably long slender hairs on the distal margin; the second joint has a subquadriform outline, the length being only a little greater than the width; its distal end is obliquely truncated and furnished with five setæ of unequal lengths—one near the middle of the outer margin; two, close together, at the apex; and two, also close together, situated nearly intermediate between the apical setæ and the outer one; there is also a seta on the lower half of the inner margin, as shown in the drawing (fig. 28). Tail segments very short.

Habitat.—In siftings from Gulf-weed collected by the *Scotia* off the Canary Islands on 29th June 1904; Station 537, 29° 54′ N., 34° 10′ W.

Fam. CANTHOCAMPTIDÆ.

Genus *Ameira*, Boeck, 1865.

Ameira simulans, new species. (Pl. VII. figs. 23–28.)

Female.—Body resembling *Ameira tau* (Giesbrecht) in its general appearance. Length, 0·6 mm.

Antennules composed of eight joints; the second joint is large and nearly one and a-half times longer than the next, and about twice as long as the fourth joint, but the two end joints are very short. The approximate proportional lengths of the various joints are shown by the formula:

Number of the joints	1	2	3	4	5	6	7	8
Proportional lengths	6	11	8	6	4	5	2	2

The first pair of thoracic legs, and also the following three pairs, are all somewhat similar to those in *Ameira tau* already referred to.

The fifth pair are very small; the inner portion of the basal joint, which is transversally truncated at the end, is furnished with five setæ—four of them on the truncated apex and one on the lower half of the inner margin; the second joint (or segment) is tolerably expanded at the base, and tapers towards the bluntly rounded extremity; this joint is also provided with five setæ, one of which springs from the outer margin, and the other four from the rounded apex.

Caudal rami very short.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The species recorded above has a tolerably close resemblance to *Ameira tau*, described by Dr GIESBRECHT in his work *Die freilebenden Copepoden der Kieler Föhrde*, p. 117 (1882), but it differs in one or two important particulars, and especially in the form of the last pair of thoracic legs.

Genus *Parastenhelia*, I. C. Thompson & A. Scott, 1903.

Parastenhelia antarctica, new species. (Pl. IV. figs. 25–33.)

Female.—Somewhat similar to *Parastenhelia anglica*, Norman & Scott, in its general appearance. Length, 0·85 mm.

Antennules composed of nine joints, the first two or three moderately stout, the others becoming attenuated towards the distal extremity; the second joint is rather longer than the first or third; the fourth, fifth, and sixth are subequal in length, and are each rather shorter than the third; the three end joints are small, but the penultimate one is rather shorter than that on either side (fig. 25). The antennæ are similar to those in *Parastenhelia anglica.*

Mandibles small, tolerably slender, and narrower towards the apex, which is armed with three or four small teeth (fig. 26); mandible-palp very small and two-branched.

First maxillipeds simple; terminal claw moderately stout (fig. 27); second maxillipeds furnished with a stout spiniform bristle near the middle of the inner margin of the penultimate joint, and the terminal claw scarcely reaches beyond the proximal end of the same joint (fig. 28).

All the four pairs of swimming legs are slender. The inner ramus of the first pair is considerably longer than the outer and composed of two joints; the end joint is short, but the first is greatly elongated and furnished with a plumose bristle near the middle of the inner margin, and a few scattered spinules on the distal half of the outer margin; the terminal claws are slender; one is moderately elongated, the other shorter. The middle joint of the outer ramus is also tolerably elongated, and the first and second joints are each furnished with a slender spine near the distal end of the outer margin, and there are also several marginal spinules; the short end joint is armed with two slender terminal claws and two elongated setæ; the second basal joint of this pair has the lower margin fringed with small spinules, and a stout seta springs from both its inner and outer distal angles (fig. 28).

The second, third, and fourth pairs are similar to those in *Parastenhelia anglica* (fig. 29).

Fifth pair small; the inner portion of the basal joint, which is subtriangular in outline, reaches to about the middle of the outer second joint, and bears five setæ of unequal lengths round its distal end; the second joint is broadly ovate, and the outer and inner margins of the proximal portion of the joint are nearly parallel; but the distal end is somewhat rounded and furnished with six setæ arranged as shown in the drawing (fig. 32).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The genus *Parastenhelia* was established by I. C. THOMPSON & A. SCOTT in 1903 for two Harpactids from the pearl-oyster beds in the vicinity of Ceylon.* In the species belonging to this genus, the inner ramus of the first pair of thoracic legs is usually elongated and composed of two joints. Besides the two species from Ceylon, and the one now recorded, another is described in the *Crustacea of Devon and Cornwall,* by Canon A. M. NORMAN & T. SCOTT, p. 148, pl. x. figs. 10 and 11 *et seq.*

* *Report to the Government of Ceylon on the Pearl-Oyster Fisheries of the Gulf of Manaar,* by W. A. HERDMAN, D.Sc., F.R.S.; *Supplementary Report on the Copepoda,* by I. C. THOMPSON & A. SCOTT (1903), p. 263.

Genus *Phyllopodopsyllus*, Scott, 1896.

Phyllopodopsyllus mossmani, new species. (Pl. V. figs. 1–14.)

Female.—In its general appearance, the female of this species resembles that of *Phyllopodopsyllus bradyi*; there are, however, a few small but obvious differences which, though they may not be of so much importance as to separate this form generically, are yet sufficient to exclude it from any species hitherto described. The length of the specimen represented by the drawing on Pl. V. is 0·71 mm.

Antennules nine-jointed, like those of the type species; the first joint is large and about equal to the combined lengths of the next three joints: these three joints do not differ much in size, but the third and fourth are each rather smaller than the preceding joint; the seventh and eighth are smaller than any of the others, and are together only equal to about half the length of the end joint; the second joint wants the spur-like process with which that joint is armed in both the type species: *Phyllopodopsyllus bradyi* and the *Phyllopodopsyllus furcifer* described by G. O. Sars (fig. 2). The antennæ are similar to those of the type species, as are also the maxillæ, but the mandibles are rather stouter, and the two branches of the mandible-palp do not differ so much in length, the lower branch being in the type species distinctly smaller than the other. The two pairs of maxillipeds are similar to those in the type species (fig. 4).

The swimming legs have the inner rami all two-jointed and the outer rami three-jointed; in the first pair the inner ramus is fully one and a half times longer than the outer one, the first joint being considerably longer than the entire outer ramus; the end joint, which is much smaller than the first, is armed with a stout apical claw and an elongated seta. In the second and third pairs, the inner ramus, which scarcely reaches the end of the second joint of the outer, has the joints subequal. In the fourth pair, the inner ramus is very small, being shorter than the first joint of the outer one (see figs. 7–10).

The fifth pair form each a large foliaceous plate, somewhat oval in outline; its length is equal to about twice the width, its distal end is rounded but the inner portion slightly produced, and it is furnished with several small setæ round the inner margin and apex (fig. 11).

The caudal rami are about equal in length to the last segment of the abdomen, and the principal tail seta, which is somewhat dilated at the base, is long and slender.

Male.—The male is smaller than the female, and measures only about 0·55 mm. in length. The structure of the antennules is modified so that they form effective grasping organs. In the second pair of swimming feet the inner rami are proportionally rather longer than in the female.

The fifth pair are small and normal in structure (fig. 12). The caudal rami are more slender than in the female, and the principal tail seta is not only elongated but is also somewhat stout and spiniform.

With these exceptions, the structure of the male and female is somewhat similar.

Habitat.—Amongst small shells and other things collected on the shores of the Falkland Islands in Port Stanley by the S.Y. *Scotia*; Station 118, 51° 41′ S., 57° 51′ W.

Remarks.—Perhaps the most noticeable difference between the present species and the two already described is the absence of the tooth-like process on the second joint of the antennules. But there is also a slight difference in the form of the fifth pair of thoracic legs of the female, as well as of the caudal rami. Named in compliment to Mr MOSSMAN, meteorologist to the Expedition.

Fam. LAOPHONTIDÆ.

Genus *Laophonte*, Philippi, 1840.

Laophonte rottenburgi, new species. (Pl. VII. figs. 1–6.)

Female.—Body narrow, elongated. Length, 1 mm. ($\frac{1}{25}$ of an inch).

Antennules seven-jointed; first three moderately stout and of nearly equal length; the fourth and fifth joints are short, while the next two are each about twice as long as the fifth. The second joint is produced behind into a stout, blunt-pointed tooth (fig. 1).

Antennæ and mouth-organs somewhat similar to those of the next species.

The first pair of thoracic legs are moderately stout; the outer ramus is composed of three subequal joints, and reaches to about the middle of the first joint of the inner ramus. The inner ramus is tolerably elongated; the first joint is long and narrow, and bears seven or eight widely scattered hairs on the inner margin; the terminal claw is long and tolerably stout (fig. 3). In the next three pairs, the first joint of the inner ramus is very short, but the second is moderately elongated.

In the fifth pair, which are comparatively small, the proximal joint is of moderate size and broadly subtriangular, and the distal end, which reaches beyond the middle of the second joint, is obliquely truncated and furnished with about five setæ; the three on the inner margin are set widely apart, while the two at the outer distal angle of the joint are moderately close together, with a considerable space between them and the nearest of the other three; the second joint is broadly ovate, transversely truncated at the end, and furnished with four setæ on the truncated margin and two on the outer margin, as shown in the drawing (fig. 5).

Caudal rami short.

Habitat.—South Orkney Islands, in siftings from some dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species is easily distinguished from the other species of *Laophonte* described here by the structure of the antennules and of the last pair of thoracic legs. Named in compliment to Dr PAUL ROTTENBURG, a subscriber and one of the members of Committee.

Laophonte australis, new species. (Pl. XI. figs. 10–17.)

Female.—Body slender and elongated; similar to *Laophonte minuta*, Boeck, in general appearance. Length, 0·77 mm. (fig. 10).

Antennules moderately stout and composed of seven articulations. Antennæ with the outer ramus very rudimentary or wanting (see figs. 11 and 12).

Second maxillipeds rather slender; end joint moderately elongated and narrow, widest near the middle; inner margin nearly straight, the outer slightly gibbous; terminal claw long and slender (fig. 13).

Inner ramus of the first pair of thoracic legs elongated; outer ramus three-jointed, and scarcely half the length of the inner, and with the second joint rather longer than the first or third (fig. 14). In the second pair, the inner ramus is moderately stout and composed of two joints, the end one of which scarcely reaches beyond the second joint of the three-jointed outer ramus; the end joint of the outer ramus is tolerably elongated and slender, and about one and a half times longer than the preceding joint (fig. 15).

In the fifth pair, the basal joint is broadly expanded and its inner lobe is obliquely truncated and carries about six setæ along the truncated margin, but the third one from the inside is very small; end joint small, ovate, and furnished with five setæ on the subtruncated end, as in the drawing (fig. 16), width being equal to about two-thirds of the length; the end of this segment is obliquely truncated and provided with six setæ, arranged as shown in the drawing (fig. 14).

Caudal rami about as long as the last abdominal segment.

Habitat.—Scotia Bay, South Orkneys, in siftings from dredged material, collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

This species may be distinguished from the others by the structure and armature of the antennules and of the first and fifth pairs of thoracic legs.

Laophonte exigua, new species. (Pl. VII. figs. 16–22.)

Female.—Body small, narrow, elongated. Length, 0·62 mm.

Antennules composed of seven joints; second and third joints subequal and moderately long, fourth and fifth small; but the sixth and seventh, which are nearly equal, are each about twice as long as the fifth joint. Antennæ and mouth organs nearly as in *Laophonte wiltoni*.

The inner ramus of the first pair of thoracic legs is long and slender, but the outer is very short and composed of only two joints. In the next three pairs, the inner ramus is short, moderately stout, and composed of two nearly equal joints, the first joint being slightly larger than the other.

The fifth pair are small, and the inner portion of the basal joint scarcely reaches the middle of the second joint, and is furnished with four setæ. The second joint has the apex broadly but irregularly rounded, and furnished with six setæ, three on the inner aspect and three on the outer, with a distinct space between each group of three.

Caudal rami as long as the last abdominal segment: each ramus ends in a tolerably stiff and moderately long bristle, and one or two smaller setæ (fig. 17).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The present form has at first sight a superficial resemblance to *Laophonte minuta*, Boeck, but a closer examination reveals certain differences in the structure and armature of the first and fifth pairs of thoracic legs, as well as one or two other anatomical details sufficient to exclude it from that species.

Laophonte wiltoni, new species. (Pl. VII. figs. 7–15.)

Female.—Body slender and elongated and somewhat similar to the species described above in its general appearance. Length of the specimen represented by the drawing is about 0·9 mm.

The antennules are composed of seven joints, and the first three are tolerably large and subequal; the fourth and fifth are very short, while the next two, which are nearly of equal size, are each about one and a half times as long as the fifth. Antennæ and mouth organs nearly as in the species previously described.

The first pair of thoracic legs are tolerably slender, the outer ramus, which reaches to the middle of the first joint of the inner ramus, is three-jointed, and the middle joint is rather longer than the first or third. The next three pairs are somewhat similar to those in *Laophonte australis.*

In the fifth pair, the basal joint is somewhat narrow and subtriangular in outline, and reaches to beyond the middle of the second joint; it is provided with six setæ, three of which spring from the inner margin and two from the outer margin, and one is articulated close to the apex. The second joint is moderately expanded, the greatest width more than half the length; distal end produced, triangular in form and provided with one seta on the inner margin, one at the apex, and five on the outer margin.

Caudal rami as long as the last segment of the abdomen.

Habitat.—Scotia Bay, South Orkneys, in some siftings from dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species is rather smaller than any of the other *Laophontes* described here, and it may be distinguished from them not only by its size but also by the structure of the first pair of thoracic legs, and by other, though perhaps less obvious, differences. The species is named in compliment to Mr D. W. WILTON, one of the naturalists who took part in the Scottish National Antarctic Expedition.

Genus *Laophontodes*, T. Scott, 1894.

Laophontodes whitsoni, new species. (Pl. VIII. figs. 1–8.)

Female.—Body narrow, elongated, and tapering slightly towards the distal extremity; the animal has a general resemblance to the female of *Laophontodes typicus*, T. Scott, but is rather more slender, and the caudal rami are short, whereas in the species mentioned they are elongated. The length of the specimen represented by the drawing (fig. 1) is 0·62 mm. ($\frac{1}{40}$ of an inch).

Antennules tolerably slender, and composed of five joints, the penultimate being very small. Antennæ small; outer ramus wanting.

Mandibles and other mouth-organs nearly as in *Laophontodes typicus*; the second maxillipeds are slender, and are each provided with a long and slender terminal claw.

The first pair of thoracic legs resemble those of the species mentioned, and the next three pairs are also similar to those in the same species. In the second, third, and fourth pairs, the inner ramus is short, two-jointed, and very slender, the first joint being very small; the inner ramus of the pair is, however, proportionally rather more elongated than the others.

In the fifth pair, the basal joint is rather longer than the second one, and both are provided with a few setæ.

Caudal rami short, scarcely longer than the last segment of the abdomen.

Habitat.—Scotia Bay, South Orkneys, in some siftings from dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The form described above may be at once recognised from any previously described species by its short caudal rami; it is also rather more slender and elongated than any of those previously described.

Its occurrence in the *Scotia* collections is a further indication of, in some respects, the close similarity between the Copepod fauna of the Antarctic and that of our northern seas. G. O. Sars has recorded three species of *Laophontodes* from the coasts of Norway, and two of them also occur in British waters. Moreover, one of these northern forms (*Laophontodes typicus*) was also collected by Dr Bruce as far north as Franz Josef Land. All the three northern species are provided with long caudal rami, and are thus readily distinguished from the one now described. This species is named in compliment to Mr Thomas B. Whitson, a member of Committee and Honorary Accountant to the Expedition.

Fam. CLETODIDÆ.

Genus *Orthopsyllus*, Brady & Robertson, 1873.

Orthopsyllus linearis (Claus). (Pl. IX. figs. 10–22.)

1866, *Liljeborgia linearis*, Claus, *Die Copepoden-fauna von Nizza*, p. 22, t. ii. figs. 1–8.
1873, *Orthopsyllus linearis*, Brady & Robertson, *Ann. and Mag. Nat. Hist.*, vol. xii. p. 138.
1880, *Cletodes linearis*, Brady, *Monogr. Brit. Copep.*, vol. ii. p. 95, pl. lxxx. figs. 1–14.
1909, *Orthopsyllus linearis*, G. O. Sars, *Crust. of Norway*, vol. v. p. 289, pl. cxcix.

Female.—The body, viewed from above, is narrow and elongated; the posterior margins of the segments are dentated; rostrum blunt and slightly produced. Caudal rami short; each ramus is provided with a stout and tolerably elongated terminal bristle. The specimen represented by the drawing (fig. 10) measures about 1·7 mm. in length.

The antennules are short and composed of four joints; the second joint is armed with a tolerably stout, short, but prominent tooth on the lower aspect, while the third joint carries a moderately long sensory filament. Antennæ small; outer ramus uniarticulate. Mandibles small and provided with a small one-branched palp.

Thoracic legs small. In the first pair, the inner ramus is rather longer than the outer, and the proximal joint is nearly twice as long as the end one. In the next three pairs, the inner ramus is very short, and the proximal joint extremely small (see figs. 16–19).

The fifth pair has the basal joint tolerably broad and lamelliform, and produced interiorly to near the end of the second joint; the distal half of the inner margin of the basal joint is obliquely and somewhat unevenly rounded, and furnished with five setæ, three on the inner margin and two at the apex; the second joint is moderately narrow, its width at the widest part being scarcely equal to half the length: this joint bears six setæ; the apical seta is tolerably stout and elongated, but the one on either side of it is small; the other three setæ, which are of moderate length, spring from the outer margin, as shown in the drawing (fig. 20).

Male.—In the male, the antennules are modified to form grasping organs. The inner ramus of the second pair of thoracic legs is three-jointed, and the second joint is produced into a long and tolerably stout spiniform appendage (fig. 21). In the fifth pair, which are very small, the basal joint is scarcely produced interiorly, and is provided with two short setæ; the outer joint is short and narrow, and furnished with three small setæ on the outer margin and two at the apex (fig. 22).

Habitat.—Scotia Bay, South Orkneys, in siftings from some dredged material collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—This species, though not very common, has apparently an extensive distribution. Professor G. O. Sars records it from Skjærstad Fjord in Norway—just within the Arctic Circle, and Dr G. S. Brady from a few British localities. Dr Claus obtained the species in the Mediterranean, and it also occurred in collections from the Gulf of Guinea brought home by the telegraph steamer *Buccaneer*. After a careful examination of the South Orkney specimens, I am unable to discover any essential difference between them and those described by the authors mentioned above.

Tribe *CYCLOPOIDA*.

Fam. OITHONIDÆ.

Genus *Oithona*, Baird, 1843.

Oithona plumifera, Baird.

1843, *Oithona plumifera*, Baird, "Notes on British Entomostraca," *Zoologist*, vol. i. pp. 193–197.

This species was observed in gatherings from various stations, extending from Station 11, 23° 50′ N., 21° 34′ W., in the North, to Station 68 in the South Atlantic, Pernambuco, 7° 42′ S., 34° 32′ W. Its distribution, which is widely extended, reaches to at least as far north as the British Islands.

Oithona minuta, T. Scott.

1894, *Oithona minuta*, T. Scott, *Trans. Linn. Soc.*, Ser. 2, "Zool.," vol. vi. p. 90, pl. ix. figs. 14–25.

This somewhat rare form was observed in only a single plankton sample collected at Station 66 in 7° 09′ S., 34° 30′ W.—that is, between two of the stations where *Calanopia americana*, Dahl, was obtained. The specimens from which the species was described were obtained in Bananah Creek, at the mouth of the river Congo, and in Loanda Harbour.

Oithona similis, Claus.

1866, *Oithona similis*, Claus, *Die Copepoden fauna von Nizza*, p. 14.
1902, „ „ Giesb., *Expéd. Antarct. Belge* (1897–1899), "Copepoda," p. 28.

The only stations where this species was met with were 102 and 116, in 36° 31′ S., 51° 56′ W., and 49° 35′ S., 57° 40′ W. respectively; Station 116 was the last station but one before reaching the Falkland Islands. *Oithona similis* was obtained in many of the plankton samples collected by the S.Y. *Belgica* during its visit to the Antarctic in 1897–1899. These samples were collected between lat. 69° 48′ S. and lat. 71° 24′ S., and long. 81° 19′ W. and long. 89° 12′ W. The distribution of this species is very extensive, and it is usually of more or less frequent occurrence all over the North Sea, as well as in the North Atlantic.

Fam. CYCLOPIDÆ.

Genus *Cyclopina*, Claus, 1863.

Cyclopina belgicæ, Giesbrecht. (Pl. I. figs. 2–13.)

1902, *Cyclopina belgicæ*, Giesb., *Expéd. Antarct. Belge*, "Copep.," p. 3, pl. vii. figs. 1–15.

A few specimens of a *Cyclopina* that agrees generally with *Cyclopina belgicæ*, Giesbrecht, were obtained in one of the gatherings collected by the *Scotia* in Scotia Bay, South Orkneys, in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

In the female of this species, the antennules are composed of eighteen articulations; the first three joints are tolerably large, and do not differ greatly in size, but the second is rather smaller than the one on either side; the next three are very short, more so than any of the others; the seventh and eighth are larger; the remaining ten joints are small, but the last two are rather longer than those immediately preceding (fig. 3).

The end joint of the posterior antennæ is provided with several geniculated setæ at its apex, and there are also one or two setæ near the middle of the upper margin; the end joint is about twice as long as the third, while the third is rather longer than the second (fig. 4).

The mandibles have their masticatory edge truncated and armed with several tolerably large teeth (fig. 5).

The other mouth organs and the swimming feet do not differ very much from those in *Cyclopina littoralis*, G. S. Brady. The fifth pair in the female has the end joint elongated and narrow; it is about three times longer than broad, and its armature comprises four setæ, three terminal and one near the middle of the outer margin (fig. 12).

As stated above, these *Scotia* specimens agree fairly well with GIESBRECHT's description and figures of his *Cyclopina belgicæ*, and are therefore ascribed to that species.

Genus *Euryte*, Philippi, 1843.

Euryte similis, new species. (Pl. I. figs. 14–22.)

Description of the Female.—The female of this species somewhat resembles that of *Euryte robusta*, Giesbrecht, in its size and general appearance (fig. 14).

The antennules are tolerably stout, and composed of twenty-one joints; the first joint is robust and about twice the length of the second, while the second is about one and a half times as long as the third; the next six joints are very short, and the others, though somewhat longer than those immediately preceding, are also tolerably short and are all more or less of similar size, except the end joint, which is rather longer than the penultimate one (fig. 15). The posterior antennæ closely resemble those of *Euryte robusta*, Giesbrecht.

Both pairs of maxillipeds, which are moderately stout, also resemble those of the species mentioned. The first pair have the basal joint furnished near the distal end with a spine which is gibbous at the base and with a furcated process; the end joints, which terminate abruptly, bear several tolerably stout, elongated, and slightly curved apical spines (fig. 17). The second maxillipeds are four-jointed; the third joint is short, but the others are of moderate length; the last one is narrow, and armed with two apical claws of unequal length (fig. 18).

The first four pairs of swimming feet are nearly all similar to those of *Euryte robusta*; both branches are moderately stout and three-jointed, and the inner is rather longer than the outer branch; in all the four pairs, the end joint of the inner branch is provided with dagger-shaped spines, but with no setæ; in the first, third, and fourth pairs, the number of spines on the end joint of the inner branch is seven, while the end joint of the second pair bears only five, arranged as shown in the drawings. In the fourth pair, the end joint of the outer branch is armed with nine dagger-shaped spines, three on both the inner and outer margins and three at the apex; the end joint of the outer branch in the third pair is also similarly armed (figs. 19–21).

The fifth pair are similar to those of *Euryte longicauda*, Philippi (fig. 21). The third and fifth segments of the abdomen are nearly of equal length and rather longer than the fourth segment; furcal segments about one and a half times the length of the last abdominal segment (fig. 22).

Remarks.—*Euryte longicauda*, Philippi, has been recorded from the Mediterranean, the Black Sea, and the coasts of France, Britain, Norway, and East Greenland. It has been obtained with other interesting Crustacea in collections made by Dr BRUCE in Franz Josef Land, and G. M. THOMSON records a variety (*E. longicauda* var. *antarctica*, G. M. Thom.) from New Zealand; and another species—*E. robusta*, Giesbrecht—is recorded from the Mediterranean. The form described above resembles the species last referred to, but appears to differ in one or two minor points, such as in the armature of the first and fourth pairs of thoracic legs and in the proportional lengths of the abdominal segments.

Habitat.—Scotia Bay, South Orkneys, June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Fam. LICHOMOLGIDÆ.

Genus *Lichomolgus*, Thorell, 1859.

Lichomolgus fucicola, G. S. Brady. (Pl. XII. figs. 23–26.)

1872, *Macrocheiron fucicolum*, Brady, *Nat. Hist. Trans. Northumb. and Durham*, vol. iv. p. 434, pl. xviii. figs. 9–18.

1880, *Lichomolgus fucicola*, Brady, *Mon. of the Free and Semi-parasitic Copepoda of the British Islands*, vol. iii. p. 41, pl. lxxxv. figs. 1–11.

A few specimens of this species were obtained from some floating seaweed collected by the S.Y. *Scotia* in July 1904; Station 539, 33° 53′ N., 32° 27′ W. The roughly serrated margin of the strongly curved claws—terminal claws—with which the female antennæ are armed, seems to be characteristic of this *Lichomolgus* (see fig. 24).

The antennules are composed of seven joints, the third joint being the smallest (fig. 23). The inner branch of the fourth pair of thoracic legs is short and biarticulate, the two joints being subequal, and the end one furnished with two terminal setæ.

The fifth pair are uniarticulate, tolerably elongated, and narrow (fig. 25). Caudal rami about as long as the last abdominal segment.

The distribution of *Lichomolgus fucicola* appears to be extensive. It has been recorded from several British localities, usually from the laminarian zone, where it lives apparently about the roots and among the fronds of the seaweeds, such as *Laminaria*. This is one of the more easily identified members of the genus.

Genus *Pseudanthessius*, Claus, 1889.

Pseudanthessius fucicolus, new species. (Pl. XII. figs. 1–13.)

Description of the Female.—In its general appearance, the female of this species resembles *Lichomolgus hirsutipes* from the Firth of Forth, and, but for the difference in the structure of the fourth pair of swimming feet, it might be referred to that genus.

The antennules, which are composed of seven joints, have the second one rather longer than the others, while the third is the smallest; the next four joints gradually decrease in length, as indicated by the formula, which shows approximately the proportional lengths of all the joints:

Proportional lengths of the joints	11	21	7	15	11	10	9
Numbers of the joints	1	2	3	4	5	6	7.

The second joint bears three small teeth on its upper edge, as shown in the drawing (fig. 2).

Antennæ moderately stout, and armed with an elongated and slightly curved terminal spine and a few moderately long setæ.

Mandibles and maxillæ somewhat resembling those of the *Lichomolgus* mentioned above.

The first maxillipeds are also somewhat similar to those of the same species.

The second maxillipeds are each composed of two joints of nearly equal length; the second joint is narrow at the proximal end, but increases in width towards the distal extremity, which is obliquely truncated; the external part of the truncated end appears to be slightly hollow, and armed with four short spines, while the inner angle is produced into a stout spiniform tooth (fig. 6).

The first and second pairs of swimming feet are somewhat similar to those of other species of the Lichomolgidæ. In the third pair, the end joint of the outer ramus carries five dagger-shaped spines round the outer margin and apex, and five setæ on the inner margin. A dagger-shaped spine also springs from the outer distal angles of the first and second joints, while the second has also a seta on its inner edge. The inner ramus has the end joint furnished with three dagger-shaped spines and two setæ, while the second joint bears two setæ and the first one seta on the inner margin, as shown in the drawing (fig. 9).

In the fourth pair, the inner ramus is uniarticulate, rather longer than the first joint of the outer ramus, and carries two setæ at the apex; there is also a small but distinct tooth near the middle of the inner margin (fig. 10).

The fifth pair consist each of a single, elongated, narrow joint which bears two setæ at its distal end.

Abdomen narrow, elongated, the penultimate segment rather shorter than that on either side. Caudal rami short, about equal in length to the last abdominal segment (fig. 12).

The male differs from the female in being provided with larger second maxillipeds, which are each armed with a moderately long and slender terminal claw; the end joint is also fringed with minute bristles, as shown in the drawing (fig. 7). The genital segment of the abdomen is also considerably enlarged (fig. 13). The length of the female is fully one millimetre, but the male is rather smaller.

Habitat.—Obtained from Gulf-weed collected by the *Scotia* in June and July 1904, between Stations 499 and 553, St Helena, 15° 57′ S., 5° 40′ W., to Tuskar Rock, 51° 13′ N., 7° 20′ W.

Fam. ASTEROCHERIDÆ.

Genus *Asterocheres*, Boeck, 1859.

Asterocheres suberites, Giesbrecht, var. *antarctica*, nov. var. (Pl. VI. figs. 3–11.)

Like *Asterocheres suberites*, Giesbrecht, in general appearance. Length, ·94 mm.

Antennules composed of twenty-one joints, moderately elongated and slender; first joint stouter and longer than any of the others, the second to the eleventh very short, especially the last two; each joint is also somewhat narrower than the one that precedes it; the twelfth to the eighteenth are of moderate length and subequal, the three end joints rather small, but the penultimate one is somewhat longer than either of the other two. The formula shows approximately the proportional lengths of the various joints:

Number of the joints	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Proportional lengths of joints	21	4	3	3	3	3	3	3	2	3		5	7	7	7	8	9	9	4	5	4

Antennæ moderately slender and armed with a long claw-like spine; the first and fourth joints short, the second and third elongated; outer ramus small, uniarticulated, and bearing two or three short terminal bristles (fig. 3).

Siphon short, somewhat triangular; mandibles styliform; maxillæ and maxillipeds nearly as in *A. suberites*, Giesbrecht.

The four pairs of swimming legs also resemble those of the species named. The fifth pair are very small and uniarticulate. The caudal furca are rather longer than the last segment of the abdomen, and about equal to the length of the penultimate segment (fig. 11).

Habitat.—Scotia Bay, South Orkneys, June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Remarks.—The species recorded above so closely resembles *Asterocheres suberites*, Giesbrecht, as to be scarcely separable from it. There is a slight difference in the form of the siphon; the outer marginal spines of the exopods of some of the swimming feet are stouter, and the fifth pair of feet are distinctly smaller. One or two other slight differences may be observed, as, for example, in the proportional lengths of the joints of the antennules, and of the abdominal segments, but this Antarctic form can scarcely be regarded as more than a variety of *A. suberites*.

Fam. ARTOTROGIDÆ.

Genus *Artotrogus*, Boeck, 1859.

Artotrogus proximus, new species. (Pl. XI. figs. 1–9.)

Description of the Female.—The outline of the female, seen from above, is suborbicular; the cephalothoracic segment is greatly expanded, and forms the largest portion of the animal; the remaining thoracic segments are comparatively small; the abdomen is also small, but the genital segment of the abdomen is larger than the other segments, and is produced backwards on each side so as partly to enclose them, as shown in the drawing (fig. 1); the length of the specimen represented by this drawing is 2 mm. The siphon is short and subtriangular, and the mandibles are elongated and slightly dentated on the inner edge near the apex (fig. 4).

The antennules are composed of nine joints; the second joint is small, but the first and third are elongated; these three joints are together about half the entire length of the antennule; the next four joints are small, while the end one is about as long as the preceding two joints combined; a moderately long sensory filament springs from near the extremity of the end joint (fig. 2). The antennæ are composed of three joints; the first is elongated, and bears a small secondary branch; the other two are shorter, and the end one is furnished with a long, slender appendage, slightly hooked at the apex (fig. 3).

The mandibles and maxillæ are somewhat similar to the same organs in *Artotrogus orbicularis*, Boeck.

The first and second maxillipeds and the first three pairs of swimming feet are also similar to those of the species mentioned. In the fourth pair of thoracic legs, the inner ramus is more slender and rather shorter than the outer, and the end joint is provided with a single plumose seta on the inner margin; the same joint is furnished with two apical setæ, which are also plumose, and there is a minute bristle on the outer margin (fig. 8).

The fifth pair are small, uniarticulate, and furnished with two terminal setæ of unequal length (fig. 9).

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Two specimens occurred in a small sample of siftings from trawled material. The species approaches so near to *Artotrogus orbicularis*, Boeck, both in its general form and in the structure of its appendages, that there was at first some doubt as to whether it should be regarded as a distinct species. A careful examination, however, reveals certain differences, which it may be as well meanwhile to recognise, as, for example, the difference in the armature, and to some extent also in the structure of the antennæ; the difference in the form of the siphon; the rather more slender maxillipeds; the difference in the form of the fifth pair of thoracic legs and in the structure of the abdomen. These differences, while in themselves inconsiderable, are, I think, when taken together, sufficiently important to warrant the separation of this Antarctic *Artotrogus* under a distinct name.

Fam. SAPPHIRINIDÆ.

Genus *Sapphirina*, J. V. Thompson, 1829.

Sapphirina ovatolanceolata, Dana.

1849, *Sapphirina ovatolanceolata*, Dana, *Proc. Amer. Acad.*, Boston, vol. ii. pp. 8–16.

The only gatherings in which this *Sapphirina* was observed were collected at Stations 14, 32, 36, and 49, 21° 28′ N., 22° 40′ W., to 1° 53′ N., 27° 26′ W., and at Station 60, 3° 25′ S., 33° 13′ W., and Station 105, 38° 45′ S., 53° 30′ W. Only a few specimens were noticed.

Sapphirina gemma, Dana.

1849, *Sapphirina gemma*, Dana, *op. cit.*, vol. ii. pp. 8–61.

This species occurred in gatherings from two stations widely separated from each other, viz., Station 15, 20° 34′ N., 23° 12′ W., and Station 104, 37° 05′ S., 52° 22′ W.

Sapphirina iris, Dana.

1849, *Sapphirina iris*, Dana, *op. cit.*, vol. ii. pp. 8–61.
1863, „ *salpæ*, Claus, *Die freilebenden Copepoden*, p. 152.

The gatherings in which this species was met with were collected at Stations 26, 49, 72, 98, 102, 104, and 105, 14° 33′ N., 25° 09′ W., to 38° 45′ S., 53° 30′ W.; it occurred only sparingly.

Sapphirina angusta, Dana.

1849, *Sapphirina angusta*, Dana, *op. cit.*, vol. ii. pp. 8–61.

This rather distinct *Sapphirina* was obtained in gatherings from Stations 35, 36, 98, 102, 104, and 105, 9° 5′ N., 25° 28′ W., to 38° 45′ S., 53° 30′ W.

Sapphirina lactens, Giesbrecht.

1893, *Sapphirina lactens*, Giesb., *Fauna u. Flora des Golfes von Neapel*, Monogr. xix., "Pelag. Copep.," p. 619, pl. lii. figs. 15, 16, 30 *et seq.*

The only gathering in which this species was met with was from Station 104 in 37° 05′ S., 52° 22′ W.

Sapphirina vorax, Giesbrecht.

1891, *Sapphirina vorax*, Giesb., *Atti Accad. Lincei*, Roma (4), Rend., vol. vii. See also *Fauna u. Flora des Golfes von Neapel* (1893), p. 619, pl. lii. figs. 23, 28 *et seq.*

This species occurred very sparingly in three gatherings collected at Stations 12, 13, and 104, 22° 19′ N., 22° 07′ W., to 37° 05′ S., 52° 22′ W.

Sapphirina auronitens, Claus.

1863, *Sapphirina auronitens*, Claus, *op. cit.*, p. 153.

This also occurred very sparingly in gatherings from three stations, viz., from Stations 12, 13, and 44, 22° 19′ N., 22° 07′ W., to 3° 42′ N., 26° 26′ W.

Sapphirina nigromaculata, Claus.

1863, *Sapphirina nigromaculata*, Claus, *op. cit.*, p. 152, pl. viii.

The gatherings in which this species was observed were collected at Stations 12, 29, and 85, 22° 19′ N., 22° 07′ W., to 23° 8′ S., 39° 40′ W.

Sapphirina intestinata, Giesbrecht.

1891, *Sapphirina intestinata*, Giesb., *op. cit.* (4), Rend., vol. vii. p. 478.

This species was collected at Stations 26, 44, and 90, 14° 33′ N., 25° 09′ W., to 26° 50′ S., 42° 20′ W., and was apparently not very common.

Sapphirina opalina, Dana.

1849, *Sapphirina opalina*, Dana, *Proc. Amer. Acad.*, Boston, vol. ii. pp. 8–61.

The only gathering in which this species was obtained was from Station 59, 2° 30′ S., 32° 42′ W.

Sapphirina gastrica, Giesbrecht.

1891, *Sapphirina gastrica*, Giesb., *op. cit.* (4), Rend., vol. vii. p. 478.

This species was collected at Stations 7, 8, and 12, 26° 23′ N., 20° 20′ W., to 22° 19′ N., 22′ 07° W., but only a few specimens were observed.

Sapphirina stellata, Giesbrecht.

1891, *Sapphirina stellata*, Giesb., *op. cit.* (4), Rend., vol. vii. p. 478.

This *Sapphirina* was obtained in a gathering collected at Station 28, 13° 07′ N., 25° 09′ W.

Sapphirina darwinii, Haeckel.

1864, *Sapphirina darwinii*, Haeckel, *Zeitschr. med. Naturw.* (Jena), 1 Bd. p. 105, pls. ii. and iii.

The only gathering in which this species was observed was that from Station 68A in the South Atlantic—Pernambuco bearing 12 miles W., 8° 00′ S., 34° 34′ W.

Genus *Saphirella*, T. Scott, 1894.

Saphirella abyssicola, T. Scott. (Pl. IV. figs. 2–4.)

1894, *Saphirella abyssicola*, Scott, *Trans. Linn. Soc.* (2, "Zool."), vol. vi. p. 126, pl. xiii. figs. 57, 58, pl. xiv. figs. 5–10.

This species, which appeared to be of rare occurrence in the *Scotia* collections, was obtained in a gathering from Station 68A—Pernambuco bearing 12 miles W., 8° 00′ S., 34° 34′ W.

Genus *Copilia*, Dana, 1849.

Copilia mirabilis, Dana.

1852, *Copilia mirabilis*, Dana, *U.S. Explor. Exped.*, 1838–1842 ("Crust."), vol. xiii p. 1232, pl. lxxxvi.

This species was observed in gatherings from the following twelve stations: 12, 14, 18, 22, 25, 26, 27, 29, 33, 35, 36 and 85, 22° 19′ N., 22° 07′ W., to 23° 8′ S., 39° 40′ W.

Copilia denticulata, Claus.

1863, *Copilia denticulata*, Claus, *Die freilebenden Copepoden*, p. 161, Taf. 25, figs. 14–20.

This species was only met with in a gathering from Station 36, 8° 42′ N., 25° 28′ W.

Fam. ONCÆIDÆ.

Genus *Oncæa*, Philippi, 1853.

Oncæa venusta, Philippi.

1843, *Oncæa venusta*, Phil., *Wiegman's Archiv für Naturgesch.* (1843), p. 62, pl. iii. fig. 3.

This species was observed in gatherings from Stations 18, 25, 36, 49, 56, and 62, 19° 59′ N., 23° 34′ W., to 4° 15′ S., 33° 38′ W.

Oncæa mediterranea, Claus, var.

1863, *Antaria mediterranea*, Claus, *Die freilebenden Copepoden*, p. 159, Taf. 30.

The only gatherings in which this form occurred were from three stations in the South Atlantic, viz., 55, 64, and 93, 0° 22′ S., 31° 00′ W., to 30° 5′ S., 45° 28′ W.

Oncæa conifera, Giesbrecht.

1891, *Oncæa conifera*, Giesb., *Atti Accad. Lincei*, Roma (4), vol. vii. p. 8.

This species, which appeared to be of more frequent occurrence than the two just referred to, was observed in gatherings from Stations 14, 18, 19, 26, 29, 32, and 33, 21° 28′ N., 22° 40′ W., to 9° 40′ N., 25° 28′ W., in the North Atlantic, and at Stations 56, 59, 62, and 90 in the South Atlantic, 0° 42′ S., 31° 20′ W., to 26° 50′ S., 42° 20′ W.

Fam. CORYCÆIDÆ.

Genus *Corycæus*, Dana, 1845.

Corycæus venustus, Dana.

1849, *Corycæus venustus*, Dana, *Proc. Amer. Acad.*, Boston, vol. ii. p. 8.

This *Corycæus* occurred sparingly in gatherings from three stations in the South Atlantic, viz., 90, 93, and 95, 26° 50′ S., 42° 20′ W., to 32° 15′ S., 47° 30′ W.

Corycæus ovalis, Claus.

1863, *Corycæus ovalis*, Claus, *Die freilebenden Copepoden*, p. 158.

The only gathering in which this species was obtained was from Station 44, 3° 42′ N., 26° 26′ W.

Corycæus obtusus, Dana.

1852, *Corycæus obtusus*, Dana, *Crust. U.S. Expl. Exped.*, p. 1214, pl. lxxxv. fig. 6.

With the exception of *Corycæus speciosus* this appeared to be the most commonly distributed member of the genus in the *Scotia* collection. It was observed in gatherings from about twenty-seven stations, ranging from Stations 13, 15, and 19, North Atlantic, 21° 58′ N., 22° 26′ W., to 19° 12′ N., 24° 08′ W., to 85, 90, and 95, South Atlantic, 23° 8′ S., 39° 40′ W., to 32° 15′ S., 47° 30′ W., but it was nowhere very plentiful.

Corycæus flaccus, Giesbrecht.

1891, *Corycæus flaccus*, Giesb., *Atti Accad. Lincei*, Roma (4), vol. vii. p. 480.

This tolerably distinct species was met with, though somewhat sparingly, in gatherings collected at Stations 7, 12, 15, 22, 85, and 86, 26° 23′ N., 20° 20′ W., to 24° 26′ S., 40° 25′ W.

Corycæus rostratus, Claus.

1863, *Corycæus rostratus*, Claus, *op. cit.*, p. 480.

The only gatherings in which this *Corycæus* was obtained were collected at Station 26, 14° 33′ N., 25° 9′ W., and Station 95, 32° 15′ S., 47° 30′ W., the one in the North, and the other in the South Atlantic.

Corycæus speciosus, Dana.

1849, *Corycæus speciosus*, Dana, *Proc. Amer. Acad.*, Boston, vol. ii. pp. 8–61.

This fine species was of frequent occurrence in the *Scotia's* tow-net collections; the remarkably divergent caudal rami made it easily recognised. It was observed in gatherings from thirty-six different stations, ranging from Stations 7 and 12 in the North Atlantic to Stations 93 and 95 in the South, 26° 23′ N., 20° 20′ W., to 32° 15′ S., 47° 30′ W.

Corycæus longistylis, Dana.

1849, *Corycæus longistylis*, Dana, *op. cit.*, vol. ii. pp. 8–61.

This species occurred sparingly in gatherings from Stations 7, 11, 12, 13, and 14, 26° 23′ N., 20° 20′ W., to 21° 28′ N., 22° 40′ W.

Corycæus carinatus, Giesbrecht.

1891, *Corycæus carinatus*, Giesb., *op. cit.* (4), vol. vii. p. 481.

This *Corycæus* was observed in gatherings from twenty-five different stations, extending from Stations 11, 13, and 15 to 88, 90, and 94, 23° 50′ N., 21° 34′ W., to 30° 25′ S., 45° 45′ W. The species was apparently more or less uniformly distributed throughout the area traversed by the *Scotia* between the limits stated.

Corycæus longicaudis, Dana.

1849, *Corycæus longicaudis*, Dana, *op. cit.*, vol. ii. pp. 8–61.

The distribution of this species appeared to be somewhat limited; the only gatherings in which it was met with were those collected at Stations 25, 27, 29, 30, and 31, 15° 15′ N., 25° 09′ W., to 11° 10′ N., 25° 20′ W.

Corycæus elongatus, Claus.

1863, *Corycæus elongatus*, Claus, *Die freilebenden Copepoden*, p. 157, pl. xxiv. figs. 3 and 4.

This species occurred very sparingly at Station 11, 23° 50′ N., 21° 34′ W., and Station 85, 23° 8′ S., 39° 40′ W.

Tribe *CALIGOIDA.*

Genus *Dysgamus*, Steenstrup & Lütken, 1861.

Dysgamus atlanticus, Steenstrup & Lütken. (Pl. XIII. fig. 13.)

1861, *Dysgamus atlanticus*, Steenstrup & Lütken, *Bidrag til Kundskab om det aabne Havs Snyltekreb og Lernæer*, p. 368, Tab. iv. fig. 8.

Only the males of *Dysgamus* have apparently been observed hitherto, and it is doubtful if the genus can be considered a valid one till females are obtained.

The specimens on which the genus was founded were taken, probably while swimming freely at the surface, at several places in the North Atlantic, between lat. 8° and 28° N., and long. 21° and 36° W.

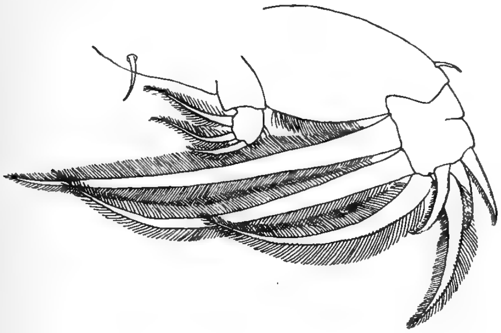

Fig. 1.—Foot of first pair.

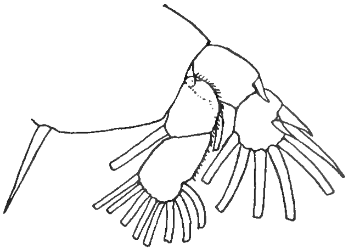

Fig. 2.—Foot of second pair.

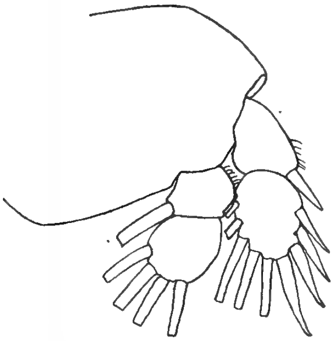

Fig. 3.—Foot of fourth pair.

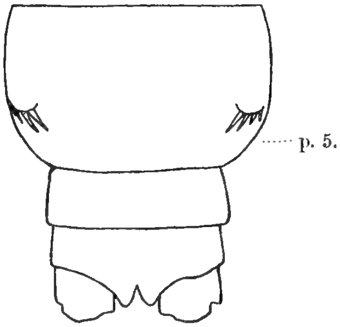

Fig. 4.—Abdomen and fifth pair of feet.

Dysgamus atlanticus, Steenstrup & Lütken.

This species has a close resemblance to *Caligus* in its general form and colour; the frontal plates are, however, without lunules or sucker-disks. The carapace is broadly ovate and depressed, but the last two thoracic as well as the abdominal segments are short and comparatively narrow. The first four pairs of thoracic legs are all two-branched, and the branches two-jointed; the first pair has the inner branch very small, but in the other three pairs the branches are subequal; there is, as in *Caligus*, a fifth pair, very minute but quite distinct (see text-figures annexed). The eyes, though visible, are not very conspicuous. The *Scotia* specimens were collected in the Atlantic at the following stations: 25, 31, 44, 79, 82, 83, and 98. The first two stations are north of the equator, viz., 15° 15′ N., 25° 09′ W., and 11° 10′ N., 25° 20′ W. The other stations are south of the equator, Station 98 being in 34° 02′ S., 49° 07′ W. The *Scotia* specimens differ somewhat from the drawings given by STEENSTRUP & LÜTKEN in the work referred to, in having the abdominal portion rather stouter and shorter, but they agree so well otherwise that I have little hesitation in ascribing them to their species. CHARLES BRANCH WILSON, in his work on "American Copepoda parasitic on Fishes,"* describes a *Dysgamus*, of which he obtained a single specimen, and his drawings show it to be not unlike the specimens collected by the *Scotia;* this *Dysgamus* he ascribes to a new species, *Dysgamus ariommus*, and speaks of the fifth legs as being entirely lacking, whereas in the *Scotia* specimens the fifth pair, as already stated, are, though small, quite distinct.

Only one, or at most two, specimens were obtained in any single gathering, and males only were observed, and, like the *Caligus ropax* frequently found in tow-net collections in British waters, they were captured apparently as free-swimming organisms.

The only other writer who records *Dysgamus* is Dr BASSETT-SMITH in his work "A Systematic Description of Parasitic Copepoda found on Fishes," published in *Proc. Zool. Soc. London*, 18th April 1889.

CLADOCERA AND OSTRACODA.

Cladocera were very scarce in the *Scotia* collections. The few specimens observed belong to the genus *Evadne*, two species of which are represented in the collection, viz.:—

Genus *Evadne*, Lovén, 1836.

Evadne tergestina, Claus. (Pl. XIII. fig. 14.)

This species occurred in a tow-net gathering collected at Station 85, 23° 8′ S., 39° 40′ W. Only one or two specimens were noticed.

Evadne spinifera, P. E. Müller. (Pl. XIII. fig. 15.)

E. spinifera was also obtained in the gathering from Station 85, 23° 8′ S., 39° 40′ W., and was equally scarce with the species previously mentioned.

OSTRACODA.

The Ostracoda observed in the *Scotia* collections belong chiefly to the two groups Podocopa and Myodocopa, and include representatives of the families Cypridæ, Cytheridæ, Cypridinidæ, and Conchœciadæ.

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* "North American Parasitic Copepods belonging to the Family Caligidæ: Part II. The Trebinæ and Euryphorinæ," *Proc. U.S.A. National Museum*, vol. xxxi. p. 713, pl. xx. figs. 62–70.

PODOCOPA.

Fam. CYPRIDÆ.

Genus *Macrocypris*, G. S. Brady, 1868.

Macrocypris maculata, G. S. Brady. (Pl. XIV. figs. 1 and 2.)

1865, *Cytherideis maculata*, Brady, *Trans. Zool. Soc.*, vol. v. p. 367, pl. lvii. fig. 12, *a–b*.
1880, *Macrocypris maculata*, Brady, *Ostracoda of the "Challenger" Exped.*, p. 44, pl. i. fig. 2, *a–d*.

Habitat.—Scotia Bay, South Orkneys; collected April 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. Several specimens were obtained; they varied somewhat in size. One of the larger specimens measures 1·5 mm. in length; height rather less than half the length, highest in the middle; dorsal margin arcuate, sloping about equally towards both ends, but the posterior is rather narrower than the other; lower margin slightly concave and sinuate, especially towards the front. Seen from above, the shell is elliptical in outline, widest in the middle, width equal to about one-third of the length, tapering equally to each end; both ends narrow; colour brownish. This species appears to be widely distributed.

Fam. CYTHERIDÆ.

Genus *Cythere*, O. F. Müller, 1785.

Cythere inornata, new species. (Pl. XIV. figs. 9 and 10.)

Shell, seen from the side, oblong; height equal to about half the length; dorsal margin nearly straight, ventral margin slightly incurved. The posterior extremity slopes at first abruptly downwards, then becomes boldly rounded; the anterior end is somewhat similar, but is rather more produced, especially below. Seen from above, the shell is moderately tumid, widest in the middle, greatest width equal to rather more than half the length, sides evenly rounded, but tapering rather more towards the anterior end, which is wedge-shaped. Shell surface rough, with numerous small circular pits and setiferous papillæ between. Length of shell about 1·2 mm.

Habitat.—Scotia Bay, South Orkneys, June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Cythere quadridens, new species. (Pl. XIV. figs. 15 and 16.)

Shell, seen from the side, oblong, highest in front, the height equal to rather more than half the length; anterior end boldly rounded; posterior extremity truncated above, slightly produced below the middle, and provided with about four more or less distinct tooth-like projections. The dorsal margin shows a slight elevation immediately over the anterior hinge, thence it slopes backwards to the posterior extremity in a nearly straight line, where it is abruptly angulated; lower margin slightly excavated behind the anterior extremity, and thence converges gently backwards. Seen from above, the shell is widest behind the middle, greatest width scarcely equal to half the length; the margins taper gently towards the bluntly rounded anterior end, but behind they converge somewhat abruptly, the posterior extremity being slightly produced and expanded; the dorsal margin also shows a slight foliation. The general surface of the shell is sculptured with numerous small rounded pits. Length of the shell about ·85 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Cythere latibrosa, new species. (Pl. XIV. figs. 3 and 4.)

This form, seen from the side, is somewhat similar in its general outline to that described above, but differs in the following particulars: it is higher in front in proportion to the length, the dorsal slope is rather greater, and the shell sculpture is rather different. Seen from above, the shell is somewhat tumid, the outline very irregularly hastate, greatest width equal to about half the length; lateral margins incurved in the middle, converging gently in front, and abruptly behind; both extremities somewhat truncated, the posterior end rather more so than the other, and with two or three tooth-like projections. Surface of the shell sculptured with numerous irregular and angular excavations. Length, ·74 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

This species has a somewhat close resemblance to *Cythere wyville-thompsoni*, G. S. Brady, but the anterior serrations observed in that species are wanting in this, and the armature of the posterior end also differs.

Cythere foveolata, G. S. Brady. (Pl. XIV. figs. 7 and 8 (♂), and figs. 13 and 14 (♀).)

1880, *Cythere foveolata*, Brady, *Ostracoda of the "Challenger" Exped.*, p. 75, pl. xiii. 5, *e–h*.

Shell of the female tumid; seen from the side, subrhomboidal, highest in the middle, greatest height rather more than half the length; both ends obliquely rounded; dorsal margin gently rounded in the middle part, then sloping somewhat steeply towards each end, but more distinctly so in front; ventral margin slightly sinuate in front, and curving upwards behind. Seen from above, the shell is broadly ovate, widest in the middle, greatest width equal to about half the length; sides slightly arcuate in the middle, converging rapidly to the pointed anterior extremity, but abruptly rounded behind. Shell surface marked all over with closely set and conspicuous excavations, and with the hinge line somewhat prominent. The outline of the male is more compressed and angular. Length, female ·77 mm.; male ·74 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

The *Scotia* specimens differ slightly from those recorded by Dr BRADY in being somewhat larger and in the general contour being also slightly different, but notwithstanding these differences, I am inclined to consider them as belonging to BRADY's species.

Cythere antarctica, new species. (Pl. XIV. figs. 5 and 6.)

Shell, seen from the side, elongated, highest over the posterior hinge, greatest height equal to rather more than half the length; the dorsal margin slopes steeply backwards from the highest point, and more gently towards the front, and with a shallow notch near the anterior extremity; posterior end boldly rounded and somewhat produced below; anterior end truncated above, rounded below, with a small subcentral projection separating the upper from the lower portion; ventral margin incurved and sinuous. The shell, seen from above, widest in front, the greatest width equal to rather less than half the length; sides not very boldly rounded, converging gently backwards to the sharp-pointed posterior end; anterior extremity blunt and slightly produced. Shell surface thickly covered with minute circular pits. Length, ·7 mm.

Habitat.—Scotia Bay, South Orkney Islands; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Cythere peregrina, new species. (Pl. XIV. figs. 11 and 12.)

Shell, seen from the side, oblong, highest behind the middle, greatest height scarcely equal to half the length; dorsal margin sloping gently from behind the middle in a nearly straight line towards the front, but the hinder slope is shorter and steeper; both ends evenly and not very boldly rounded; ventral margin slightly and evenly convex. Shell tumid when seen from above, widest in the middle, width equal to half the length; sides rather boldly arcuate and converging towards both ends; both extremities acuminate. Shell covered with numerous and extremely fine lines extending longitudinally over its surface. Length about ·75 mm., but varies to some extent; one or two rather larger specimens reach to about 1 mm. in length.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Genus *Xestoleberis*, G. O. Sars, 1865.

Xestoleberis reniformis, G. S. Brady. (Pl. XIV. figs. 17 and 18.)

1907, *Xestoleberis reniformis*, Brady, *National Antarctic Exped.: Natural History*, vols. iii.–v., "Ostracoda," p. 6, pl. i. figs. 4, 5.

A few specimens—adult and (?) young—of a *Xestoleberis* occurred among other Ostracoda collected in Scotia Bay, South Orkneys; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. They so closely resemble the form described by Dr Brady in his paper on the "Ostracoda of the English National Antarctic Expedition" that I ascribe them to the same species. They differ a little from the description and figures given by Brady, but the peculiar outline of the shell, both when seen from the side and from above, seems to be characteristic of the species. Length of specimen represented by the drawings, ·62 mm.

Genus *Cytherura*, G. O. Sars, 1865.

Cytherura ornata, new species. (Pl. XIV. figs. 19–21.)

Carapace moderately tumid; seen from the side, subrhomboidal, highest in front of the middle, greatest height equal to rather more than half the length; dorsal margin well rounded, sloping more steeply in front than behind; ventral margin flexuous; anterior margin broadly rounded, obscurely crenulate; posterior extremity somewhat produced in the middle to a blunt angular point. Seen from above, the sides are evenly and not very strongly convex, widest in the middle, greatest width equal to half the length; anterior extremity somewhat acuminate, posterior end forming a short angular projection. Surface of the shell ornamented with minute excavations and lines, as shown in the drawing (fig. 19). Length, ·54 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Cytherura porrecta, new species. (Pl. XIV. figs. 22 and 23.)

Carapace elongated; seen from the side, oblong, about equal in height at both ends, greatest height less than half the length; dorsal and ventral margins sinuous; anterior end boldly and evenly rounded; posterior extremity produced in the middle line into a prominent subtriangular and blunt-pointed beak; a sinuous and moderately conspicuous longitudinal fold extends backwards along the middle line, then curves round to meet the ventral margin. Seen from above, shell outline sagittate, widest in front of the middle, width rather less than half the length; sides sinuate, abruptly rounded behind, converging in front; anterior end acuminate; posterior extremity produced into a prominent beak. Shell surface covered with numerous small and rounded excavations. Length, ·45 mm.

Habitat.—This small form was obtained in the same gatherings from *Scotia* with those described above; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Cytherura sculptilis, new species. (Pl. XIV. figs. 24 and 25.)

Shell somewhat like *Cytherura similis*, Brady & Norman; seen from the side, broadly ovate, highest just in front of the middle, height equal to more than half the length; dorsal margin strongly arched, sloping towards the anterior end; anterior slope flattened; posterior slope evenly rounded and terminating in the posterior angulation; ventral margin arcuate behind, flexuous in front; anterior extremity bluntly rounded, the margin obscurely crenulated; posterior extremity produced and somewhat acuminate below the middle, lower edge sloping backwards in a curved line continuous with the ventral margin. Shell, seen from above, broadly elliptical, widest in the middle, width rather less than half the length; sides evenly rounded, converging more gradually behind than in front; both extremities somewhat acuminate. Shell surface ornamented with fine but irregular reticulations, and with the interspaces minutely punctate; there are also small whitish papillæ where the lines intersect. Length of the specimen represented by the drawing, ·5 mm., but another specimen measured only ·53 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Genus *Paradoxostoma*, Fischer, 1855.

Paradoxostoma retusum, G. S. Brady. (Pl. XIV. fig. 26.)

1890, *Paradoxostoma retusum*, Brady, *Trans. Roy. Soc. Edin.*, vol. xxxv. p. 513, pl. iv. fig. 20.

Shell, seen from the side, oblong, narrower in front than behind, highest behind the middle; height rather less than half the length; dorsal margin moderately convex, evenly rounded except near the posterior extremity, where it becomes slightly flexuous; anterior end narrow, evenly rounded; posterior extremity produced above the middle into a bluntly rounded beak, thence, sloping downwards and forwards in a nearly straight line, it merges into and becomes continuous with the sinuated ventral margin. Seen from above, compressed, widest in the middle, about four times longer than wide; sides evenly rounded, the front end somewhat obtuse, the posterior extremity acuminate. Shell smooth, semitransparent, with a few faint impressed lines at the posterior end (fig. 26). Length, ·78 mm.

Habitat.—Scotia Bay, South Orkneys; collected June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

The *Scotia* specimens differ slightly from the form described by Dr Brady in their larger size, as well as to a small extent in their general outline; the peculiar conformation of the posterior extremity is, however, quite characteristic of the species referred to.

Paradoxostoma antarcticum, new species. (Pl. XIV. figs. 27 and 28.)

Carapace ovate; seen from the side, highest behind the middle, height scarcely equal to half the length; dorsal margin boldly arched, forming a continuous even curve backwards to the blunt angulation of the posterior extremity, but with a longer slope to the front than to the rear; anterior end narrow and rounded; posterior obliquely truncated, slightly produced above, thence sloping downwards and forwards to meet the ventral margin, which is slightly convex. Shell, seen from above, compressed, fusiform, widest behind the middle, fully three times longer than broad; extremities equal and acuminate. Surface of shell smooth, with small, round, indistinct markings scattered over it. Length, ·8 mm.

Habitat.—Scotia Bay, South Orkneys; collected in June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

Paradoxostoma læve, new species. (Pl. XIV. figs. 29 and 30.)

Shell, seen from the side, elongate, subovate, higher behind than in front, greatest height just behind the middle, and equal to fully two-fifths of the length ; anterior extremity subangular, narrowly rounded; greatest projection below the middle; posterior end obtusely rounded, dorsal margin evenly but not very boldly arcuate, sloping gradually towards the front and more convex behind; ventral margin slightly sinuate in front of the middle. Seen from above, the outline is narrowly ovate, the greatest width, which is near the centre, is equal to about one-third of the length; the sides are flatly arcuate, and both extremities subacuminate; valves smooth, polished, with a few scattered opaque white points. Length about ·65 mm.

Habitat.—Obtained in the same gatherings with those described above, collected in Scotia Bay, South Orkney Islands, in June 1903 ; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W.

MYODOCOPA.

Fam. Cypridinidæ.

Genus *Philomedes*, Liljeborg, 1853.

Philomedes assimilis, G. S. Brady. (Pl. XIII. figs. 16 and 17.)

1907, *Philomedes assimilis*, Brady, *National Antarctic Exped.*: "Ostracoda," p. 5, pl. i. figs. 16–21, pl. ii. figs. 1–6.

One or two specimens of a *Philomedes*, which I ascribe to the species mentioned, occurred in a small sample of dredged material from Scotia Bay, collected in April 1903 ; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. The length of the specimen represented by the drawing (fig. 16) is 1·8 mm.

Genus *Asterope*, Philippi, 1840.

Asterope australis, G. S. Brady. (Pl. XIII. figs. 18 and 19.)

1890, *Asterope australis*, Brady, *Trans. Roy. Soc. Edin.*, vol. xxxv. (pt. ii.), p. 515, pl. ii. figs. 1, 2.
1898, ,, ,, ,, *Trans. Zool. Soc.*, vol. xiv. (pt. viii.), p. 431, pl. xliii. figs. 1–8.
1906, *Cylindroleberis australis*, G. W. Müller, *Die Ostracoden der "Siboga" Exped.*, p. 14.

This species was obtained in a small gathering of dredged material collected in Scotia Bay, South Orkneys, on 3rd June 1903; Station 325, 60° 43′ 42″ S., 44° 38′ 33″ W. The length of the specimen—a female—represented by drawing (fig. 18) is 2·75 mm.

Asterope oculata, G. S. Brady. (Pl. XIII. figs. 20 and 21.)

1902, *Asterope oculata*, Brady, *Trans. Zool. Soc.*, vol. xvi. p. 179, pl. xxi. figs. 6–13.

This species occurred in a small gathering collected off Gough Island on 22nd April 1904 ; Station 461, 40° 20′ S., 9° 56′ 30″ W. The size of the specimen represented by the drawing (fig. 20) is 1·8 mm. Dr Brady records *A. oculata* from Trincomalee, Ceylon.

Fam. HALOCYPRIDÆ.

The Halocypridæ being for the most part pelagic in their habits, are widely dispersed throughout the Atlantic, Pacific, and Indian Oceans, but appear to be more frequent in tropical regions. The species recorded here are chiefly from these regions, and were collected by the S.Y. *Scotia* on the outward voyage to the Antarctic; no Halocypridæ were observed in the collections from the South Orkneys.

Genus *Halocypris*, Dana, 1852.

Halocypris inflata, Dana. (Pl. XIII. figs. 29–31.)

1852, *Halocypris inflata*, Dana, *U.S. Explor. Exped.*, 1837–1842, vol. xiii. p. 1301, pl. xci. fig. 8.
1852, „ *brevirostris*, Dana, *op. cit.*, p. 1303, pl. xci. fig. 9.
1906, „ *inflata*, G. W. Müller, "Ostracoda," "*Siboga*" *Exped.*, p. 2.

This species was obtained in gatherings from Stations 21, 26, and 59, the first in 18° 28′ N., 24° 28′ W., the last in 2° 30′ S., 32° 42′ W. The specimen represented by the drawing measures 1·65 mm. The species is widely distributed in the Atlantic, the Pacific, and Indian Oceans, and appears to be subject to some amount of variation, and has been described under several names (*cf.* G. W. MÜLLER, *op. cit.*).

Halocypris globosa, Claus. (Pl. XIII. fig. 32.)

1874, *Halocypris globosa*, Claus, "Die Fam. Halocypriden," *Schriften Zool. Inhalt*, Heft i. (Wien, 1874), p. 7, Taf. 3, figs. 36 and 39.
1906, *Halocypris globosa*, G. W. Müller, *op. cit.*, p. 2.

H. globosa was obtained in a gathering from Station 16, 20° 29′ N., 23° 16′ W., collected 29th November 1902. In this species the shell has a short rotund form; seen from the side, the dorsal margin is flattened, but the lower is boldly arched in the form of a semicircle, the depth across the middle being equal to about four-fifths of the length. The specimen represented by the drawing (fig. 32) measured ·85 mm.

Genus *Conchœcia*, Dana, 1852.

Conchœcia spinirostris, Claus. (Pl. XIII. fig. 26.)

1874, *Conchœcia spinirostris*, Claus, "Die Fam. Halocypriden," p. 6, Taf. 1, figs. 1, 6*a*, 8; Taf. 2, figs. 11, 14, 15.
1890, *Conchœcia porrecta*, Claus, *Arbeit. Zool. Institut Wien*, vol. ix., Heft i., p. 12; Heft iii. (1891), p. 61, Taf. 7.
1896, *Conchœcia spinirostris*, Brady & Norman, *Trans. Roy. Dublin Soc.* (N.S.), vol. v. p. 689, pl. lx. fig. 22.
1906, *Conchœcia spinirostris*, G. W. Müller, "Ostracoda," "*Siboga*" *Exped.*, p. 7.

This widely distributed species occurred in surface gatherings from Stations 14, 16, and 59; the first in 21° 28′ N., 22° 40′ W., the last in 2° 30′ S., 32° 42′ W., collected

November and December 1902. According to Dr G. W. MÜLLER, *C. spinirostris*, Claus, and *C. porrecta*, Claus, are forms of the same species.

Conchœcia procera, G. W. Müller. (Pl. XIII. figs. 27 and 28.)

1891, *Conchœcia variabilis* (pr. prt.), G. W. Müller, *Zool. Jahrb.*, Abtheil Syst., vol. v. p. 273, Taf. 28, figs. 27, 38.
1894, *Paraconchœcia oblonga*, Claus, *Denkschriften d. Akad. Wien*, vol. lxi. p. 3, Taf. 3, figs. 21–23 (non *C. oblonga*, Cl., 1890, 91).
1894, *Conchœcia procera*, G. W. Müller, *F. Fl. Neapel*, vol. xxi. p. 228, pl. iii. figs. 47, 48, 50, 58.
1906, „ „ *idem*, "Ostracoda," "*Siboga*" *Exped.*, p. 4.

Specimens which I have ascribed to this species were obtained in a surface tow-netting collected at Station 14, 21° 28′ N., 22° 40′ W., on 28th November 1902. The specimen represented by the drawing measured about 1·5 mm.

Conchœcia elegans, G. O. Sars.

1865, *Conchœcia elegans*, G. O. Sars, *Forhandl. Vidensk.-Selsk. Chr.*, p. 117.
1891, *Paraconchœcia gracilis*, Claus, *Die Halocypriden des atlantischen Oceans und Mittelmeeres*, p. 66, pl. xii.
1896, *Conchœcia elegans*, Brady & Norman, *Trans. Roy. Dublin Soc.* (N.S.), vol. v. p. 684, pl. lx. fig. 23, pl. lxv. figs. 11–22.
1906, *Conchœcia elegans*, G. W. Müller, "Ostracoda," "*Siboga*" *Exped.*, p. 4.

A single specimen of this species occurred in a surface gathering collected at Station 14, 21° 28′ N., 22° 40′ W., 28th November 1902. This species has been found fairly common in Loch Etive, Scotland, and is said to be very abundant among the Lofoten Islands down to 300 fathoms (G. O. SARS), while Dr CLAUS reports it as having been taken at a depth of 1500 metres in lat. 37° 45′ N., long. 13° 38′ W. *C. elegans* is also a Mediterranean species. Dr G. W. MÜLLER gives its distribution as extending to lat. 35° in the South Atlantic.* *Paraconchœcia gracilis*, Claus, is considered by Dr G. W. MÜLLER to be identical with *C. elegans*, G. O. Sars.

Genus *Euconchœcia*, G. W. Müller, 1890.

Euconchœcia chierchiæ, G. W. Müller. (Pl. XIII. figs. 22–25.)

1890, *Euconchœcia chierchiæ*, G. W. Müller, "Ueber Halocypriden," *Zool. Jahrb.*, Bd. v. p. 227, pl. xxviii. figs. 1–10 (1890).
1894, *Halocypris aculeata*, T. Scott, *Trans. Linn. Soc.: Zool.*, ser. 2, vol. vi. p. 142, pl. xv. figs. 5, 6, 33, 34, 38.
1902, *Euconchœcia chierchiæ*, G. S. Brady, *Trans. Zool. Soc.*, vol. xvi. p. 190, pl. xxiv. figs. 9–15.

A few specimens of this species occurred in a surface gathering collected at Station 49, 1° 53′ N., 27° 26′ W., and at Station 68, 7° 42′ S., 34° 32′ W., off Pernambuco, in December 1902.

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* "Sie findet sich weiter im nördlichen und südlichen Atlantischen Ocean bis zu 35° südlicher Breite," *Nordisches Plankton*, vii., "Ostracoda," p. 4 (1901).

ALPHABETICAL INDEX TO GENERA AND SPECIES.

EXPLANATION OF PLATES.

Plate I.

Parathalestris affinis, sp. n.

Fig. 1. Foot of fourth pair.

Cyclopina belgica, Giesbrecht.

Fig. 2. Female, dorsal view.
,, 3. Antennule.
,, 4. Antenna.
,, 5. Maxilla.
,, 6. Mandible and palp.
,, 7. First maxilliped.
,, 8. Second maxilliped.
,, 9. Foot of first pair.
,, 10. ,, second pair.
,, 11. ,, fourth pair.
,, 12. ,, fifth pair.
,, 13. Abdomen and caudal rami.

Euryte similis, sp. n.

Fig. 14. Female, dorsal view.
Fig. 15. Antennule.
,, 16. Antenna.
,, 17. First maxilliped.
,, 18. Second maxilliped.
,, 19. Foot of first pair.
,, 20. ,, second pair.
,, 21. ,, fourth pair.
,, 22. ,, fifth pair.

Tisbe gracilipes, sp. n.

Fig. 23. Antennule, female.
,, 24. Antenna.
,, 25. Second maxilliped.
,, 26. Foot of first pair.
,, 27. ,, fourth pair.
,, 28. ,, fifth pair.
,, 29. Abdomen and caudal rami.

Plate II.

Bradya proxima, sp. n.

Fig. 1. Female, side view.
,, 2. Antennule, female.
,, 3. Antenna.
,, 4. Mandible.
,, 5. Second maxilliped.
,, 6. Foot of third pair.
,, 7. ,, fourth pair.
,, 8. ,, fifth pair, female.
,, 9. Abdomen and caudal rami.

Ectinosoma antarctica, Giesbrecht.

Fig. 10. Antennule, female.
,, 11. Antenna.
,, 12. First maxilliped (*a*); second maxilliped (*b*).
,, 13. Foot of fifth pair, female.

Parathalestris clausi (Norman).

Fig. 14. Second maxilliped.
Fig. 15. Foot of first pair.
,, 16. ,, second pair.
,, 17. ,, fifth pair, male.

Dactylopusia frigida, sp. n.

Fig. 18. Antennule, female.
,, 19. Antenna.
,, 20. Second maxilliped.
,, 21. Foot of first pair.
,, 22. ,, fourth pair.
,, 23. ,, fifth pair, female.
,, 24. Abdomen and caudal rami.

Dactylopusia perplexa, sp. n.

Fig. 25. Antennule, female.
,, 26. Antenna.
,, 27. Mandible and palp.
,, 28. Foot of first pair.
,, 29. ,, fifth pair, female.

Plate III.

Idomene forficata, Philippi.

Fig. 1. Female, seen dorsally.
,, 2. Outer ramus of antenna.
,, 3. Second maxilliped.
,, 4. Foot of first pair.
,, 5. ,, fourth pair.
,, 6. ,, fifth pair, male.

Parathalestris coatsi, sp. n.

Fig. 7. Female, seen dorsally.
,, 8. Antennule, female.
,, 9. Antenna.
,, 10. Mandible and palp.
,, 11. Second maxilliped.
,, 12. Foot of first pair.

Parathalestris coatsi—contd.

Fig. 13. Foot of second pair.
,, 14. ,, fourth pair.
,, 15. ,, fifth pair, female.
,, 16. Abdomen and caudal rami.

Parathalestris affinis, sp. n.

Fig. 17. Female, seen dorsally.
,, 18. Antennule, female.
,, 19. Antenna.
,, 20. Mandible.
,, 21. Maxilla.
Fig. 22. First maxilliped.
,, 23. Second maxilliped.
,, 24. Foot of first pair.
,, 25. ,, fifth pair.

Tisbe austrina, sp. n.

Fig. 26. Antennule, female.
,, 27. Antenna.
,, 28. Second maxilliped.
,, 29. Foot of first pair.
,, 30. ,, fifth pair, female.

PLATE IV.

Idomene forficata, Philippi.

Fig. 1. Antennule, female.

Saphirella abyssicola, T. Scott.

Fig. 2. Female, seen dorsally.
,, 3. Antennule, female.
,, 4. Mandible (*a*), maxilla (*b*).

Porcellidium affine, Quidor.

Fig. 5. Female, seen dorsally.
,, 6. Male, seen dorsally.
,, 7. Antennule, female.
,, 8. Antenna.
,, 9. Foot of first pair.
,, 10. ,, fifth pair, female.
,, 11. ,, fifth pair, male.
,, 12. Abdomen and caudal rami, female.
,, 13. ,, ,, male.

Machairopus major, sp. n.

Fig. 14. Female, dorsal view.
Fig. 15. Antennule, female.
,, 16. Mandible and palp.
,, 17. Maxilla.
,, 18. Second maxilliped.
,, 19. Foot of first pair.
,, 20. ,, second pair.
,, 21. ,, third pair.
,, 22. ,, fourth pair.
,, 23. ,, fifth pair, female.
,, 24. Abdomen and caudal rami.

Parastenhelia antarctica, sp. n.

Fig. 25. Antennule, female.
,, 26. Mandible.
,, 27. First maxilliped.
,, 28. Second maxilliped.
,, 29. Foot of first pair.
,, 30. ,, second pair.
,, 31. ,, fourth pair.
,, 32. ,, fifth pair, female.
,, 33. Abdomen and caudal rami.

PLATE V.

Phyllopodopsyllus mossmani, sp. n.

Fig. 1. Female (♀), and male (♂), side view.
,, 2. Antennule, female.
,, 3. Antennule, male.
,, 4. Antenna.
,, 5. Mandible and palp.
,, 6. Second maxilliped.
,, 7. Foot of first pair.
,, 8. ,, second pair, female.
,, 9. ,, second pair, male.
,, 10. ,, fourth pair.
,, 11. ,, fifth pair, female.
,, 12. ,, fifth pair, male.
,, 13. Abdomen and caudal rami, female.
Fig. 14. Abdomen and caudal rami, male.

Harpacticus piriei, sp. n.

Fig. 15. Foot of fifth pair, female.

Psamathe longicauda, Philippi.

Fig. 16. Female, seen dorsally.
,, 17. Antennule, female.
,, 18. Antenna.
,, 19. First maxilliped.
,, 20. Second maxilliped.
,, 21. Foot of first pair.
,, 22. ,, fifth pair, female.

Plate VI.

Dactylopusia perplexa, sp. n.

Fig. 1. Second maxilliped.
,, 2. Foot of fourth pair.

Asterocheres suberites, Giesbrecht, var.

Fig. 3. Antennule, female.
,, 4. Antenna.
,, 5. First maxilliped.
,, 6. Second maxilliped.
,, 7. Siphon.
,, 8. Foot of first pair.
,, 9. ,, second pair.
,, 10. ,, fourth pair.
,, 11. Abdomen and caudal rami.

Psamathe fucicola, sp. n.

Fig. 12. Antennule, female.
,, 13. Antenna.
Fig. 14. Mandible and palp.
,, 15. Maxilla.
,, 16. Foot of first pair.
,, 17. ,, fourth pair.
,, 18. ,, fifth pair.
,, 19. Abdomen and caudal rami.

Machairopus australis, sp. n.

Fig. 20. Antennule, female.
,, 21. Antenna.
,, 22. Mandible and palp.
,, 23. First maxilliped.
,, 24. Second maxilliped.
,, 25. Foot of first pair.
,, 26. ,, second pair.
,, 27. ,, fourth pair.
,, 28. ,, fifth pair.

Plate VII.

Laophonte rottenburgi, sp. n.

Fig. 1. Antennule, female.
,, 2. Second maxilliped.
,, 3. Foot of first pair.
,, 4. ,, third pair.
,, 5. ,, fifth pair, female.
,, 6. Abdomen and caudal rami.

Laophonte wiltoni, sp. n.

Fig. 7. Female, dorsal view.
,, 8. Antennule, female.
,, 9. Antenna.
,, 10. Second maxilliped.
,, 11. Foot of first pair.
,, 12. ,, second pair.
,, 13. ,, fourth pair.
,, 14. ,, fifth pair.
,, 15. Abdomen and caudal rami.

Laophonte exigua, sp. n.

Fig. 16. Antennule, female.
,, 17. Antenna.
,, 18. Foot of first pair.
,, 19. ,, second pair.
,, 20. ,, fourth pair.
,, 21. ,, fifth pair, female.
,, 22. Abdomen and caudal rami.

Ameira simulans, sp. n.

Fig. 23. Antennule, female.
,, 24. Second maxilliped.
,, 25. Foot of first pair.
,, 26. ,, fourth pair.
,, 27. ,, fifth pair, female.
,, 28. Abdomen and caudal rami.

Plate VIII.

Laophontodes whitsoni, sp. n.

Fig. 1. Female, dorsal view.
,, 2. Antennule, female.
,, 3. Antenna.
,, 4. Second maxilliped.
,, 5. Foot of first pair.
,, 6. ,, second pair.
,, 7. ,, fourth pair.
,, 8. ,, fifth pair, female.

Pseudozosime browni, sp. n.

Fig. 9. Female, dorsal view.
,, 10. ,, side view.
,, 11. Antennule, female.
,, 12. Antenna.
,, 13. Maxilla.
,, 14. First maxilliped.
,, 15. Second maxilliped.
,, 16. Foot of first pair.
,, 17. ,, second pair.
,, 18. ,, fourth pair.
,, 19. ,, fifth pair, female.

Harpacticus fucicolus, sp. n.

Fig. 20. Antennule, female.
,, 21. Antenna.
Fig. 22. Second maxilliped.
,, 23. Foot of first pair.
,, 24. ,, fifth pair, female.

PLATE IX.

Pseudothalestris intermedia, sp. n.

Fig. 1. Antennule, female.
,, 2. Second maxilliped.
,, 3. Foot of second pair, male; third inner ramus of left foot.
,, 4. Fifth pair, female.

Pseudothalestris assimilis, var. *antarctica*.

Fig. 5. Second maxilliped.
,, 6. Foot of first pair.
,, 7. ,, second pair, male.
,, 8. Foot of fifth pair, male.
,, 9. Abdomen and caudal rami.

Orthopsyllus linearis, Claus.

Fig. 10. Female, dorsal view.
,, 11. Antennule, female.
,, 12. Antenna.
,, 13. Mandible and palp.
,, 14. First maxilliped.
Fig. 15. Second maxilliped.
,, 16. Foot of first pair.
,, 17. ,, second pair, inner ramus.
,, 18. ,, third pair, inner ramus.
,, 19. ,, fourth pair.
,, 20. ,, fifth pair, female.
,, 21. ,, third pair, male, inner ramus.
,, 22. ,, fifth pair, male.

Amphiascus fucicolus, sp. n.

Fig. 23. Antennule, female.
,, 24. Antenna.
,, 25. Second maxilliped.
,, 26. Foot of first pair.
,, 27. ,, fourth pair.
,, 28. ,, fifth pair, female.

Idomene forficata, Philippi.

Fig. 29. Foot of fifth pair, female.

PLATE X.

Alteutha dubia, sp. n.

Fig. 1. Female, seen dorsally.
,, 2. Antennule, female.
,, 3. Antenna.
,, 4. Second maxilliped.
,, 5. Foot of first pair.
,, 6. ,, fourth pair.
,, 7. ,, fifth pair, female.
,, 8. Abdomen and caudal rami.

Alteutha austrina, sp. n.

Fig. 9. Female, dorsal view.
,, 10. Antennule, female.
,, 11. Second maxilliped.
,, 12. Foot of first pair.
Fig. 13. Foot of fourth pair.
,, 14. ,, fifth pair, female.
,, 15. Abdomen and caudal rami.

Paralteutha typica, gen. et sp. n.

Fig. 16. Female, dorsal view.
,, 17. Antennule, male.
,, 18. Antenna.
,, 19. Mandible and palp, male.
,, 20. Second maxilliped.
,, 21. Foot of first pair.
,, 22. ,, fourth pair.
,, 23. ,, fifth pair, female.
,, 24. ,, fifth pair, male.
,, 25. Abdomen and caudal ramus.

PLATE XI.

Artotrogus proximus, sp. n.

Fig. 1. Female, dorsal view.
,, 2. Antennule, female.
,, 3. Antenna.
,, 4. Mandible.
,, 5. Maxilla.
,, 6. First maxilliped.
,, 7. Second maxilliped.
,, 8. Foot of fourth pair.
,, 9. ,, fifth pair, female.

Laophonte australis, sp. n.

Fig. 10. Female, side view.
,, 11. Antennule, female.
,, 12. Antenna.
,, 13. Second maxilliped.
,, 14. Foot of first pair.
,, 15. ,, second pair.
,, 16. ,, fifth pair, female.
,, 17. Abdomen and caudal rami.

Harpacticus piriei, sp. n.

Fig. 18. Antennule, female.
,, 19. Antenna.
,, 20. Second maxilliped.
,, 21. Foot of first pair.
Fig. 22. Foot of second pair.
,, 23. ,, third pair.
,, 24. ,, fourth pair.
,, 25. Abdomen and caudal rami.

PLATE XII.

Pseudanthessius fucicolus, sp. n.

Fig. 1. Female, dorsal view.
,, 2. Antennule, female.
,, 3. Antenna.
,, 4. Mandible.
,, 5. Maxilla.
,, 6. First maxilliped.
,, 7. Second maxilliped.
,, 8. Foot of first pair.
,, 9. ,, third pair.
,, 10. ,, fourth pair.
,, 11. ,, fifth pair.
,, 12. Abdomen and caudal rami, female.
,, 13. Abdomen and caudal rami, male, a = fifth foot.

Dactylopusia ferrieri, sp. n.

Fig. 14. Female, side view.
,, 15. Antennule, female.
Fig. 16. Maxilla.
,, 17. First maxilliped.
,, 18. Second maxilliped.
,, 19. Foot of first pair.
,, 20. ,, second pair.
,, 21. ,, fourth pair.
,, 22. ,, fifth pair.

Lichomolgus fucicola, Brady.

Fig. 23. Antennule, female.
,, 24. Antenna.
,, 25. Foot of fourth pair.
,, 26. Abdomen and caudal rami.

Pseudothalestris intermedius, sp. n.

Fig. 27. Foot of first pair.
,, 28. ,, second pair.
,, 29. ,, fifth pair.

PLATE XIII.

Fig. 1. *Calanopia americana*, Dahl. Antennule, ♂.
,, 2. ,, ,, ,, Foot of first pair.
,, 3. ,, ,, ,, ,, fourth pair.
,, 4. ,, ,, ,, ,, fifth pair, ♀.
,, 5. ,, ,, ,, ,, fifth pair, ♂.
,, 6. ,, ,, ,, Abdomen and caudal rami, ♂.
,, 7. *Pleuromamma gracile* (Claus). Fifth pair of feet, ♀.
,, 8. ,, ,, var. *Esterleyi*, nov. Foot of second pair, ♀, basal part.
,, 9. ,, ,, ,, ,, Fifth pair of feet, ♀.
,, 10. ,, ,, ,, ,, Abdomen, ♀, side view.
,, 11. *Clytemnestra scutellata*, Dana, ♀. Terminal joints of antennule.
,, 12. ,, ,, ,, Last abdominal segment and caudal rami.
,, 13. *Dysgamus atlanticus*, Stp. and Ltk., ♂. Dorsal view.
,, 14. *Evadne tergestina*, Claus. Side view.
,, 15. ,, *spinifera*, P. E. Müller. Side view.
,, 16. *Philomedes assimilis*, Brady, ♀. Side view.
,, 17. ,, ,, ,, Post abdomen.
,, 18. *Asterope australis*, Brady, ♀. Side view.
,, 19, ,, ,, ,, Post abdomen.
,, 20. ,, *oculata*, ,, Side view.
,, 21. ,, ,, ,, Post abdomen.
,, 22. *Euconchœcia chierchiæ*, G. W. Müller, ♀. Side view.
,, 23. ,, ,, ,, Antennule.
,, 24. ,, ,, ,, Post abdomen.

Fig.	25.	*Conchœcia spinirostris*, Claus, ♂.	Side view.
,,	26.	,, ,, ,,	Post abdomen.
,,	27.	,, *procera*, G. W. Müller, ♂.	Side view.
,,	28.	,, ,, ,,	Post abdomen.
,,	29.	*Halocypris inflata*, Dana, ♀.	Side view.
,,	30.	,, ,, ,,	Antennule.
,,	31.	,, ,, ,,	Post abdomen.
,,	32.	,, *globosa*, Claus, ♀.	Side view.

PLATE XIV.

Fig.	1.	*Macrocypris maculata*, G. S. Brady.	Side view.
,,	2.	,, ,, ,,	Seen from above.
,,	3.	*Cythere latibrosa*, sp. n.	Side view.
,,	4.	,, ,, ,,	Dorsal view.
,,	5.	,, *antarctica* ,,	Side view.
,,	6.	,, ,, ,,	Dorsal view.
,,	7.	,, *foveolata*, Brady, ♂.	Side view.
,,	8.	,, ,, ,,	Dorsal view.
,,	9.	,, *inornata*, sp. n.	Side view.
,,	10.	,, ,, ,,	Dorsal view.
,,	11.	,, *peregrina* ,,	Side view.
,,	12.	,, ,, ,,	Dorsal view.
,,	13.	,, *foveolata*, Brady, ♀.	Side view.
,,	14.	,, ,, ,,	Dorsal view.
,,	15.	,, *quadridens*, sp. n.	Side view.
,,	16.	,, ,, ,,	Dorsal view.
,,	17.	*Xestoleberis reniformis*, Brady.	Side view.
,,	18.	,, ,, ,,	Dorsal view.
,,	19.	*Cytherura ornata*, sp. n.	Side view.
,,	20.	,, ,, ,,	Dorsal view.
,,	21.	,, ,, ,,	Ventral view.
,,	22.	,, *porrecta* ,,	Side view.
,,	23.	,, ,, ,,	Dorsal view.
,,	24.	,, *sculptilis*, sp. n.	Side view.
,,	25.	,, ,, ,,	Dorsal view.
,,	26.	*Paradoxostoma retusum*, Brady.	Side view.
,,	27.	,, *antarcticum*, sp. n.	Side view.
,,	28.	,, ,, ,,	Dorsal view.
,,	29.	,, *læve*, sp. n.	Side view.
,,	30.	,, ,, ,,	Dorsal view.

Note.—I am indebted to my son, Andrew Scott, A.L.S., for the drawings mentioned below—viz., all the figures on Plate V. except figure 15; figures 1–19 on Plate VIII.; and figures 1–9 on Plate XI. Also for the undernoted figures on Plate XIV., viz., figures 3–8, 13–16, and 19–23.

ADDENDA.

Oithona frigida, Giesb., *Expéd. Antarct. Belge*, "Copep.," p. 29, pl. vi. In a *Scotia* gathering, 0–200 fathoms, lat. 69° 22′ S., 26° 36′ W., 28th February 1903, Station 273.

Lepeophtheirus nordmanni, M.-Edw.

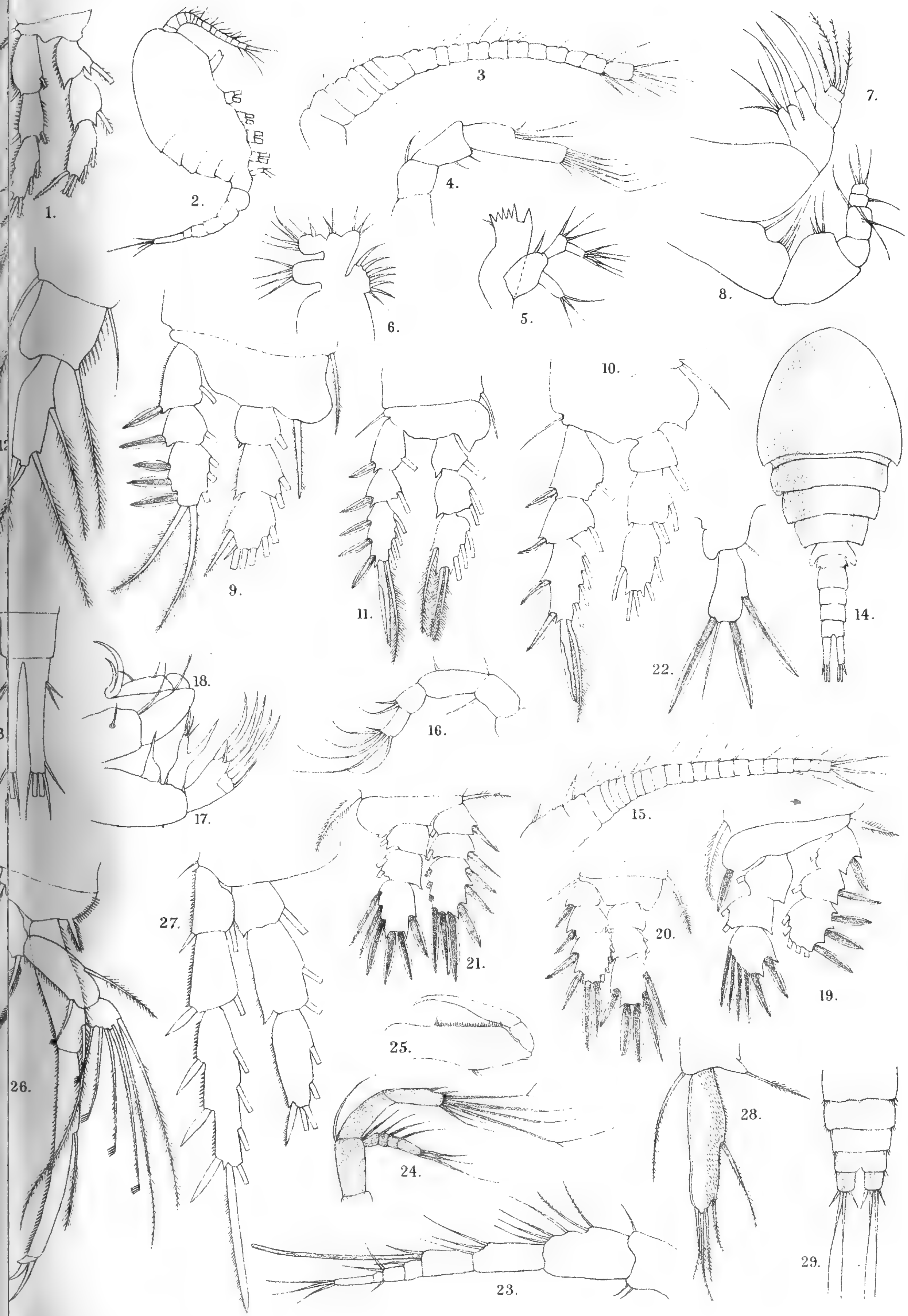
Cecrops latreillii, Leach.

These two parasitic Copepods were obtained on a short Sunfish, *Orthagoriscus mola* (Lin.), captured in lat. 39° 1′ S., long. 53° 40′ W., the first on the skin, the other on the gills, 1st January 1903, Station 107.

Alebion carcharix, Kröyer. This species was obtained on a shark, *Carcharias*, sp., captured in lat. 9° 23′ N., long. 25° 31′ W., on 5th December 1902, Station 34.

One or two specimens of *Labidocera lubbocki*, Giesb., were obtained in a gathering from the South Atlantic, but the exact locality is somewhat uncertain.

SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE I.



McFarlane & Erskine, Lith. Edinr

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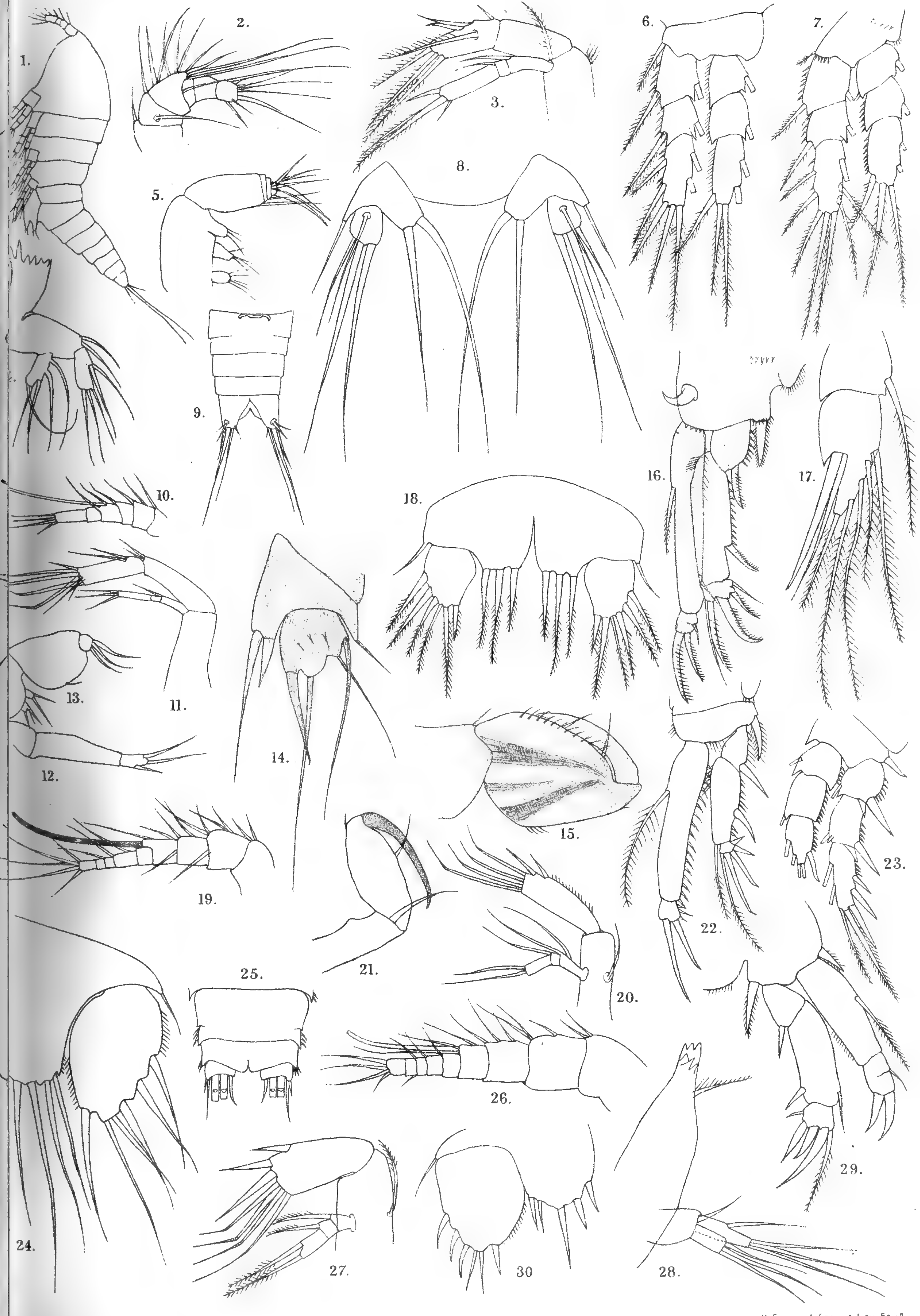
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE II.



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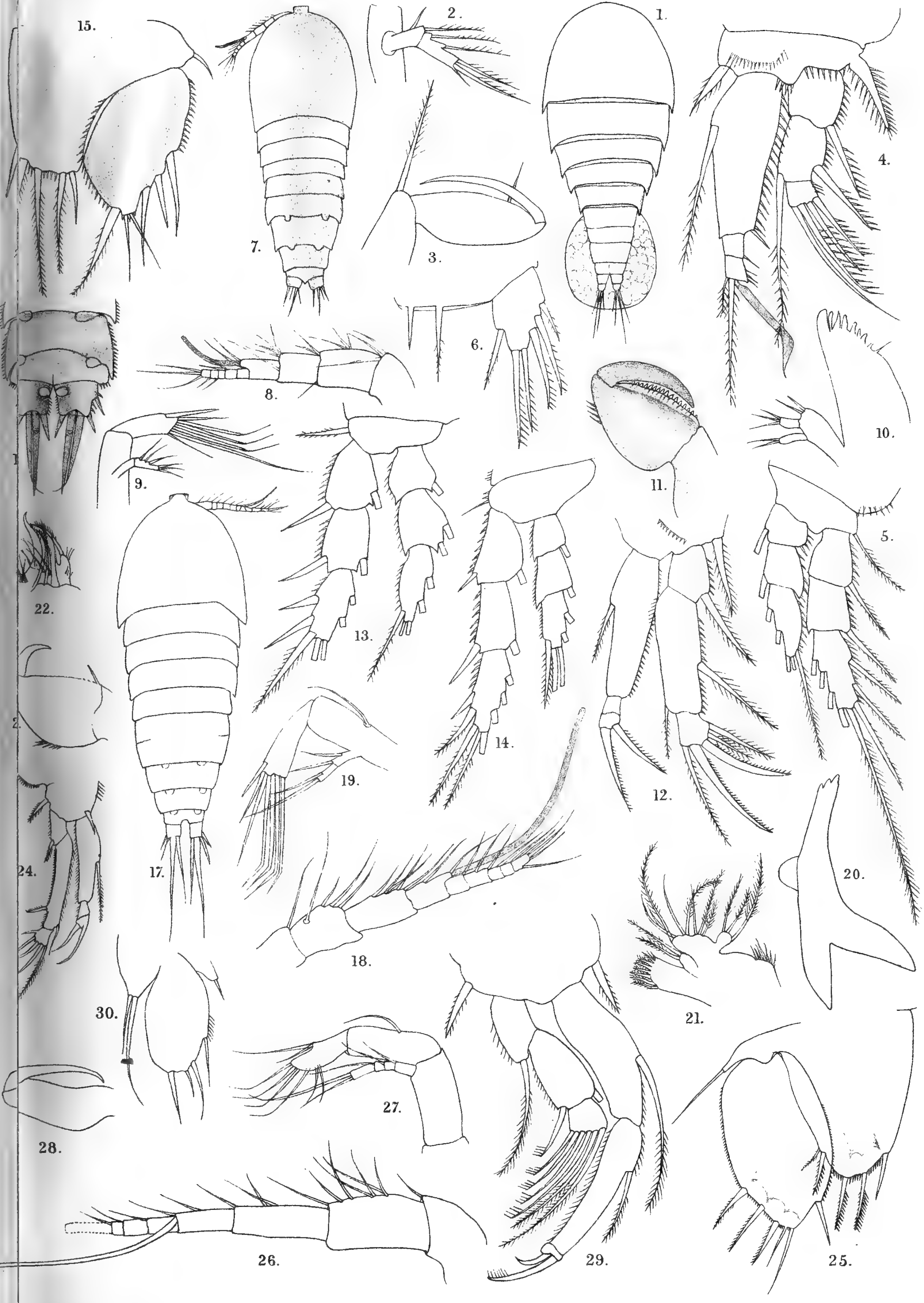
SCOTT : "SCOTIA" ENTOMOSTRACA.—PLATE III.



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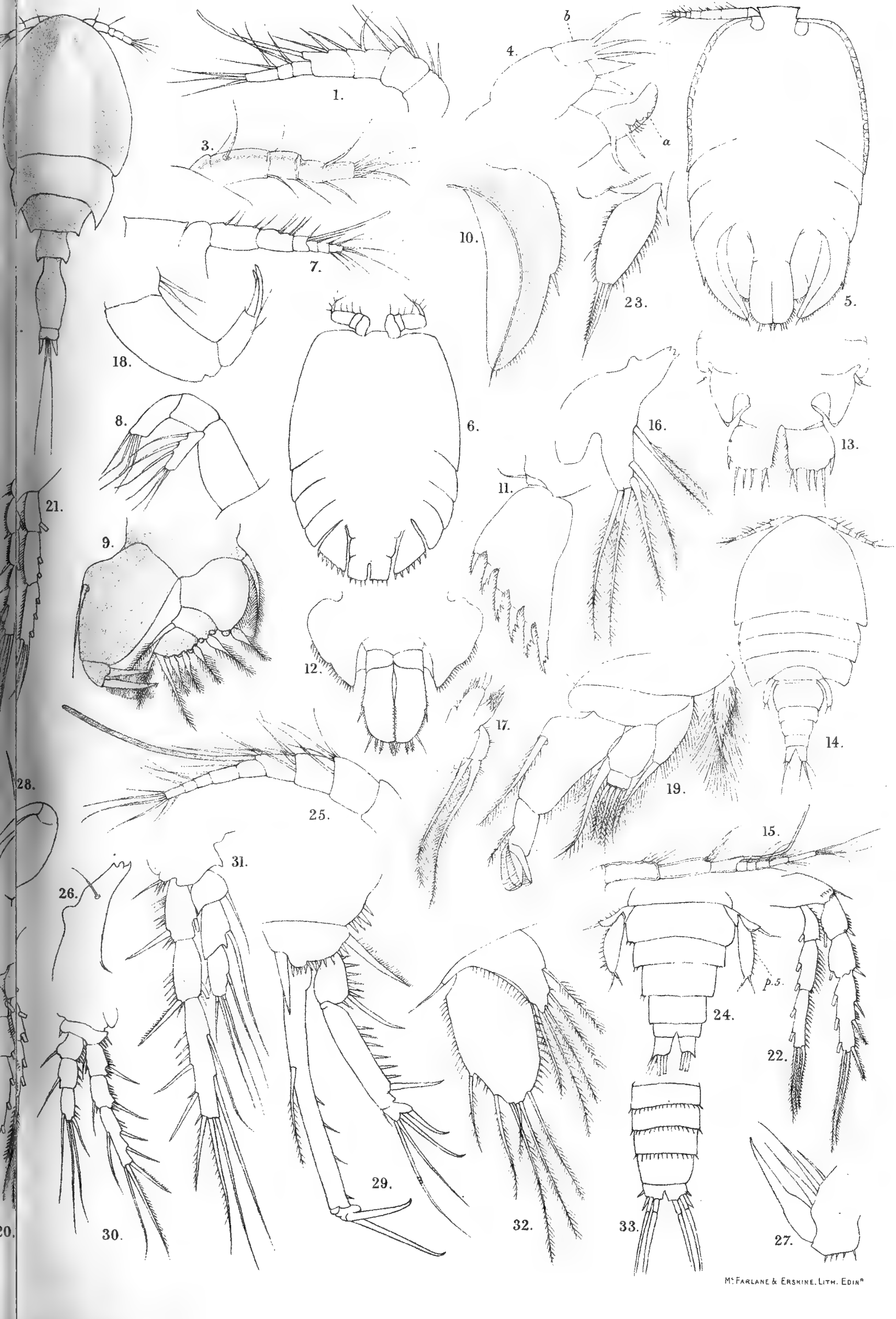
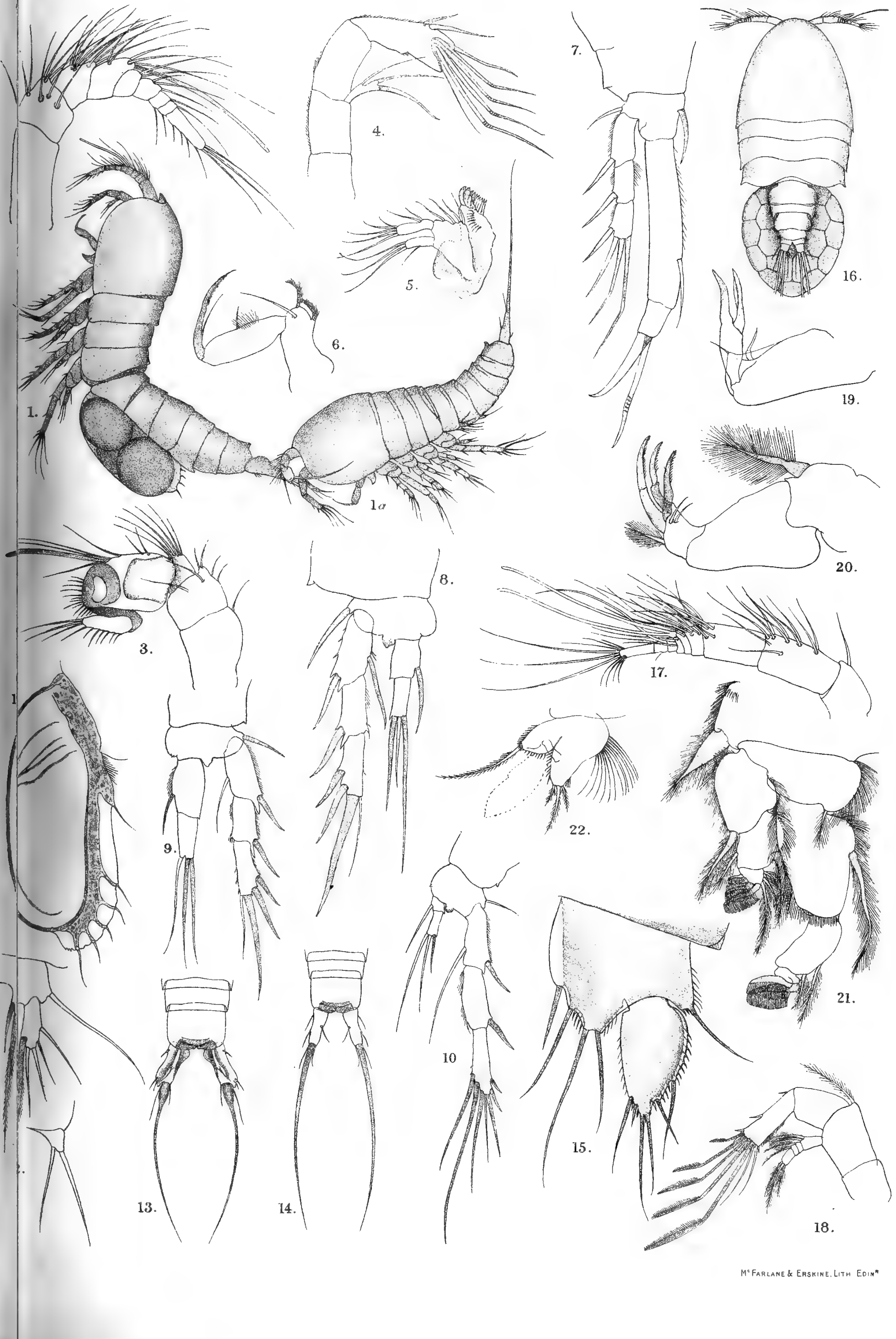
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE IV.



McFarlane & Erskine, Lith. Edin^{r}

BRITISH MUSEUM NATURAL HISTORY

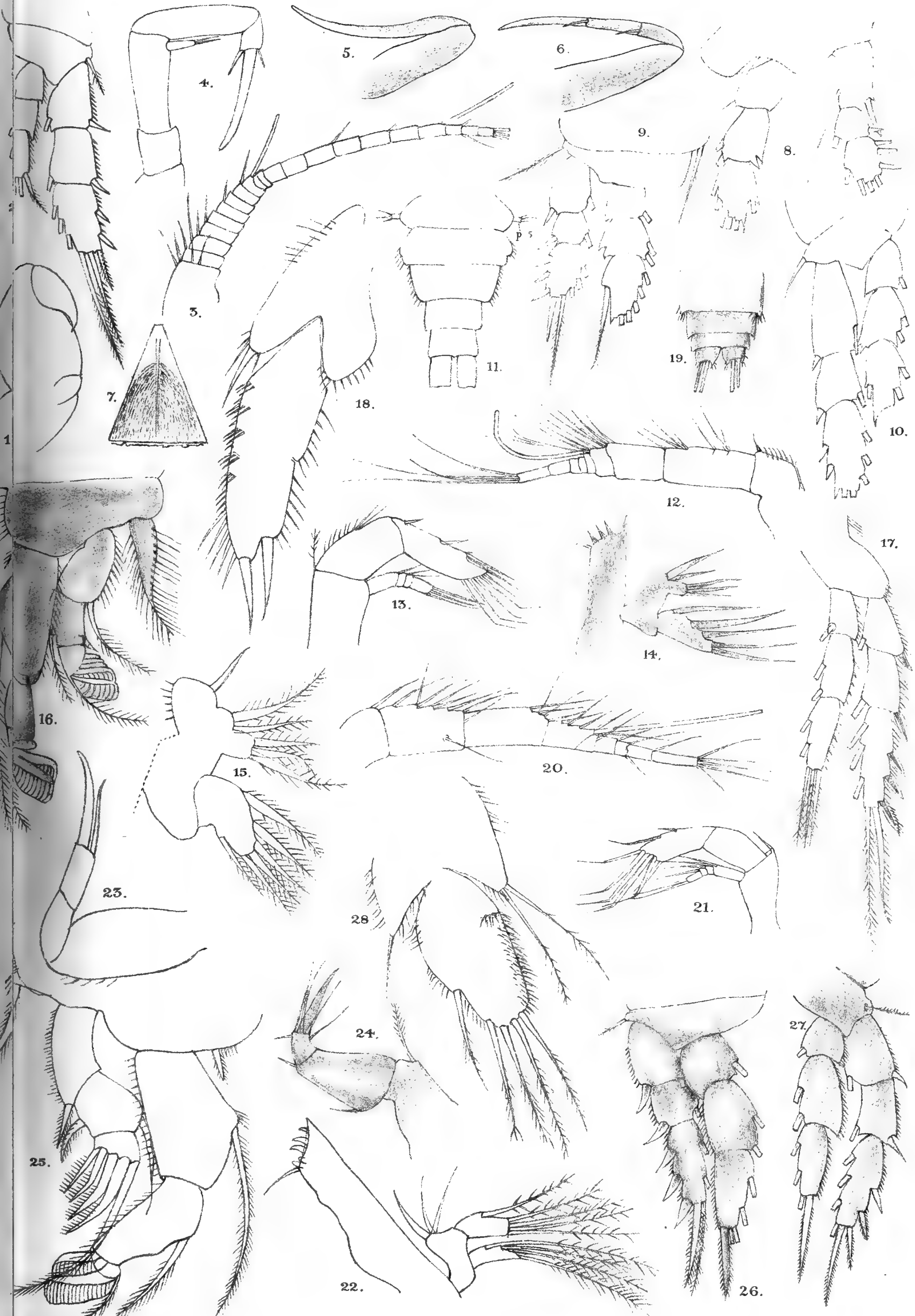
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE V.



Mc Farlane & Erskine, Lith Edinr.

BRITISH MUSEUM NATURAL HISTORY

SCOTT: "SCOTIA" ENTOMOSTRACA—PLATE VI.



M^c Farlane & Erskine, Lith. Edin^r

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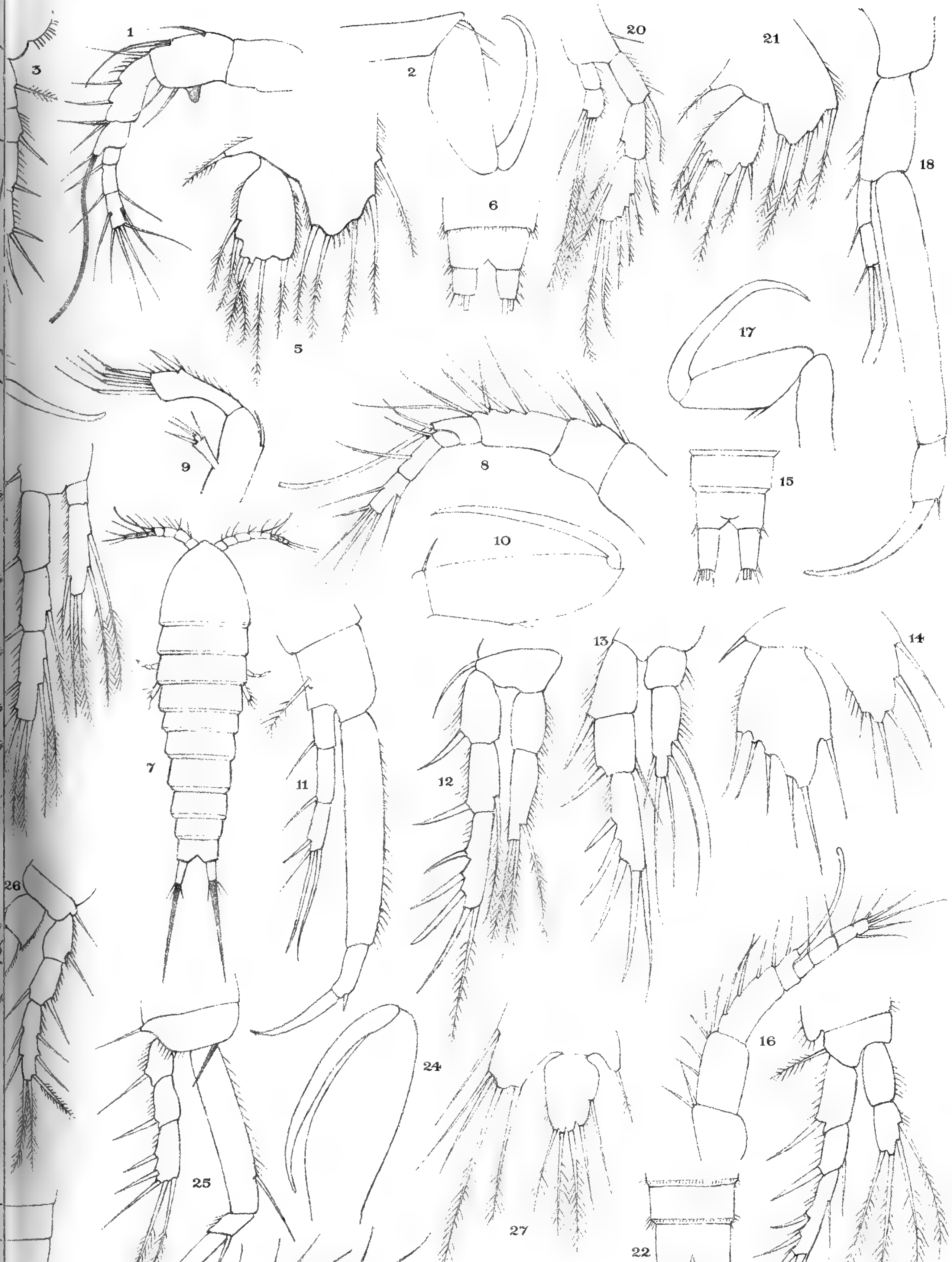
SCOTT: "SCOTIA" ENTOMOSTRACA—PLATE VII.



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Scott: "Scotia" Entomostraca.—Plate VIII.

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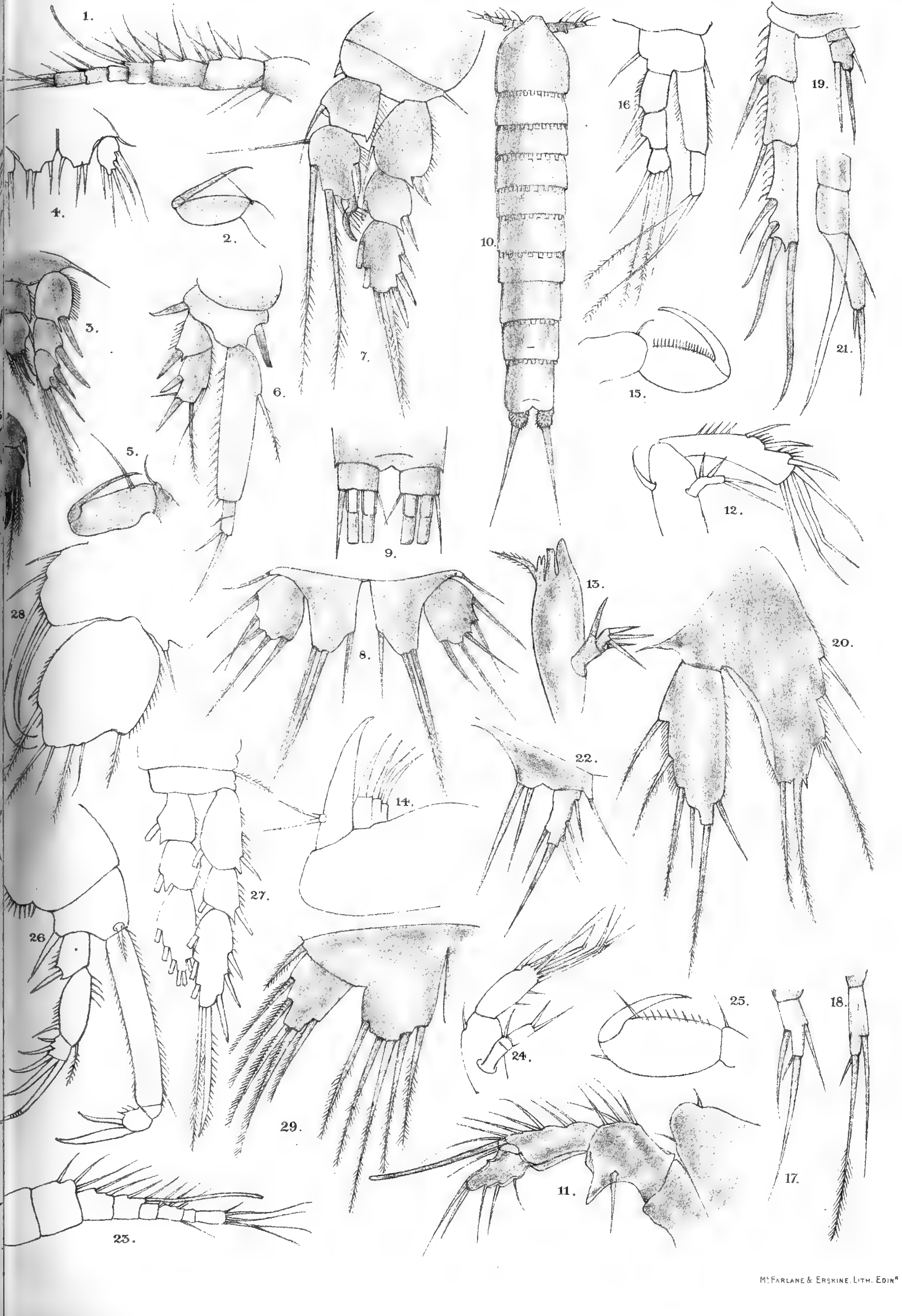
SCOTT: "SCOTIA" ENTOMOSTRACA—PLATE IX.



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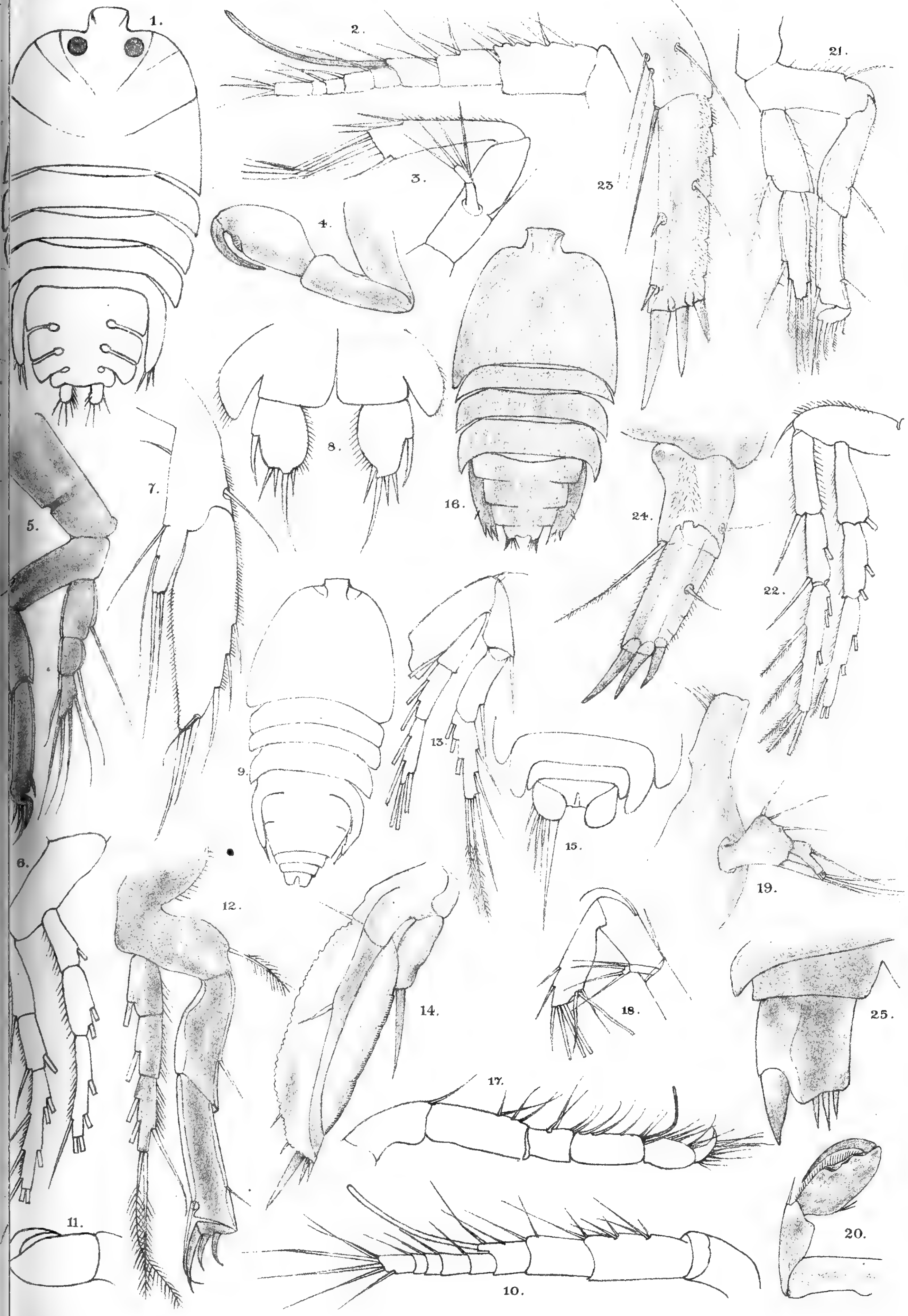
SCOTT: "SCOTIA" ENTOMOSTRACA—PLATE X.



M^{c}Farlane & Erskine, Lith. Edin^{r}

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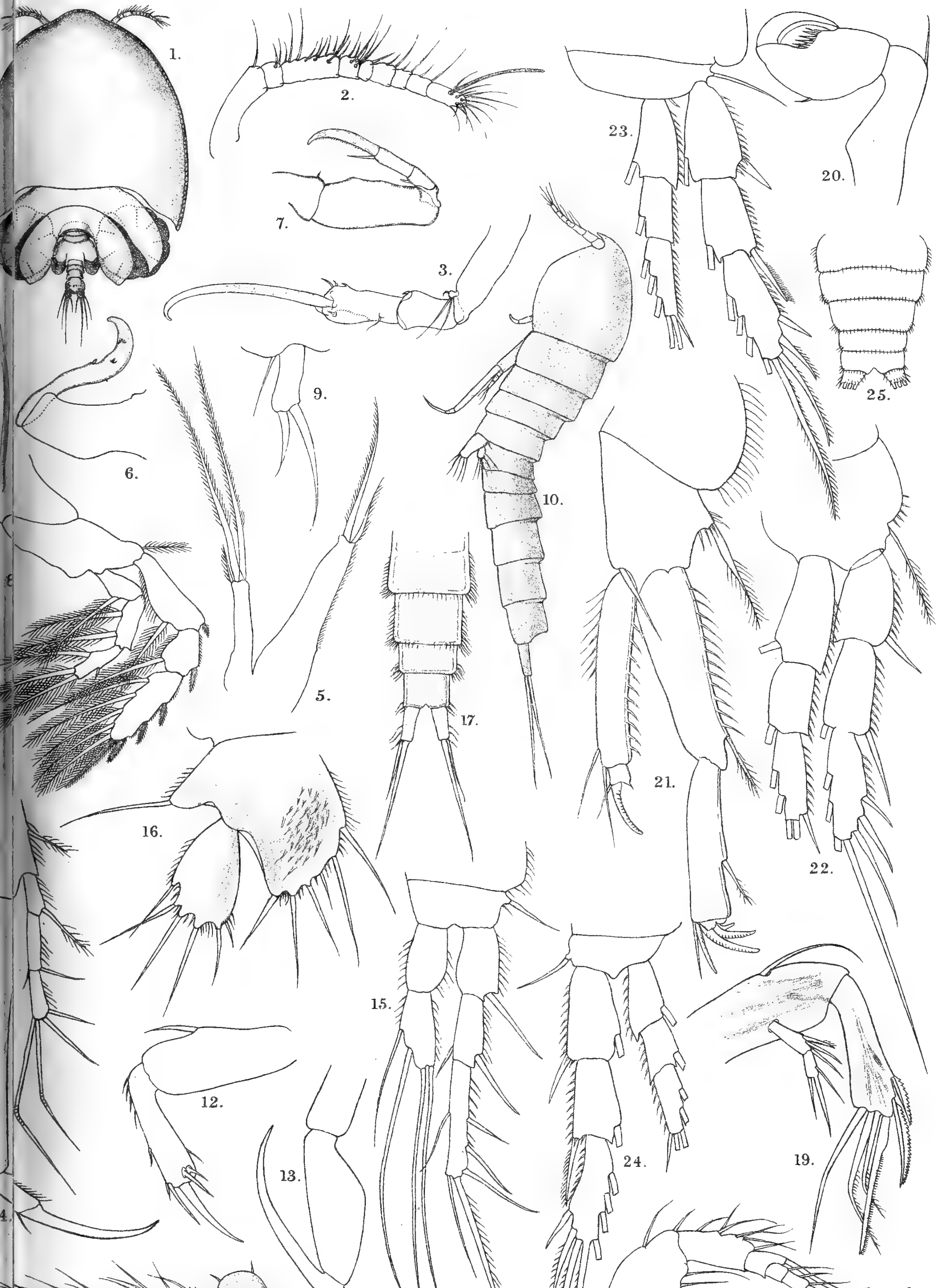
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE XI.



M^{c} Farlane & Erskine, Lith. Edin$^{r.}$

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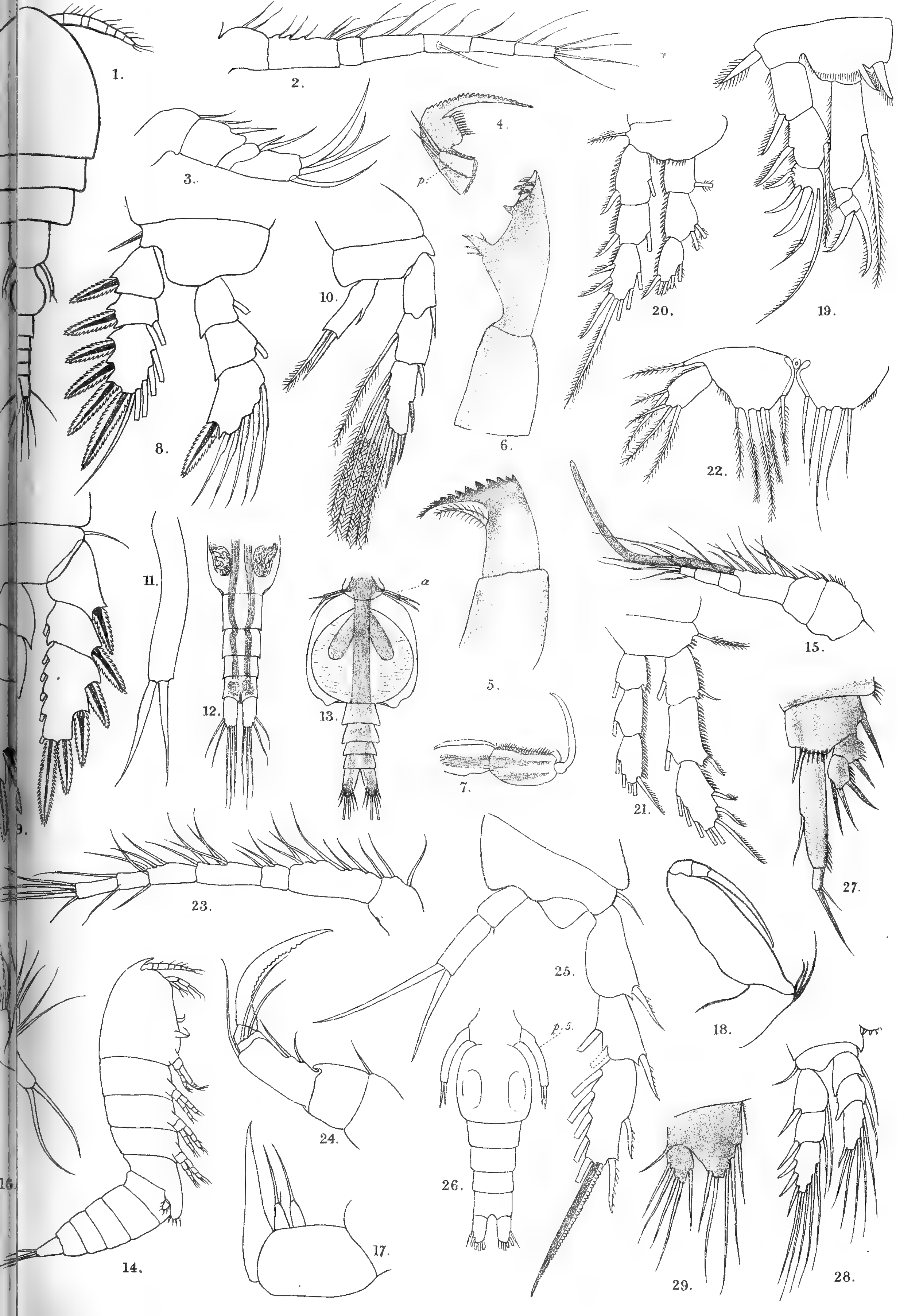
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE XII.



M^{c} Farlane & Erskine. Lith. Edin^{r}

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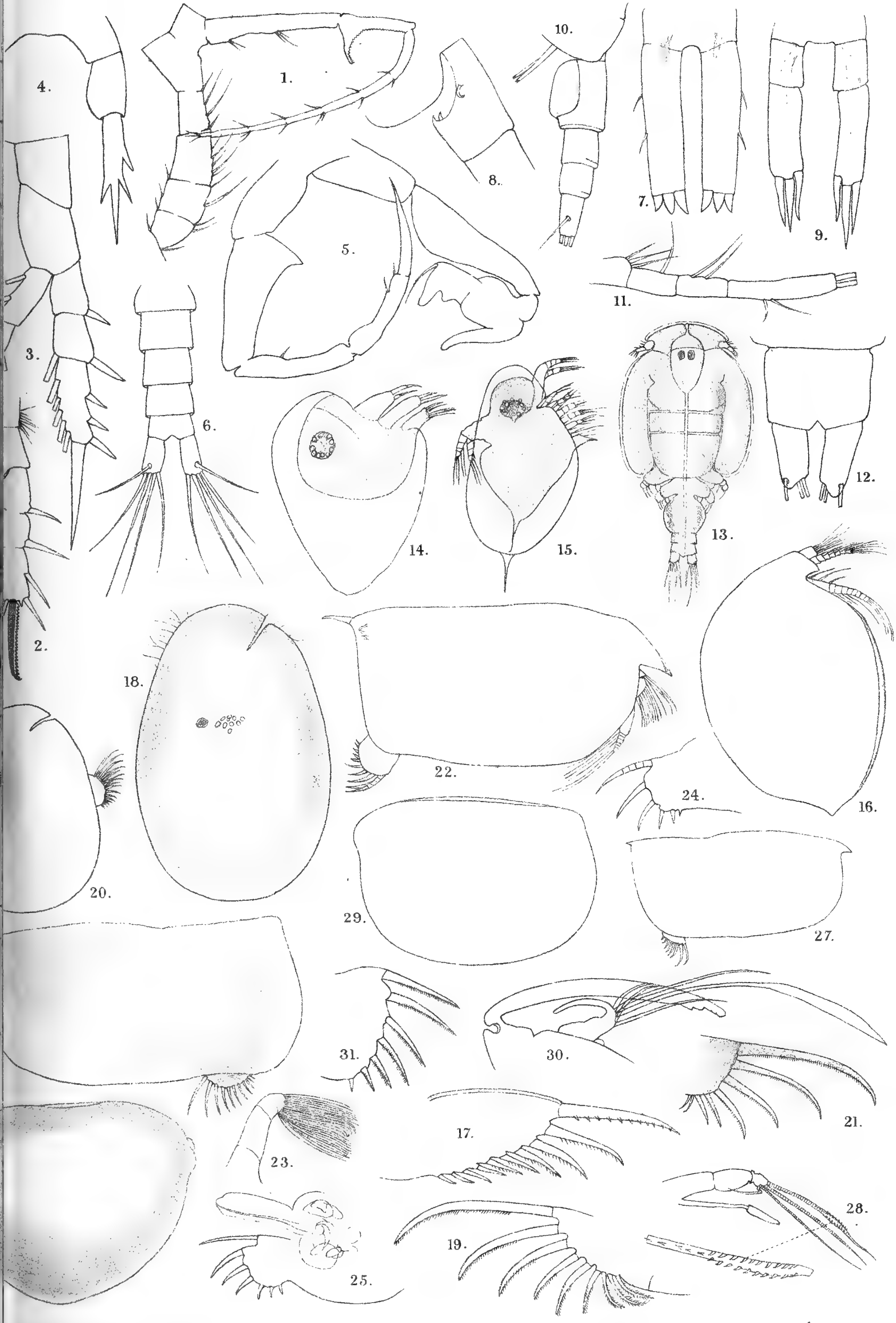
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE XIII.



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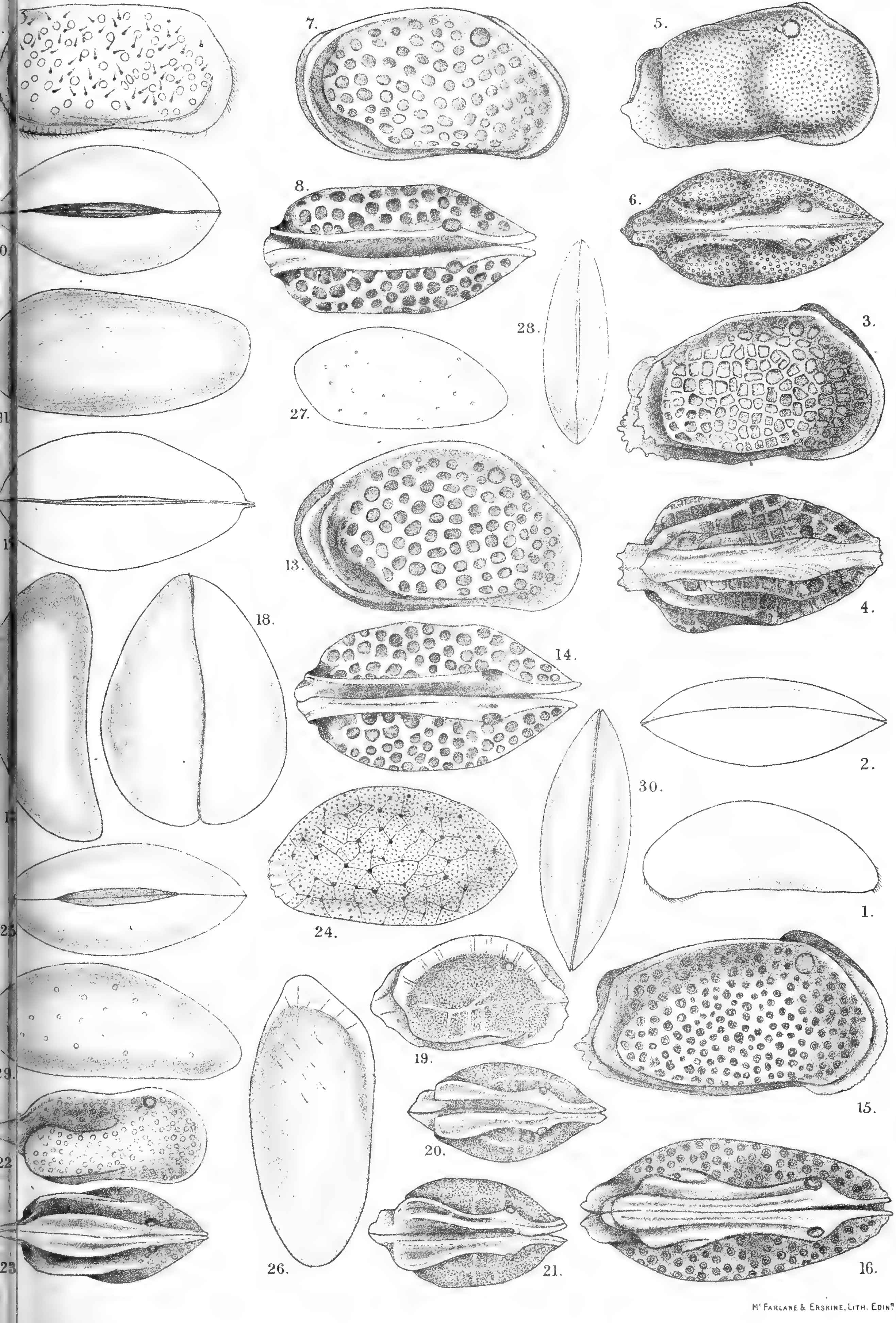
SCOTT: "SCOTIA" ENTOMOSTRACA.—PLATE XIV.



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BRITISH MUSEUM NATURAL HISTORY

XXV.—A Study in Chromosome Reduction. By A. Anstruther Lawson, Ph.D., D.Sc., F.L.S.; Lecturer in Botany, University of Glasgow. (With Three Plates.)

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Introduction.

Although the amount of active research that has been carried on during the past few years on the question of chromosome reduction and relative problems has been very great, the nuclear activities here concerned are still far from being understood. We are not yet in a position to draw general conclusions in regard to meiotic phenomena. It therefore seems to me desirable that all observations of fact and rational interpretations should be placed on record, so that when it becomes possible to generalise, all lines of evidence may be available.

A careful reading of the literature on meiosis will show that the most divergent views and widest difference of opinion expressed are those concerning three distinct phases of meiotic activity, viz. :—

1st, The phase of the nucleus known as synapsis.

2nd, The formation of the achromatic figure.

3rd, The act of reduction—especially as to the manner and place of its occurrence.

It has frequently occurred to me, that if we could concentrate research on these three important phases of meiosis many of the difficulties might be removed, and this would lead to a clearer understanding of the problem as a whole. The present investigation is therefore not intended as an exhaustive study of chromosome reduction. It is merely an attempt to call attention to certain physiological aspects of the cell during meiosis. It is believed, for instance, that osmosis and the high state of nutrition that prevails are important factors in so-called "synapsis," spindle formation, and chromosome reduction.

The material that has been used in the present investigation is *Smilacina*, the advantages of which have already been described in my former paper (Lawson, 1911a) on the phase of the nucleus known as synapsis. This material has been supplemented, especially for the reduction stage, by *Kniphofia* and *Aloe*, plants which offered excellent material for nuclear study.

The Early Prophase of the First Meiotic Division.

In fig. 1 we have represented a section of a mature microspore mother cell with the nucleus in the characteristic so-called reticulum stage. It will be seen that the cell wall is very thin indeed, forming straight lines and sharp angles with those of the neighbouring cells. The mother cells lie very close together, forming a dense mass of merismatic tissue with no trace of intercellular spaces between them. They completely fill the pocket of the anther, and the absence of curvature in the cell walls clearly shows the high uniform pressure which the individual cells exert upon one another. The cytoplasm appears in the form of a reticulum in section with a fairly uniform mesh. No clear volumes of cell sap of any measurable size that might be interpreted as vacuoles are present, but, on the contrary, the cytoplasm is uniformly dense with large quantities of granular food substances suspended in its meshes.

The chromatin reticulum or network appears to be made up of a number of very fine threads. These threads are finely granular, and appear to interlace and cross one another at frequent intervals. They are so long and so fine that it is quite impossible to estimate their number even approximately. The number of free ends that could be distinguished, however, made it perfectly evident that the number was a large one. Although the threads appear to be very finely granular and at places (see fig. 1) appear to have a fairly uniform thickness, a close examination reveals the fact that they are really not single but double, the two longitudinal portions being incompletely separated from one another by elongated vacuolate spaces.

The nuclei of these mother cells are very much larger than the nuclei in the surrounding vegetative tissue. They are almost spherical in form, and the enveloping plasmatic membrane marks a sharp line separating the cytoplasm from the nuclear sap. The enclosed karyolymph is apparently exerting a high osmotic pressure upon the enveloping plasmatic membrane, and as a result the nucleus has a distended and turgid appearance. Large and distended as the nucleus appears, the chromatin substance is very evenly and uniformly distributed throughout the spherical cavity. The threads representing the chromatin in a very finely divided condition are of fairly equal distance from one another. This uniformity, however, is interrupted by the presence of one, or more frequently two, very large nucleoli. These latter bodies frequently have clear vacuole-like areas within them, but, what seems to be more interesting, surrounding each nucleolus there is a clear zone of karyolymph into which the chromatin threads do not encroach. I have observed this feature of the nucleoli in many other plants besides *Smilacina*. These points are all clearly indicated in fig. 1.

The large size of the nucleus of these mother cells is due not directly to the increase in chromatin substance—although this is no doubt a factor of importance,—but rather to the increased amount of nuclear sap which is taken in endosmotically. The conditions here are highly suggestive of a correlation between the amount of chromatin (which contains osmotically active organic acids) and the amount of nuclear sap taken into the nuclear vacuole. But whether such a correlation exists or not, it seems quite evident and beyond a mere assumption, that the enlargement of the nuclear cavity is the result of an increase in the amount of its contained fluid, and this brings about a corresponding increase in the osmotic pressure acting upon the enveloping plasmatic membrane. The distended and spherical form of the nucleus suggests no other interpretation.

The Growth Period.

As already pointed out, the chromatin threads, at this early stage of the prophase (fig. 1), are evenly and uniformly distributed throughout the nuclear cavity except in the immediate vicinity of the nucleoli. With the first indication of the passing of the threads from the reticulum stage into the spireme condition, *i.e.* when the threads become more sharply defined and appear to be shortening and thickening as shown in fig. 2, this uniform distribution of the chromatin throughout the nuclear cavity no longer prevails. Co-incident with these slight changes in the length and thickness of the chromatin threads, there is an evident increase in the amount of karyolymph, and the amount of chromatin as indicated by the cubical volume it occupies appears to be stationary.

This is the beginning of what I have in a previous paper (Lawson, 1911a) called the "growth period"—a period during which there is undoubtedly a great increase in the volume of the nuclear sap, with no corresponding increase in the volume occupied by the chromatin substance. In order to more clearly express what is meant by this term, and to limit its application, I shall hereafter call it the "meiotic growth period." This increase in the amount of nuclear sap first shows itself by a slight distension of the nuclear plasmatic membrane beyond the outer limits of the chromatin. This distension appears in section, as a clear crescent-shaped area between the chromatin and the nuclear membrane. The early stages of this have already been fully described and figured in my previous paper, and I have no modifications to make in the account there given; but by way of confirmation I shall describe and figure one or two of the later stages. Figs. 2 and 3 represent such stages. In fig. 2 we see that the crescent-shaped area enlarges so as to almost completely surround the chromatin mass. As indicated in figs. 3 and 6, the chromatin mass is, as in the great majority of cases, left in an excentric position. Occasionally, however, it may be found in a perfectly central position with a clear uniform zone of karyolymph completely surrounding it.

Whether the chromatin mass is left in an excentric or a central position is a matter of no consequence. Both effects are brought about, not by the shrinkage or contraction of the chromatin mass—as has been so frequently stated by other writers (Farmer, 1905; Davis, 1909; Grégoire, 1910; Digby, 1910; Overton, 1909; and others), but by the enlargement of the nuclear vacuole and the withdrawal of the nuclear membrane from the chromatin mass. This may be easily demonstrated beyond any question—especially in those early stages before the chromatin mass has lost its spherical form—by actual measurements, or by making one camera drawing upon another on the same paper. In the later stages, represented in figs. 3 and 6, this is not so easily demonstrated, because as the nuclear volume enlarges, the chromatin mass gradually loses its spherical form and becomes very irregular in outline and unsymmetrical, and it is impossible to obtain a perfectly median section of an unsymmetrical mass whose irregular form extends in several planes. In sections of such stages the chromatin mass may appear slightly smaller in its sectional area, and this should not be interpreted as indicating a diminution in the chromatin volume.

From the conditions shown in figs. 2, 3, and 6, it seems evident that the rate of increase in the amount of karyolymph within the nuclear cavity is greater than the rate of shortening and thickening of the chromatin threads. The one is obviously much more rapid than the other. This inequality of rate results in a withdrawal of the nuclear membrane from the chromatin mass and not a withdrawal of the chromatin mass from the membrane—as interpreted by many writers and recently insisted upon by DAVIS (1911). It also results in the maximum size of the nuclear vacuole having been reached before the spireme threads have been fully developed. As shown in figs. 3, 6, and 7, there appears a large clear space, filled with nuclear sap, beyond the limits of the chromatin area. The characteristic lateral position of the chromatin mass during the growth period has already been explained and accounted for in a previous paper (LAWSON, 1911A), and I am still of the opinion therein expressed.

I have elsewhere expressed the view (LAWSON, 1911A) that high osmotic tension explains the fairly sudden expansion of the nuclear cavity and is responsible for this meiotic growth period. Professor FARMER (1912) has expressed the opinion that this view is probably correct. No opinion, however, has been expressed as to the reasons for this sudden change in the osmotic relations. In this connection it may perhaps prove to be a fact of some significance, that the accumulation of the nuclear sap is always accompanied by a change in the form of the chromatin. If we compare figs. 1, 2, 3, and 6, it becomes perfectly evident that as the nuclear vacuole becomes larger and larger, the chromatin threads become more sharply defined, shorter and thicker. In other words, it would seem that as the chromatin substance becomes less finely divided, endosmosis proceeds. Although there is, as pointed out above, a difference in the rate of these changes, one is very much tempted to see here a correlation between the chromatin (an osmotically active substance), which is undergoing a change to a more condensed form, and the varying osmotic relations expressed in the increased amount of karyolymph.

I am still of the opinion that no real contraction—as ordinarily understood by the term synapsis—occurs during the meiotic growth period. In the case under observation there was no appreciable diminution in the cubical space through which the chromatin is distributed.* I do not maintain, however, that this is true for all cases.

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* FARMER (1912). In this connection Professor FARMER makes the following statement: "A critical study of his own figures convincingly proves that, even in the object selected by Dr LAWSON himself, a contraction of the chromatin-containing mass clearly occurs during synapsis. This is shown by a method of tracing, and also by calculation based on the diameters actually figured. Thus, as nearly as could be measured, the diameters of the mass taken as a sphere, shown figs. 1, 7, and 13, are respectively 24, 22, and 20 mm. The *volume* of the respective spheres occupied by the chromatin works out at 7238, 5575, and 4190 cub. mm. That is to say, a shrinkage occurs of about 43 per cent., as between the presynaptic stage of fig. 1, and the synaptic stage of fig. 13."

To those who have not had an opportunity of reading my paper on "The Phase of the Nucleus known as Synapsis," such a criticism will no doubt appear to be very damaging; but to those who have made a critical study of the text

I have met with some evidence that a very slight diminution in the chromatin volume may occur, but I interpret this in the same way that DAVIS (1911) has recently done; *i.e.* it is entirely due to the shortening and thickening of the threads. But this diminution, which is a very slight one, I do not interpret in any sense as a "synaptic contraction" as generally understood by many writers (FARMER, 1905; GRÉGOIRE, 1910; OVERTON, 1909; DIGBY, 1910; and others), nor do I believe it to be a feature peculiar to meiosis. It occurs in all somatic divisions, for there is here also a shortening and thickening of the threads in the development of the somatic spiremes from the reticulum threads.

So that if we accept the interpretation of this so-called contraction, in so far as it exists, as expressed by DAVIS (1911)—and for my part I believe it is the correct one, namely, that it is due entirely to the shortening and thickening of the threads—we have here a feature which is common to both somatic and meiotic mitosis, and therefore can have no real significance in meiotic phenomena. It should no longer be considered as a feature peculiar to chromosome reduction. I may add that I am quite in agreement with this interpretation, and feel convinced that it will eventually find general acceptance.

In their recent criticisms of my paper (LAWSON, 1911A) both DAVIS (1911) and FARMER (1912) appear to assume that the real point of contention is one of diminution in the space occupied by the chromatin, when, as a matter of fact, this is of secondary importance. The real point of contention is whether or not there is any fusion, or intimate association of chromatin filaments during the period known as synapsis, and of what significance such a union bears to the real act of chromosome reduction. I have attempted to make it clear, therefore, that the only question of importance in this connection is not whether the shortening and thickening of the threads bring about a slight diminution in the chromatin volume—for it is generally agreed that the spireme threads do shorten and thicken,—but whether or not there is a co-mingling and fusion of the threads at this time. I have examined a great many preparations showing this phase of the nucleus, and it seems to me a matter of no significance whatever if the shorter and thicker spireme threads of the early spireme stage seem to fill a volume slightly under that occupied by the same threads in an earlier and more finely divided

as well as the figures of my paper, quite a different view of the case will present itself; for the following description of fig. 13 will be found on page 597: "As stated above, certain sections were passed over, because they were not cut in a median plane through the chromatin mass. In this connection it might be well to point out that when the nucleus reaches its full size, it may be 25μ or 30μ in its longest diameter; and cutting sections of an anther at this time, we invariably obtain numbers of sections of cells that do not pass through the median line of the nucleus. Some of these sections may show a very large nuclear cavity and a very small shaving of chromatin at one end. Such small areas of chromatin at first suggest a considerable contraction, and they were frequently found. This fact is mentioned here because I feel sure that some of the figures that have been published to show the synaptic contraction have been drawn from such oblique sections. Fig. 13 is inserted here to illustrate this point. It was drawn from a section that was not median."

I have made these quotations at length, because I believe this inadvertent overlook on the part of Professor FARMER will be very misleading to those who have not read the text of my paper carefully; while the paragraph itself is a complete reply to the criticism.

condition. Up to the present I have been unable to find any real evidence that will lend support to views of those who have described this phase as a "synaptic contraction," "synaptic knot," "a violent contraction," "the end result of fertilisation," "the critical stage in the life history." With such views as these I still find myself in disharmony. I am also still of the opinion that the enlargement of the nuclear vacuole and the resulting withdrawal of the nuclear membrane from the chromatin mass, which is left on one side, have in a large measure been responsible for the exaggerated idea of contraction * first expressed by MOORE in 1895 and developed since then by other writers. I do not quote these writers in any sense of criticism—I merely wish to show how an erroneous idea has grown out of all proportion to the facts revealed by close analytical observations. It would seem that errors of interpretation are inevitable in such highly complex and intricate problems, but I do not think that such errors are altogether without value; they stimulate research. I feel sure, however, that the term *synapsis* will gradually find its place as an historical relic with such terms as *centrosome*, *centrosphere*, *archoplasm*, and *kinoplasm*, terms which have been useful in their way, but which have ceased to be conspicuous features in recent cytological literature of the higher plants.

THE DEVELOPMENT OF THE SPIREMES.

At a very early stage of the prophase, even as early as that shown in figs. 1 and 2, there is convincing evidence of the double nature of the individual chromatin threads. In the stage represented in fig. 1, the threads are so very fine and cross one another so frequently, that one cannot be certain that each thread is double throughout its full length. The longitudinal fissure, however, appears at such frequent intervals along the threads, that there cannot be much doubt as to the early manifestation of the double nature. A careful study of these early stages has strengthened the inference drawn in a previous investigation (LAWSON, 1911), namely, that the reticulum represented in figs. 1 and 2 is made up of a number of chromatin threads which are double, and that this number corresponds to the diploid number of chromosomes which prevails throughout the soma of the sporophyte.

In fig. 2 is represented a slightly older stage, where the threads are undoubtedly thicker and probably shorter. This condition is a transition between the so-called reticulum and the spireme. The double nature of the threads may be observed a little more clearly than that shown in fig. 1.

A still later condition is shown in fig. 3. Here it may be seen that the spireme is fairly well developed. The individual threads may be easily followed for considerable distances. Those threads that project beyond the main chromatin mass show very clearly the two longitudinal halves of the threads lying parallel to one another. That

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* The extreme cases of contraction that have been so frequently described and figured are in my opinion due to unsatisfactory fixation. In this connection it should be noted that Professor SCHAFFNER (1909) has persistently upheld this view.

the threads have become shorter and thicker than in the previous stages is very obvious. This change is further indicated by the frequent appearance of the free ends of the double filaments throughout the chromatin mass.

This shortening and thickening* of the chromatin threads at this early stage proceeds with the increasing amount of karyolymph, but when the latter reaches its maximum there is a distinct tendency for the threads to spread out and become more uniformly distributed throughout the nuclear sap. This feature is brought out in figs. 6, 7, and 8. This spreading out of the filaments makes it possible to observe more clearly the nature of the longitudinal fissure. From these figures it will be seen that the fissure does not completely separate the halves of the thread, but takes the form of small lacunæ, which are much longer than broad, giving the filament a distinctly vacuolated appearance. Although these lacunæ may be of considerable length and separated from one another by short bridges of chromatin substance, they seem not to interfere with the fairly uniform thickness of the filaments. As shown in figs. 4 and 5, the two halves of the split filament lie almost perfectly parallel to one another. Fig. 4 represents a more highly magnified detail of the split thread in the stage shown in fig. 3, and fig. 5 is taken from the stage in fig. 6.

Just as figs. 2 and 3 represent transitions from the so-called reticulum to the spireme stage, so figs. 6 and 7 represent transitions from the spireme condition to condensed chromosomes. Both these changes appear to be nothing more than a progressive shortening and thickening of the chromatic filaments. And just as it was impossible to say when the reticulum stage ceased and the spireme commenced, so in the later stages it is impossible to make a sharp discrimination between the spiremes and chromosomes. Under these circumstances I think we may safely regard each individual chromatin thread throughout all of these stages as a definite chromosome in different conditions of condensation. As a result of a careful and detailed study of these reticulum and spireme stages, I find myself quite in agreement with Grégoire and other writers, who hold the view that, although the threads may appear vacuolated, granular, or even beaded, they are composed of one uniform material.

In fig. 7 we have represented a stage where the chromatin threads have shortened and thickened to such an extent that we may obtain a fair estimate of their number. This is made possible because the spiremes have separated from one another and are more evenly distributed through the karyolymph. It should be noted in passing that this shortening and thickening is of the same nature as that which occurs in the earlier stages of the growth period, but later, on account of the

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* The following extracts are taken from my paper on "The Phase of the Nucleus known as Synapsis": "We find the chromatin threads slightly thicker and evidently granular, and the interstices between them larger and more clear. This would suggest a shortening and thickening but not a contraction." Then again: "During this process of loosening and spreading out of the chromatin into the clear area of the nuclear cavity the threads continue their process of shortening and thickening."

It is interesting to compare these statements with a more recent extract from Davis' (1911) paper: "There is no question in the writer's mind but that the events of synapsis are the result of a true contraction, *i.e.* a shortening and thickening of the strands or threads of the chromatic reticulum."

shortness of the threads, they seem to have more freedom to move and separate from one another. So that the cubical space now occupied by the chromatin (fig. 7), instead of having decreased, has considerably increased. This continues, as shown in figs. 8, 9, and 10, until the spaces between the spiremes are fairly equalised and the chromatin area completely fills the nuclear vacuole.

We might regard fig. 7 as a stage representing the close of the growth period, *i.e.* when there appears to be no further increase in the amount of nuclear sap. The nuclear vacuole has reached its maximum size. A close study of the chromatin up to this time (from figs. 1 to 7) failed to reveal any real evidence in support of the view held by some cytologists that the chromatin consists of a continuous spireme thread. I was unable to find any indication that the chromatin filament "segmented transversely so as to form definitive chromosomes."* My present observations in every way confirm the opinion expressed elsewhere (LAWSON, 1911) that the chromatin thread—in *Smilacina*—never forms a continuous spireme, but that there are as many spiremes as there are chromosomes. In this connection I am quite in agreement with the conclusions of STOMPS (1910) in his work on reduction in *Spinacea*. I can also confirm this author's observations that the free ends of the chromatin threads may be distinguished as far back as the reticulum stage represented in fig. 2.

When the spiremes have become distributed throughout the nuclear cavity, the individual threads may be studied to better advantage in sections that have not been cut in a median plane through the nucleus. Such sections are shown in figs. 8, 9, 10, and 14. From these figures it will be seen that although the spiremes are now comparatively very much condensed, they are still of great length. Their double nature may be easily seen. If we follow the series of stages back, it will become perfectly evident that this double nature is not due to the lateral fusion of filaments during the growth period, but is due to the same longitudinal fission described for the earlier stages and represented in figs. 1, 2, 3, 4, and 5. More highly magnified details of the longitudinal fission in older spiremes are shown in figs. 11, 12, and 13. Here it will be seen that the fission by no means completely separates the two longitudinal halves, for the latter are in frequent contact (figs. 11 and 13).

The beaded nature of the spireme is very noticeable in the stages represented in figs. 8, 9, and 10. The disks or short segments which give this beaded appearance are no doubt the structures described as chromomeres by ALLEN (1905). This feature has been noted by several other writers, and I have observed it in many plants. It seems to be of fairly general occurrence, but up to the present no facts have been revealed to indicate the significance, if any, these chromomeres have in the mitotic process. In the material under observation it was quite clear that this feature was not of long duration. It gradually fades out as shown in figs. 14 and 15, and in fig. 16 no trace of the chromomeres could be distinguished.

In fig. 15 we have represented a section that has been cut in a median plane—

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* FARMER, J. B. (1905).

or nearly so—through the nucleus. It reveals some features of considerable importance. First, it will be noted that as the development of the chromosomes proceeds, by the condensation of the chromatin composing the spiremes, the longitudinal fission becomes less evident and is only made out with difficulty. Second, it should be noticed from this figure (15) that the number of spiremes is large—that the real act of reduction has not yet occurred. It shows that throughout the entire period between the stage represented in fig. 1 and the stage represented in fig. 15, we have had the diploid number of chromatin threads. The important thing that has occurred during this period is not the fusion or blending of filaments, or the interchange of chromatin substance or influence between them, but the actual longitudinal fission of somatic chromosomes, which becomes evident at a very early period. Longitudinal fission has been observed so frequently and in so many types of plants, that there is now no room for doubt as to its general occurrence in the spiremes of all somatic mitoses. I am quite convinced that this longitudinal fission in the early meiotic prophase corresponds to the longitudinal fission which occurs in ordinary somatic divisions. This view has also been expressed by GATES (1911) and one or two other writers. If this interpretation is the correct one, then we have, up to the stage represented in fig. 15, what are really the preliminary stages of an ordinary somatic mitosis. If the two longitudinal halves of each chromosome were allowed to separate from one another and pass to opposite ends of the cell, an ordinary somatic division would result with the diploid number of chromosomes. This, however, in the meiotic prophase is prevented by a series of events which bring about the haploid condition.

Before going into a description of the details of these events, I would call attention to an important physiological aspect of the cells in which the meiotic phenomena occur. I have already mentioned the fact in another paper (LAWSON, 1911) that these mother cells—in which this peculiar form of nuclear activity occurs—are really temporary storage cells. A mere superficial examination will suffice to convince anyone that "storage cells" is the correct designation for these structures. In the first place, the presence of large quantities of dense granular food substances suspended in the cytoplasm points to this conclusion. The cytoplasm is so charged with food substances, that vacuoles as we ordinarily have them in vegetative cells are not present. Another feature which characterises these cells and leaves no room for doubt as to their storage function, is to be seen in the thickness of the cell walls. The gradual thickening of the cell wall may be easily followed in the series of stages here figured. For instance, in figs. 8 to 25 and from 28 to 43 the thickening of the wall progresses with other activities until, as shown in figs. 41, 42, and 43, it becomes enormously thick. There is no doubt in my mind that these thick walls are used as reserve food. The wall becomes completely dissolved after the second meiotic division, and is no doubt absorbed by the developing microspores (figs. 43, 44, 55, 57, 58).*

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* SACHS, J. (1875), *Text-Book of Botany* (English translation. Clarendon Press, Oxford), p. 485.

I mention these facts because I believe they have a direct bearing on the series of events associated with meiosis. It is a fact of common knowledge that one of the main results of nutrition is the production of new cells, and wherever we have merismatic activity, *i.e.* active nuclear divisions, a high state of nutrition prevails. Here, in these spore mother cells, we have not only a high state of nutrition—the cells themselves being temporary storage organs,—but also merismatic activity. I know of no other phase in the life history where this peculiar double function persists. I do not mean to imply by this that all storage cells should become merismatic because of their high state of nutrition, but I think it safe to imply that all merismatic cells—to be actively merismatic—should be well nourished. Now the archesporium is without doubt a meristem, and the point I wish to emphasise in this connection is that we have here in these cells a much higher state of nutrition than prevails in the cells of ordinary somatic meristems. This important physiological aspect of meiosis has, in my opinion, not received the attention it deserves. I consider it highly suggestive of at least a partial explanation of meiotic phenomena. I shall, however, refer to this aspect of the problem under the head of theoretical considerations after we have examined the changes which occur in the chromatin and which accomplish the real act of reduction.

The Bivalent Chromosomes.

As already pointed out, when the stage represented in fig. 15 has been reached, the spireme threads have lost much of their beaded appearance and the longitudinal fission is much less evident. The two longitudinal halves (somatic daughter chromosomes) appear to lie very much closer to one another. These changes in the granular nature of the threads and the approximation of the two longitudinal halves may easily be accounted for by the condensation of the chromatin substance as the threads continue to shorten and thicken. This condition (fig. 15) closes a period which in all essentials compares with the early prophase of an ordinary somatic mitosis, and what follows it marks the beginning of the real act of reduction.

As the longitudinal fission becomes less evident, as shown in fig. 16, there takes place an approximation of the spiremes in pairs. The lateral pairing of the chromosomes, which are still of great length, is clearly shown in figs. 16, 17, and 18. The uniting spiremes, which are comparable to split somatic chromosomes, first come to lie parallel to one another, as shown in fig. 17, and as they become shorter and thicker the union becomes a close and intimate one, as shown in figs. 18 and 19. That the union here is a lateral one and not end to end is perfectly obvious. There appears to be some difference of opinion as to whether the pairing of chromosomes is brought about parasynaptically or telosynaptically. But the observations of Rosenberg (1909), Grégoire (1910), Yamanouchi (1908), Miyake (1905), and others, put it beyond much doubt that the parasynaptic is of much more general occurrence than the telosynaptic method. On this question, however, I am quite in agreement with those who (Digby, 1910; Gates, 1911; and others) attribute little importance to this matter, for, as we shall see later, the union here is a temporary one. Up to the time of this lateral pairing of the spiremes (fig. 15), as I have already suggested, I have been unable to recognise any fundamental difference from the series of changes which occur in the early stages of an ordinary somatic mitosis. I do not regard the enlargement of the nuclear cavity as in any sense a fundamental difference, for, as I have elsewhere stated, this feature may be rationally accounted for on the basis of the high state of nutrition which prevails in these cells. This same feature, to some extent at least, is a character of ordinary storage cells, which are likewise under a high state of nutrition but which are not merismatic. The slight diminution in the volume occupied by the chromatin which may occur in the early stages cannot be claimed as a fundamental difference, for this is undoubtedly entirely due to the shortening and thickening of the chromatin threads, a feature which is common to all somatic mitoses. After this stage (fig. 15), however, the changes that occur are no longer comparable to the somatic prophase, for the early pairing of the spiremes prevents the separation of the daughter halves of the somatic chromosomes and results in the organisation of the bivalent chromosomes.

As to the manner in which the bivalent chromosomes are developed, it should be noted that FARMER (1905) in his work on *Lilium* and *Osmunda* describes this as resulting from the approximation of sides of loops of serially distinct regions of the spireme as a whole—that with the looping of the chromatin filament and the approximation of the sides of the loop, the spireme segments transversely leaving the two halves of the loop as the bivalent chromosome. A similar process has more recently been described for *Galtonia* by DIGBY (1910). I have made careful search for like conditions in the material under present investigation, namely, *Smilacina*, *Kniphofia*, and *Aloe*. In none of these plants have I been able to find any evidence in support of the views of these writers. It should be remembered that the interpretations of FARMER (1905) and his pupil are based on the assumption that the chromatin consists of one continuous spireme which segments transversely so as to form definitive chromosomes. The recent work of STOMPS (1910) has, I think, established it beyond much doubt that in *Spinacia*, at least, the chromosomes are never arranged in a continuous spireme. I shall attempt to prove that this is also true for *Smilacina*, *Kniphofia*, and *Aloe*. Let us examine the prophase of these plants in turn, taking *Smilacina* first. In the reticulum stages the difficulties of identifying the individual spiremes are of course quite obvious. Our conclusion from these very early stages are based upon the number of free ends that may be distinguished—and here we cannot be certain that these ends are not sometimes due to sectioning. A little later, however, when we have transition stages from the reticulum to the spireme conditions, and at the close of the growth period, a large number of independent spiremes may be distinguished with comparative ease. In the consecutive series of stages represented in figs. 6, 7, 8, 9, and 10, the number of free independent chromatic filaments that are clearly observable is sufficiently convincing that in no stage of the prophase in *Smilacina* is there one continuous spireme. This becomes even more convincing as the threads become more condensed. That all of the free ends observable in figs. 13, 14, and 15 are due to the cutting of a continuous coiled spireme by the microtome knife, cannot be maintained, for, as shown in fig. 15, the ends occur with great frequency in positions that are not at the surface of the sections. It should also be mentioned that throughout this entire series no feature that would even suggest a transverse segmentation was found. If further evidence were needed to show that the looping method of FARMER (1905) and DIGBY (1910) is not a feature of the prophase of *Smilacina,* it may be found in the series of later stages represented in figs. 17, 18, and 19. Here the free ends of the uniting chromosomes are clearly visible. The still later stages shown in figs. 20, 21, 22, 23, and 24 demonstrate how the pairing chromosomes coil and twist very tightly about one another as they become more condensed and shorter.

In *Kniphofia* I was fortunate in securing a beautiful series of prophase stages, which confirm in all essentials the description given above of the manner in which the bivalent chromosomes are developed in *Smilacina.* In fig. 45, for instance, we have represented a stage soon after the close of the growth period. A number of free independent spiremes may be seen quite easily, and each one shows evidence of a longitudinal fissure. Fig. 46 represents a slightly older condition, where the spiremes are thicker and the longitudinal fission is less evident. In figs. 47, 48, and 49 it may be observed how the pairing and conjugation of the spiremes (somatic chromosomes) actually occur. It will be noticed that the ends of the two chromosomes, about to unite, come together first. This feature should not be mistaken for a looping or for a telosynaptic union. As shown in figs. 48 and 49, the union is clearly a lateral one, resulting in a coiling and twisting of the two chromosomes about one another, in exactly the fashion described above for *Smilacina.*

In *Aloe* the very same conditions seem to prevail. Fig. 50 is drawn from a section taken at a time soon after the close of the meiotic growth period. It corresponds to the stage represented in fig. 15 of the *Smilacina* series and fig. 45 of the *Kniphofia* series. As in these other two plants, the conditions here show a number of independent spiremes each with a longitudinal fissure. The free ends of the chromatin threads may be seen without the slightest difficulty. The manner of their approximation and lateral conjugation in pairs is illustrated in figs. 51 and 52. Fig. 51 is interesting, because if the preceding stages had not been examined it might be mistaken for a looping. A close examination, however, will convince the observer that this effect is produced by the approximation of the ends of two chromosomes before the sides have come in contact—and not to the bending of a single filament. The characteristic coiling and twisting of the pairing chromosomes about one another is indicated in fig. 52. The resulting bivalent chromosomes continue to condense and shorten until the time of spindle formation.

These observations on the meiotic prophase of *Smilacina*, *Kniphofia*, and *Aloe*, convince me beyond question that the chromatin never consists of one continuous spireme. All the facts revealed point to the conclusion that there are as many spiremes as there are chromosomes. It naturally follows that the looping method of reduction cannot occur in these plants.

Returning now to the *Smilacina* series, we must take note of certain other features of the bivalent chromosomes. In the early stages of the prophase, before the spiremes have united in pairs, the great length of the chromatic filaments renders it impossible to obtain an exact count of the threads present. The spiremes, however, are sufficiently independent of one another to allow of a rough estimate. Repeated counts of this nature make it quite certain that the number is a large one. The number, for instance, in the stage shown in fig. 15 is much greater than that in fig. 24. As soon, however, as the larger number has been reduced by half as a result of the pairing, and this being followed by a marked condensation, the number of bivalent chromosomes may be estimated with a fair degree of accuracy. Numerous counts were made from sections like that shown in fig. 24, which is almost median. The highest number found was fourteen, and this was so frequently found both at this time and later (fig. 33), that this is probably the characteristic haploid number* for the species.

Another feature of importance to note in connection with the chromosomes is their difference in size. In the spireme stage, before reduction occurs, the difference in the length of the chromatic filaments is not very noticeable. The threads are of great length even up to the time of pairing. Moreover they stretch out in various planes, so that, although one may be safe in assuming that the threads are not all of the same length, this cannot be convincingly demonstrated. After pairing, however, and when the shortening and thickening of the bivalent structures has gone on for some time, the heteromorphic nature of the chromosomes becomes very evident. In figs. 20, 21, 22, and 24, clear instances of long and short chromosomes are shown. This is even more striking in a polar view of the equatorial plate later on (fig. 33). As indicated in this figure, there are at least three distinct sizes of chromosomes. Of the fourteen bivalent chromosomes here shown, one is distinctly larger than the others, six are quite small, and the remainder are about half way between these two extremes in regard to their size. Perhaps the most significant feature in this connection is the evidence which shows quite clearly that the chromosomes which conjugate with one another in the act of reduction are of the same length, that is, short ones unite with short ones and long ones with long ones. Instances of this are demonstrated in figs. 20, 21, 22, 23, and 24.

Another feature that appeared to be very constant, and one that has been noted by several other writers, is to be seen in fig. 24. When the bivalent chromosomes are completely organised, they distribute themselves at the extreme periphery of the nuclear vacuole, the majority of them being in close touch with the nuclear membrane.

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* In an earlier investigation on this plant, the shorter chromosomes were mistaken for portions of the arms of the V-shaped structures. This led to an error in the count.

THE ACHROMATIC FIGURE.

The amount of karyolymph taken into the nucleus during the meiotic growth period, seems to remain fairly constant up to the stage when the first indications of spindle formation become visible. A careful study of the nuclear vacuole during this period was made, and it was found, after many measurements and calculations, that the nuclear vacuole at the stage shown in fig. 24 was more than half the cubical volume of the cytoplasm.* Up to this stage there has been no trace of the achromatic figure. The nucleus is undoubtedly the most conspicuous part of the cell—the granular cytoplasm occupying a narrow zone about it.

Immediately following this staeg, a very noticeable decrease in the nuclear volume takes place. From the conditions shown in fig. 25 it may be clearly seen that the amount of karyolymph present is very much less than that in the earlier stage shown in fig. 24. It may also be clearly seen that as the nuclear volume decreases, the volume occupied by the cytoplasm apparently increases. The cytoplasmic zone is distinctly wider, but its structure is not uniform throughout. That region of the cytoplasm immediately surrounding the decreasing nucleus becomes converted into a weft of fine delicate threads which appear at places to radiate out for some distance from the nuclear membrane. A much more evident decrease in the nuclear volume is shown in fig. 28. The volume here is considerably less than half that shown in fig. 24. Here also the transformation that occurs in the cytoplasm becomes more evident. The fine threads are more numerous and more sharply defined. They appear as tufts or sheaves which attenuate as they extend towards the periphery. We have here what has been commonly called the multipolar figure, and which has been described † for so many of the vascular plants.

Fig. 25 represents the close of the prophase, where the nuclear membrane is reported by other writers to break down and disappear. In another work (LAWSON, 1911B) I have shown that this does not occur in *Disporum*, *Gladiolus*, *Yucca*, and *Hedera*. That there is likewise no collapse of the nuclear membrane in *Smilacina* is, I think, convincingly demonstrated in the series of stages represented in figs. 24, 25, 28, and 29. There is no doubt whatever in my mind that, in well-fixed material, the persistence of the nuclear membrane may be demonstrated throughout all of these stages. The karyolymph, as such, does gradually disappear. It diffuses into the cytoplasm, and I am quite convinced that the plasmatic membrane enclosing the karyolymph is functional throughout this osmotic transfer. As to the persistence and function of the nuclear membrane in this connection, the present investigation on *Smilacina* confirms in every way the conclusions arrived at in the work mentioned above (LAWSON, 1911B).

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* I should here correct a slight error in my previous paper (LAWSON, 1911B). In the latter I occasionally used the term *cell volume* when the *cytoplasmic volume* was really intended. All calculations made in this connection were based on the comparison of *cytoplasm* to *nucleus* as to cubical volume.

† STRASBURGER (1895, 1905, 1907), FARMER (1895, 1905, 1910), JUEL (1897), SARGANT (1897), OSTERHOUT (1897), SMITH (1900), MOTTIER (1897, 1898, 1907), MIYAKE (1905), ALLEN (1903, 1905), OVERTON (1905, 1909), GRÉGOIRE (1903, 1910), DAVIS (1899, 1909), BERGHS (1904, 1905), LAWSON (1898, 1900, 1903).

There is no doubt in my mind that these stages (figs. 25, 28, 29, and 30) represent normal changes taking place in the living cell—changes that precede the separation of the halves of bivalent chromosomes. It seems to me that the only explanation that will rationally account for the diminishing nuclear fluid is that based on osmotic diffusion—that the karyolymph has exosmosed into the cytoplasm by means of the plasmatic membrane,* and that the latter is functional in this way until the diffusion of the karyolymph is complete and the membrane in question envelops the chromosomes. Throughout these changes it should be noticed (figs. 25, 28, 29, and 30) that as the nuclear vacuole becomes smaller and smaller the differentiated threads of cytoplasm become more numerous, longer, and more sharply defined.

If we compare the conditions represented in figs. 29 and 30 with those represented in fig. 24, it becomes perfectly obvious that a change has taken place in the relative positions of the nuclear and cytoplasmic substances; that in this readjustment the cytoplasm comes to occupy a cubical space that is half as great again as that which it previously occupied. It seems very improbable that such great changes as these could take place without in some way affecting the configuration of the cytoplasm. It seems even more improbable that the large nuclear vacuole—as, for instance, that in fig. 24—should diminish and finally vanish without generating a state of tension in the cytoplasm. From a study of this and other types it was invariably found that the form of the cytoplasm is effected by these changes, and that a state of tension is set up by reason of the cytoplasm being obliged to occupy a greatly increased cubical space. This manifests itself by a marked change in the configuration of the cytoplasmic reticulum, which takes the form of drawn-out threads or fibrils—drawn out from the reticulum by the receding nuclear membrane. There is not much doubt in my mind that if the changes occurring in the living cell could be accurately followed, this explanation for the origin and formation of the spindle fibrils would prove to be the correct one. As it is, I consider it the most rational explanation that has yet been offered from interpretations of fixed material. I therefore find myself unable to accept the view so often expressed that the achromatic figure (or "kinoplasm") takes an *active* part in mitosis. I believe these fibrils merely express a state of tension which is caused in the first place by nuclear osmotic changes.

If we now examine fig. 29, we find the karyolymph has been almost completely diffused into the cytoplasm, and as a result the nuclear membrane closes in about the bivalent chromosomes which are now crowded closely together. In the stage shown in fig. 30 there is still less karyolymph present, and the nuclear membrane is no longer

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* FARMER (1912). In his recent article on "Nuclear Osmosis and its Assumed Relation to Nuclear Division," Professor FARMER accuses me of using the word *permeable* instead of the word *semi-permeable*. He states: "The author *continually* calls it a *permeable* membrane." Such a statement as this is not quite in accordance with the facts, and is very misleading. The term that I have *continually* used throughout the paper is a *permeable plasmatic membrane*. I have used this term advisedly, knowing full well that most cytologists believed that the *plasmatic* membranes of the cell were semi-permeable. I prefer to continue the use of the term *plasmatic membrane* in this connection and in the sense generally understood by cytologists.

observable, as it is now in close contact with the majority of the chromosomes. Although the membrane cannot now be traced and observed as a definite object—being a mere differentiated plasmatic film of unmeasurable thickness,—I think the events that follow justify the assumption that it completely envelops each bivalent chromosome, for these latter bodies are no doubt still saturated with nuclear sap. But the main point of interest here is not so much the actual demonstration of the plasmatic membrane closely applied to the saturated chromosomes, but the drawing in, with the membrane, of the cytoplasmic fibrils until they reach the chromosomes. This I consider to be clearly demonstrated in figs. 29, 30, and 31. As I have already stated in another work (LAWSON, 1911B), this offers a much more rational explanation for the attachment of the spindle fibrils to the chromosomes than the generally accepted view that the spindle fibrils push into the nuclear cavity and attach themselves with their free ends to the individual chromosomes.

If, as I have attempted to demonstrate above, the cytoplasmic fibrils which eventually form the achromatic spindle are expressions of lines of tension, then it follows that the positions of these lines would shift as the nuclear membrane receded, and later, as this membrane envelops the bivalent chromosomes, each of these structures becomes furnished with a system of fibrils. The conical-shaped sheaves of fibrils which constitute the multipolar figure have frequently been described as approaching one another and coalescing in two groups to form the bipolar figure. The difficulties here are obvious, and the facts available do not sustain this idea. The cytoplasmic reticulum seems not to be disturbed in the slightest degree by such a coalescence. No real evidence has been recorded to show that a lateral movement and fusion of the cones really occurs. On the other hand, if we accept the more rational interpretation that the fibrils are drawn-out threads of cytoplasm and merely represent lines of tension, the difficulties of understanding their movements and apparent shifting of position become very much lessened. For, as I have pointed out elsewhere (LAWSON, 1911B), the apparent change in position is due to the relaxing of the tension along certain lines and the establishment of new tensions along others. In other words, while the lines of tension do shift, the fibrils themselves do not. These latter withdraw or reappear according to the shifting of the position of the nuclear membrane —the latter being a continuation of the same plasmatic substance. The manner in which this shifting results eventually in the bipolar arrangement has been fully described in my last paper (LAWSON, 1911B), and a further repetition is unnecessary. I shall only add that the main conclusion there stated has been fully sustained by the present investigation.

It seems evident, then, that the results produced by nuclear osmotic changes offer a fair and rational explanation of three very important phases of mitosis. First, the origin and formation of the fibrils which constitute the achromatic figure. Second, the attachment of the fibrils to the chromosomes. And third, the movements associated with the resolution of the multipolar figure into a bipolar arrangement. In these three phases [*] alone I consider the facts revealed sufficient to establish nuclear osmosis as a great and potent factor in mitotic phenomena.

THE METAPHASE.

As the nuclear membrane continues to recede, it becomes closely applied to the surface of the bivalent chromosomes, and each of these bodies is thus furnished with its own system of cytoplasmic fibrils. In another paper (LAWSON, 1911B) I have suggested how it is possible for this shifting of the lines of tension to result in the suspension of the chromosomes at the equator. I expressed it as my opinion that the osmotic surfaces, *i.e.* the plasmatic membranes enveloping each chromosome, are determining factors in the suspension of these bodies between two sets of fibril sheaves, and hence the formation of the equatorial plate. No new facts have been revealed in the present investigation to cause me to alter that opinion.

There is no doubt in my mind that the fibrils composing the mature achromatic figure represented in fig. 31 have the same origin and structure as those of the earlier stages shown in figs. 30, 29, 28, and 25. If we now compare fig. 24 with fig. 31, the conclusion is irresistible, that the mature achromatic spindle of the metaphase is an expression of a state of tension due to the closing in of the large nuclear vacuole of the prophase shown in fig. 24.

The main point of interest in the metaphase is the separation of univalent halves of the bivalent chromosomes and the movement of these halves (somatic chromosomes) in opposite directions. As shown in figs. 31 and 32, this separation is initiated by a lateral movement of the bivalent chromosomes, these structures spreading out in a plane parallel with the equator of the spindle. In fig. 33 a polar view of the equatorial plate is represented. From this and the preceding figures it will clearly be seen that the bivalent chromosomes are heteromorphic and take the form of double V's. It will also be seen that the separation of the univalent halves (somatic chromosomes) commences not at the arms but at the bend of the V. A later stage in this separation is shown in fig. 34, where the chromosomes are represented on their way to the poles. The condition shown in fig. 36 is interesting, because it convincingly proves that the movement of the chromosomes is not to the poles themselves but in that general direction. It also shows quite clearly that the contraction of the fibrils plays no active rôle in this movement, for it may be clearly seen that many of the chromosomes pass beyond the region of the poles. This figure does not represent an isolated case; many sections just like it were observed.

In regard to this movement of the chromosomes to opposite sides of the cell, I can offer no positive explanation. From what we know of these chromatin bodies it would seem that there are times when they are attracted to one another; for instance, at the

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[*] In his recent review of my last paper Professor FARMER (1912) does not refer to either of these three important phases of mitosis. The discovery of the stages showing the persistence of the nuclear membrane throughout the prophase was also passed over without mention by the reviewer.

anaphase, where they become massed together, or during the act of reduction, when they unite in pairs. There are other times when they seem to be repelled from one another, as, for instance, at the close of the prophase, as shown in fig. 24, or in the present case, when they move to opposite sides of the cell. Here the idea of electrical conditions suggests itself as a plausible explanation. Without underestimating the value of this idea, the evidence in support of it is as yet not of a highly convincing nature. That electrical energy is generated in the cell is no doubt quite true, and it would seem not improbable that it plays a rôle in the attraction and repulsion of the chromosomes. But the idea of chemotactic conditions should not be overlooked in this matter.

THE ANAPHASE.

The two groups of chromosomes are now at opposite ends of the cell, with numerous drawn-out threads of cytoplasm stretching between them. There is no doubt in my mind that these threads represent the same state of tension expressed in the achromatic figure of the later prophase and metaphase. The lines of tension have merely shifted with the movement of the chromosomes. As shown in figs. 37 and 38, the individual chromosomes of each group become closely massed together. It may be worthy of note that the union here is a close and intimate one, as may be seen in fig. 38. There now begins an accumulation of karyolymph within the chromosomes. This appears first as minute lacunæ, which become larger and give the chromosomes a vacuolated appearance. In *Aloe*, where the chromosomes are much larger than those in *Smilacina*, the vacuolation and the accumulation of karyolymph could be followed with great clearness. The progressive steps in this process were so exceptionally evident in *Aloe*, that I have thought it worth while to illustrate them in figs. 53, 54, 55, 56, and 57. These figures, along with that of fig. 39, convincingly prove that throughout the three changes the general contour of the individual chromosomes is never lost. The accumulation of the karyolymph is fairly rapid, and it soon extends beyond the chromosomes and comes in contact with the cytoplasm. The formation of a membrane about each daughter nucleus, as a result of this contact, is shown in figs. 39, 56, and 57 (LAWSON, 1904).

As the daughter nuclei continue to increase in size, the cytoplasmic fibrils stretching between them become curved, as if the tension were being relaxed. This is indicated in fig. 39. This curvation of the fibrils continues until the combined volumes of the daughter nuclei approximate that of the mother nucleus (fig. 24), when the tension becomes completely relaxed and the fibrils are no longer visible as such. In the meantime a thin cell wall is laid down midway between the nuclei, as shown in fig. 40.

THE SECOND MEIOTIC DIVISION.

In order to avoid repetition of unessential details, I shall not attempt to follow through the second meiotic division as closely as I have done the first. I shall merely call attention to one or two features which I consider of prime importance as characterising this peculiar form of merismatic activity.

In the first place, I would again mention the high state of nutrition that prevails before and during this second division. An examination of the stages represented in figs. 41 and 42 make it perfectly plain that an exceptionally large quantity of reserve food is stored in these cells. This is evident not only in the cytoplasm, which is very dense and granular and devoid of vacuoles, but also in the enormous thickness of the cell-walls (figs. 41 and 42). This latter becomes absorbed by the developing microspores before they separate from one another (figs. 43, 44, and 58).

I believe this high state of nutrition has a direct bearing on another important feature of meiosis—namely, that there appears to be little or no pause between the first and second meiotic divisions. The merismatic activity here shown is obviously not of the ordinary kind. It manifests itself by two nuclear divisions that follow one another very rapidly. I believe it may well be considered an accelerated form of mitosis—the acceleration being due to the high state of nutrition.

Other points of importance to be noted in this connection are the changes that occur in the chromatin in preparation for the second division. This division has been regarded as a somatic division, and I do not doubt the accuracy of that interpretation. Not enough attention has been given, however, to one striking feature that distinguishes it at once from an ordinary somatic mitosis. A study of the stages represented in figs. 39 and 40 and also figs. 55, 56, and 57, will prove quite clearly that the chromosomes become alveolised to a high degree. After this they extend out and appear as long thick spiremes (fig. 40); but the point of interest is that they never become so finely divided as in ordinary somatic mitoses, where we always find a finely divided reticulum stage. I have never been able to find a reticulum stage between the first and second meiotic divisions. Back in the very early prophase of the first division, as shown in fig. 1, we always find the chromatin in the finely divided condition forming a definite reticulum. That condition does not occur again until after the second division, when the microspores are formed as shown in figs. 44 and 58.

I attach considerable significance to this fact because I believe it is further evidence in support of the view, already expressed, that we have here in meiosis an accelerated form of merismatic activity.

Theoretical Considerations.

As ordinarily practised, cytology concerns itself with the interpretation of artifact. It is a makeshift substitute for the interpretation of changes, physical and chemical, which are believed to occur, but which cannot be satisfactorily observed in the living cell under present methods. With the methods at our disposal, it is impossible to interpret the minute structure, configuration, and changes that characterise the protoplasmic bodies of a living cell with any degree of exactness. We are dependent upon methods which, at most, can yield but approximate results. The underlying principle of these methods is the conversion of the living substance into a non-living artificial precipitate without essentially modifying its general form and configuration. The knowledge we now have of the minute structure of the cell and its organs has been based almost entirely upon the interpretation of such precipitates.

I have had this in mind throughout the present investigation, and I have endeavoured whenever possible to express my interpretations in terms of the *living* cell. Helpful as this has been in elucidating many obscure points, I nevertheless fully realise that any theories or hypotheses, based upon a study of such precipitates, must at most be tentative. They should be freely subjected to modification or even abandonment whenever more certain and exact information becomes available.

It seems very evident, from this investigation, that there are two physiological features which stand out above all others, as fundamentally important in the merismatic activities concerned. One of these is osmosis, and the other is the high state of nutrition that prevails.

These two features are, to a certain degree, related to one another, but the effects they produce are quite distinct. For instance, nuclear osmotic changes are responsible for the formation of the achromatic figure, while the high state of nutrition that prevails is concerned in the acceleration of the mitotic changes.

All that series of changes in the cytoplasm which characterise the prophase, can, in my opinion, be interpreted in no other way than that of nuclear osmotic transfer. The great changes that occur in the relative positions of the nuclear and cytoplasmic substances seem reasonably explained on this basis. As a result of these changes, the cytoplasm is obliged to occupy a greatly increased space, and it is my opinion that this cannot be accomplished without a stretching or a tension being set up in the viscous structure of its reticulum. To me the evidence seems quite convincing that this tension or stretching finds an expression in the changed configuration of the cytoplasm to drawn-out threads or fibrils. The evidence was also overwhelming in support of the view expressed that the fibrils of the mature achromatic figure are such drawn-out threads of cytoplasm and merely represent lines of tension. The conclusion naturally follows that the achromatic figure plays no essential or active rôle in mitosis. It is simply an expression of a state of tension that is produced as a result of changes in the nuclear osmotic relations.

The high state of nutrition that prevails in the cells during meioses is a physiological condition which must be considered of prime importance in this connection. The effects it produces are quite different from those caused by nuclear osmotic changes, but nevertheless characterise the whole meiotic period. In somatic meristems a high state of nutrition no doubt exists, but in the meiotic meristem (spore mother-cells) the state of nutrition is very much higher. This difference—although it may be only one of degree and not of kind—is in my opinion sufficiently great to find an expression in the marked differences between somatic and meiotic nuclear phenomena. For instance, as everyone knows, the merismatic activity of meiosis shows itself by two divisions that follow one another very rapidly. All of the facts seem to point to the conclusion that we have here an accelerated form of merismatic activity, and this acceleration is due to the exceptionally high nutritive conditions that prevail.

There were certain features which suggested one other theoretical conclusion, namely, that reduction itself represents an accelerated form of merismatic activity. That the high state of nutrition generates a physiological condition where two mitoses are telescoped into one, as represented in the first meiotic division. These features will be described and discussed more fully in another paper which is now in preparation.

SUMMARY.

The conclusions from this investigation may be briefly summarised as follows :—

There was no evidence found to show that the chromatin ever consists of one continuous spireme in the plants studied. On the contrary, there was convincing evidence that throughout the prophase there were as many spireme threads as there were chromosomes.

Each spireme thread showed a longitudinal fission which appears at a very early stage. There was strong evidence to prove the presence of this fission as early as the reticulum stage.

No "synaptic contraction" in its generally accepted sense occurs in the plants investigated. The phase of the nucleus known as synapsis is really a growth period, during which there is a great enlargement of the nuclear cavity and a withdrawal of the nuclear membrane from the chromatin mass.

Any slight diminution in the volume occupied by the chromatin that may occur is due entirely to the shortening and thickening of the chromatic filaments.

The so-called synaptic contraction is therefore not a feature peculiar to meiosis. A similar shortening and thickening of the chromatin threads occurs in all somatic mitoses.

The spireme threads, which become very much shorter and thicker during the prophase, and persistently show a longitudinal fission, are in every way comparable to somatic chromosomes.

Up to the time of reduction, no fundamental difference could be recognised between the meiotic prophase and the ordinary somatic prophase.

Reduction is accomplished by the lateral pairing of somatic chromosomes.

As this union or pairing is a temporary one, it appears to be a matter of no significance as to whether the reduction is brought about by an end-to-end or lateral conjugation.

Soon after the bivalent chromosomes are organised, the karyolymph begins to exosmose into the cytoplasm, and from this stage on the nuclear vacuole diminishes in size.

The nuclear membrane persists throughout the prophase, and is functional during this period in the osmotic transfer of the nuclear fluid into the cytoplasm.

With the complete diffusion of the karyolymph the nuclear membrane becomes closely applied to and completely envelops each bivalent chromosome.

This change in the relative positions of the nuclear and cytoplasmic substances causes a tension to be set up in the cytoplasm, the latter being now obliged to occupy a greatly increased space.

As the nuclear membrane recedes with the diminishing karyolymph, the cytoplasm immediately surrounding the nucleus becomes drawn out into a series of fine threads or fibrils.

These fibrils, which later constitute the achromatic figure, thus originate directly from the cytoplasmic reticulum and merely represent lines of tension.

The resolution of the multipolar figure into the bipolar arrangement is accomplished, not by the lateral movement and fusion of conical-shaped sheaves of fibrils, but by the shifting of the lines of tension as the nuclear membrane envelops each bivalent chromosome.

The attachment of the fibrils to the bivalent chromosomes is brought about by the nuclear membrane enveloping these structures. This membrane, being a continuation of the same plasmatic substance as the fibrils, becomes closely applied to the surface of the chromosomes and thus furnishes each of these structures with a system of fibrils.

The achromatic figure can thus take no active part in the separation of the chromosomes or in their movement towards the poles. It merely represents a state of tension in the cell which results from nuclear osmotic changes.

Throughout the two meiotic divisions an exceptionally high state of nutrition prevails, the cells themselves being temporary storage organs.

No resting period or reticulum stage occurs between the two meiotic divisions. The one mitosis follows immediately upon the other.

This is regarded as an accelerated form of merismatic activity, and seems to be due to the very exceptional nutritive conditions.

It is believed that this accelerated nuclear activity accounts for the absence of a reticulum stage between the two meiotic divisions.

It is further suggested that the first meiotic division represents two ordinary somatic mitoses which have become telescoped into one.

In conclusion, the writer wishes to express his indebtedness to the Executive Committee of the Carnegie Trust for a grant to defray the cost of the lithographic plates illustrating this paper.

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EXPLANATION OF FIGURES IN PLATES.

All figures were drawn with the aid of the camera lucida and to the same scale × 1800, except figs. 4, 5, 11, 12, 13, 26, and 27, which for clearness were drawn at a considerably higher magnification.

Fig. 1. A section of a mature mother-cell with the nucleus in the so-called resting or reticulum stage. The chromatin is in the form of a network of interlacing delicate threads.

Fig. 2. An older stage of the same. The chromatin threads are more sharply defined, and the distension of the nuclear cavity by the increased amount of karyolymph and the consequent withdrawal of the nuclear membrane from the chromatin mass are clearly indicated.

Fig. 3. The same at a still older stage. The nuclear vacuole has greatly increased. The chromatin threads are shorter and thicker and show a distinct longitudinal fission.

Fig. 4. A detail of the chromatin threads at a much higher magnification, showing the characteristic vacuolated nature of the longitudinal fission.

Fig. 5. Another detail of the same at a slightly later period.

Fig. 6. A tranverse section showing the growth period at about its maximum. The nuclear cavity has enlarged enormously and the chromatin threads have become very much shorter and thicker. The ends of the threads show very frequently and the longitudinal fission may be easily observed.

Fig. 7. A somewhat older stage than that represented in fig. 6. The chromatin threads are not only shorter and thicker but show a distinct beaded appearance. The longitudinal fission of the chromosomes is very evident.

Fig. 8. A slightly older stage of the same. Here it will be seen that the chromatin threads—still showing the longitudinal fission—have distributed themselves fairly uniformly throughout the nuclear cavity. After this stage the chromatin mass never has a lateral position.

Fig. 9. This represents a section about the same stage as above, but not quite median. The longitudinal fission of the chromosomes is clearly shown, not only through the entire length in some cases, but the double nature of the ends is evident.

Fig. 10. Another case of the same. Here the chromosomes are so sharply defined and so uniformly distributed within the nuclear vacuole that an approximate estimation of their number may be obtained.

Fig. 11. A more highly magnified detail of the chromosome, to show the vacuolated nature of the longitudinal fission at this time.

Fig. 12. Another detail of the same.

Fig. 13. Another detail of the same to show the incomplete separation of the two longitudinal halves of the chromosome; also the double nature of the natural ends of the chromosomes.

Fig. 14. A section that is not median. The longitudinal fission is very conspicuous. The beaded nature of the threads is not so evident.

Fig. 15. A section that has been cut in a median plane. The large number of threads present makes it quite clear that the reduction in the number of chromosomes has not yet taken place. The longitudinal fission is less evident.

Fig. 16. A later stage. The spireme threads have become much shorter and thicker. They are segregating in pairs preparatory to a lateral union.

Fig. 17. The same a little later. The lateral pairing of the chromosomes is very evident.

Fig. 18. The union of the pairing threads is more complete.

Fig. 19. Another stage showing about the same condition of the pairing chromosomes. This and the preceding fig. show beyond any doubt that the union is a lateral one.

Fig. 20. This fig. shows that the union of the univalent chromosomes is not only a longitudinal one, but that they coil closely about one another in a spiral fashion.

Fig. 21. Another stage of the same.

Fig. 22. The same. This and the two preceding figs. show clearly that as the pairing of the univalent chromosomes becomes more intimate, the bivalent structure becomes very much shorter. This is mainly due to the shortening and thickening of the two uniting elements, but also partly due to the coiling of these structures about one another.

Fig. 23. The bivalent chromosomes are now almost completely organised.

Fig. 24. The bivalent chromosomes now occupy a position at the periphery of the nuclear cavity—the majority of them being in close touch with the nuclear membrane. From this and the preceding figures it will also be seen that the bivalent chromosomes are heteromorphic. There are long ones and short ones.

Fig. 25. An early stage in the formation of the spindle. The nuclear vacuole shows a very marked decrease in size. Accompanying this decrease fine delicate threads of cytoplasm appear about the nuclear membrane, which still remains intact.

Figs. 26 and 27. More highly magnified details showing the manner in which the univalent chromosomes coil about one another in the process of pairing.

Fig. 28. Another stage in the formation of the achromatic figure. The nuclear membrane is intact and quite evident, and the karyolymph has become very much reduced. The number of cytoplasmic threads has correspondingly increased, and we have a typical multipolar spindle.

Fig. 29. A further advanced condition of the same. The karyolymph is so much reduced that the nuclear membrane is in touch with the chromosomes, which have become crowded together.

Fig. 30. The same still later. The nuclear membrane being now in intimate touch with the chromosomes is no longer visible. Up to this stage there was no evidence to show that the nuclear membrane had broken down.

Fig. 31. The mature achromatic figure with the bivalent chromosomes in their characteristic position at the equator.

Fig. 32. The same at a later stage, showing the separation of the chromosomes.

Fig. 33. A section showing a polar view of the chromosomes at the equator. The long and short chromosomes may easily be seen.

Fig. 34. The chromosomes on the way to the poles.

Fig. 35. A polar view of the same.

Fig. 36. The chromosomes at the poles.

Fig. 37. The chromosomes have passed beyond the region of the poles of the spindle, and are becoming grouped together in two masses at opposite ends of the cell. Numerous drawn-out threads of cytoplasm stretch between the two masses.

Fig. 38. A slightly later stage of the same.

Fig. 39. The chromosomes have become vacuolated by the accumulation of karyolymph, and a plasmatic membrane envelops each daughter nucleus.

Fig. 40. The daughter nuclei at a later stage. A cell membrane has been laid down midway between the daughter nuclei. As the nuclear vacuoles enlarge the cytoplasmic threads stretching between them vanish.

Fig. 41. A spindle of the second meiotic division with the chromosomes passing to the poles. This figure also shows the enormous thickening of the cell-wall.

Fig. 42. The same, with the chromosomes at the poles of the spindle.

Fig. 43. The result of the second meiotic division showing three of the four spores enclosed within the common thick mother membrane.

Fig. 44. A section of a microspore after the absorption of the mother-wall and the separation of the tetrads. The chromatin has again become very finely divided in the so-called reticulum stage.

Fig. 45. A section of a mother-cell of *Kniphofia*. The chromatin is in the form of spireme threads which show the longitudinal fission.

Fig. 46. The same at a little later stage.

Fig. 47. The same, showing the lateral pairing of the thickened spiremes to form the bivalent chromosomes.

Fig. 48. The same, showing the tight coiling of the pairing chromosomes.

Fig. 49. Another example of the same.

Fig. 50. A section of a microspore mother-cell showing the numerous spiremes each with a longitudinal fission.

Fig. 51. A section of a mother-cell in *Aloe*, showing the lateral pairing of the spiremes.

Fig. 52. A later stage of the same. The coiling and twisting of the pairing chromosomes about one another is clearly shown.

Fig. 53. A portion of a section to show the chromosomes of the second meiotic division at the poles. It will be seen that the chromosomes appear to be quite homogeneous throughout.

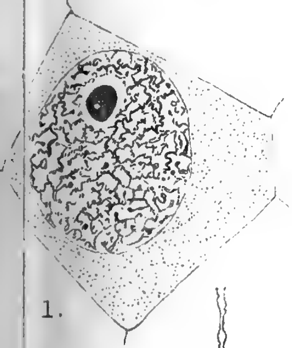
Fig. 54. The same at a slightly older stage. The first indication of the accumulation of karyolymph within the chromosomes is seen by the presence of small lacunæ. The chromosomes are becoming vacuolated.

Fig. 55. A later stage of the same. The chromosomes are crowded closely together, and the whole mass has a spongy appearance due to the presence of karyolymph in the numerous small vacuoles.

Fig. 56. Another stage of the same, where the individual chromosomes may be easily identified. A membrane now envelops the small daughter nucleus.

Fig. 57. The same at a slightly later stage.

Fig. 58. A section of a microspore still confined within the thick wall of the mother-cell. The chromatin is in the reticulum stage.



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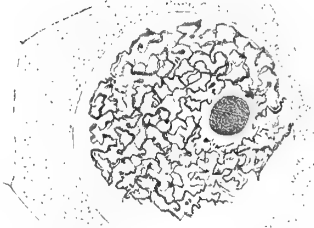

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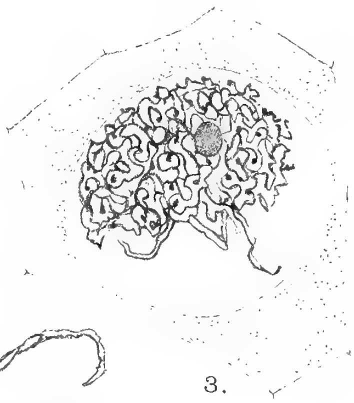

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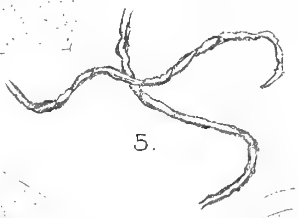

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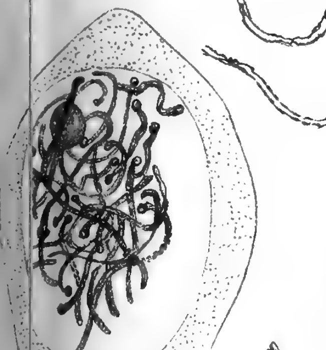

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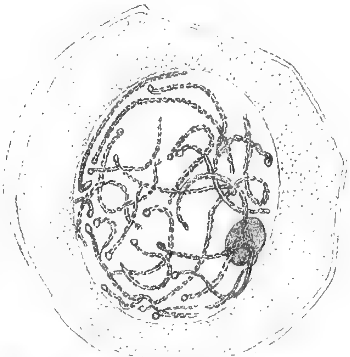

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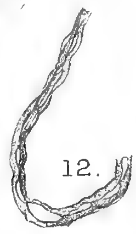

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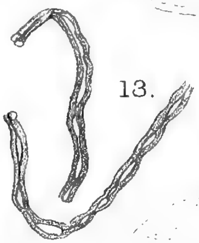

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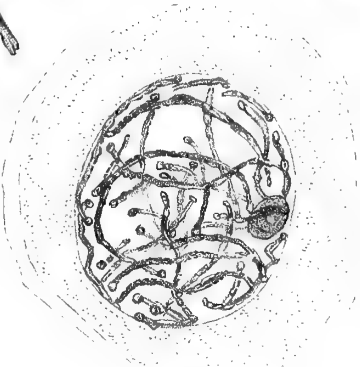

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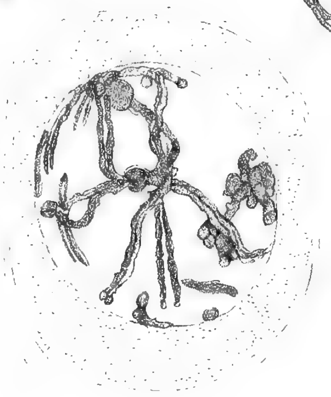

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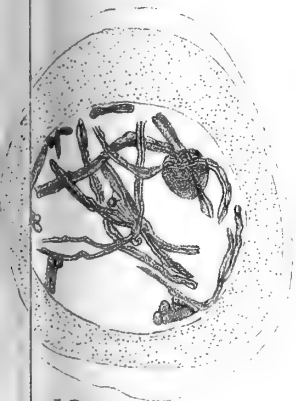

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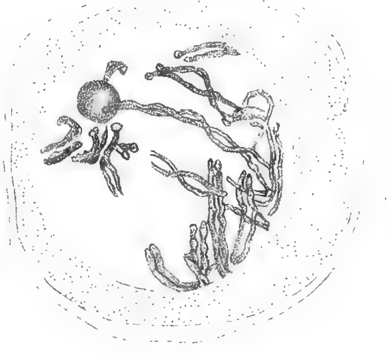

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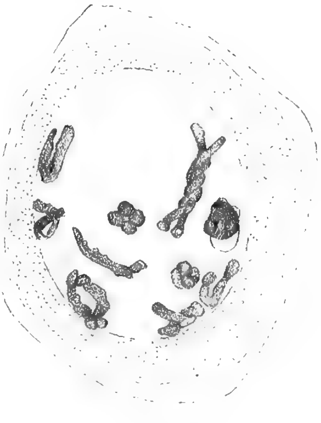

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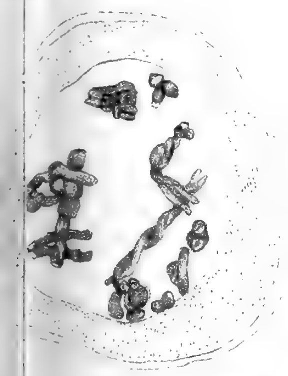

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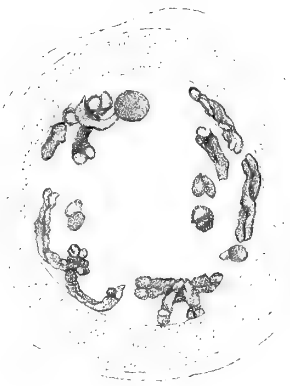

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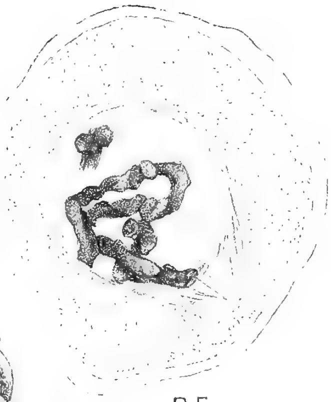

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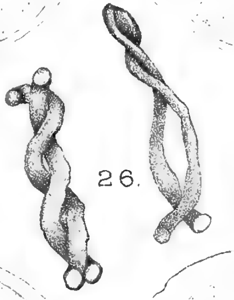

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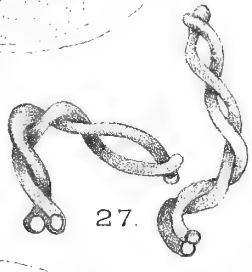

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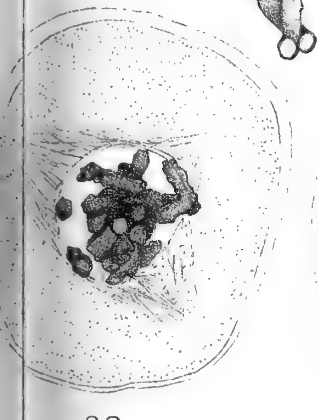

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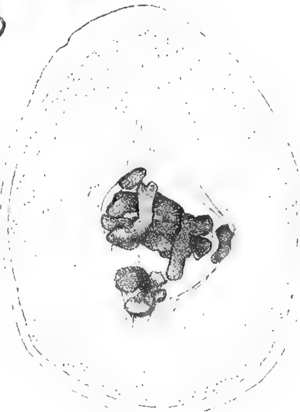

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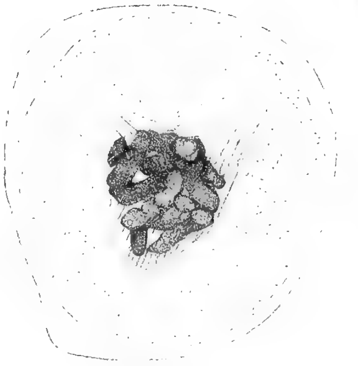

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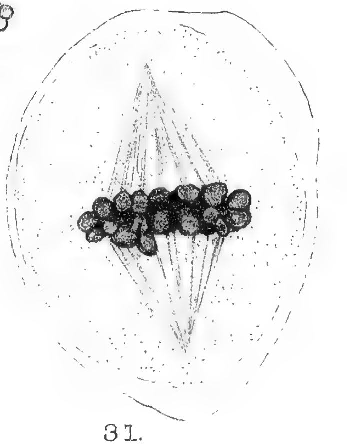

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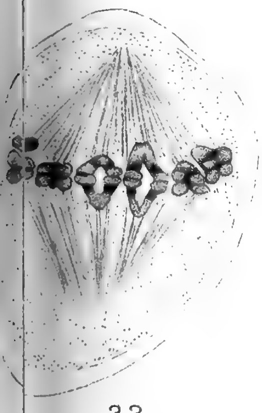

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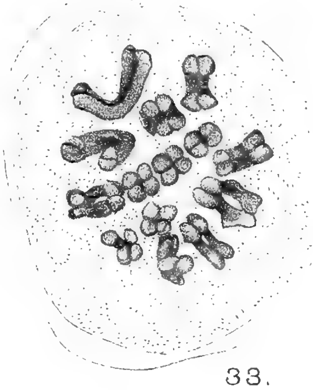

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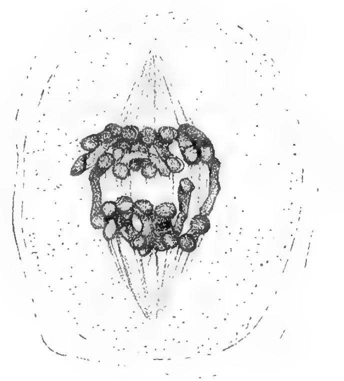

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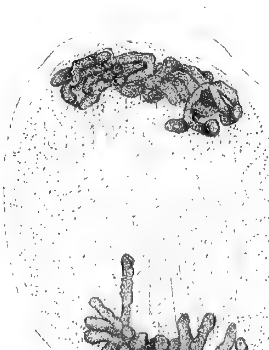

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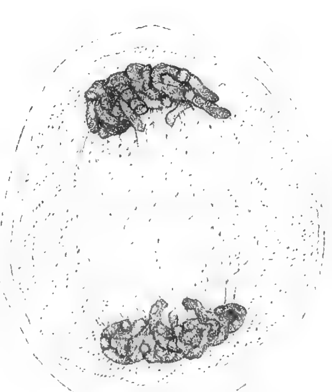

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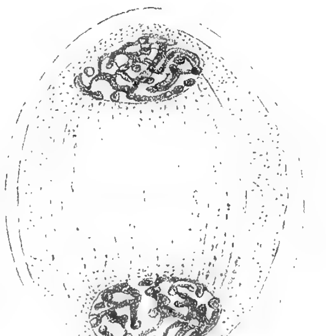

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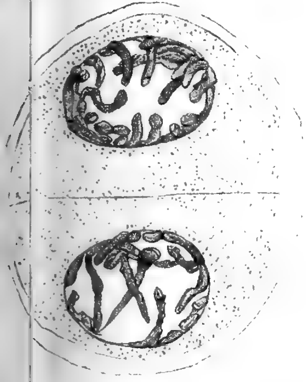

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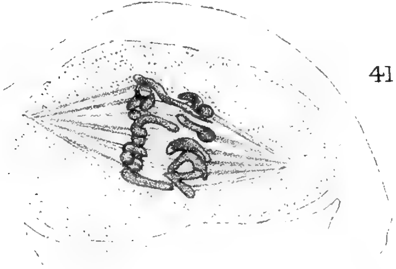

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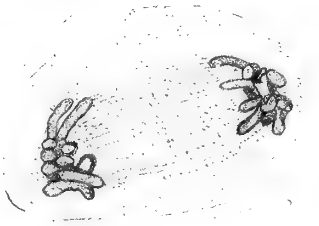

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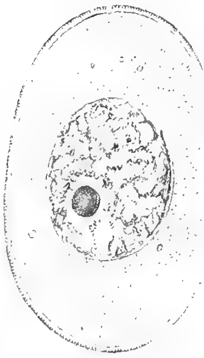

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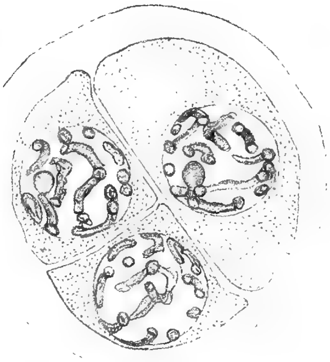

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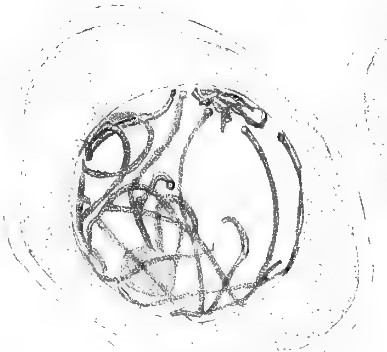

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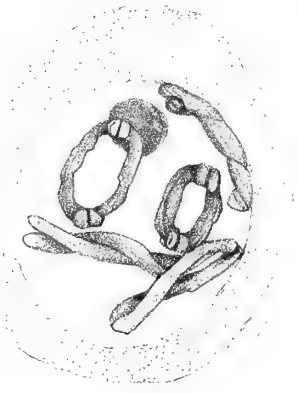

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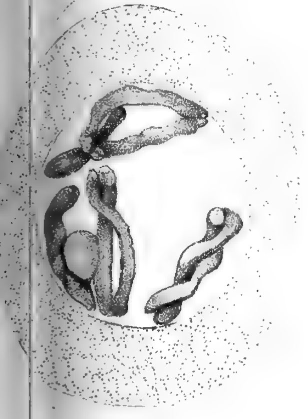

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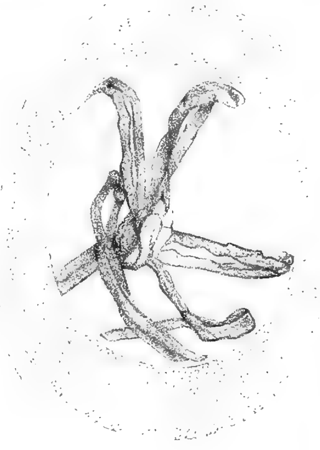

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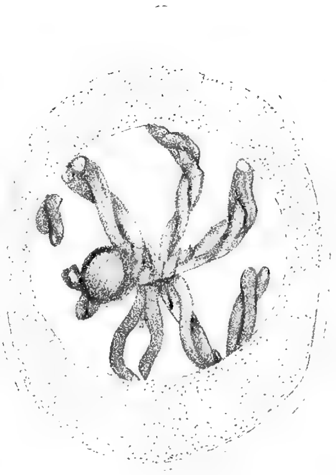

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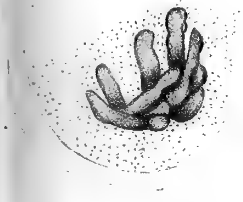

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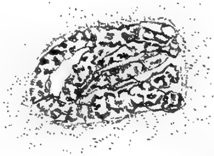

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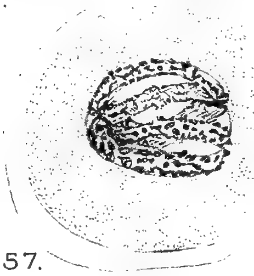

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BRITISH MUSEUM
NATURAL HISTORY

XXVI.—Temperature Observations in Loch Earn. With a further Contribution to the Hydrodynamical Theory of the Temperature Seiche. By E. M. Wedderburn, W.S.

(Read March 4, 1912. MS. received March 18, 1912. Issued separately December 14, 1912.)

INTRODUCTORY.

There are a number of gaps which exist in our knowledge of the temperature changes which occur in fresh-water lakes. The broad lines on which the changes occur are fairly well known, but on almost every point there is a lack of detailed knowledge, and every investigation shows new problems requiring attack. One of the most interesting of these problems is the causation of the temperature seiche, and the effect of varying meteorological conditions. The problem is a difficult one, as the factors to be taken into consideration are so numerous, and the data from which to form conclusions are difficult to procure. We must first obtain an accurate knowledge of the changes which are occurring in the body of water under consideration—not only at one point but at all points, and this necessitates observations at frequent intervals of time, at numerous depths, made from several points on the surface of the loch. As yet there are no satisfactory self-recording instruments by means of which we can record the temperature of water at a considerable depth below the surface, and recourse must be had to the reading of mercury thermometers.

PLAN OF THE INVESTIGATION.

In order to obtain a fairly complete record of the temperature changes occurring over a period of time, observations on a somewhat ambitious scale were undertaken in Loch Earn during August 1911, the cost of these being defrayed by a grant from the Sir John Jackson Tait Memorial Fund of the University of Edinburgh and a subsidiary grant from the Earl of Moray Endowment of the University; Loch Earn was chosen as the scene of operations for the same reasons as weighed with Professor CHRYSTAL in his seiche investigations, viz., the uniformity of its basin, its convenient size, and its accessibility. Another very cogent reason lay in the fact that the ordinary seiches had previously been so carefully investigated by CHRYSTAL, and it was hoped that the loch would be found as well tuned for the temperature seiche as for the ordinary seiche.

A map of the loch will be found in the *Transactions* of the Society, Vol. XLI.,

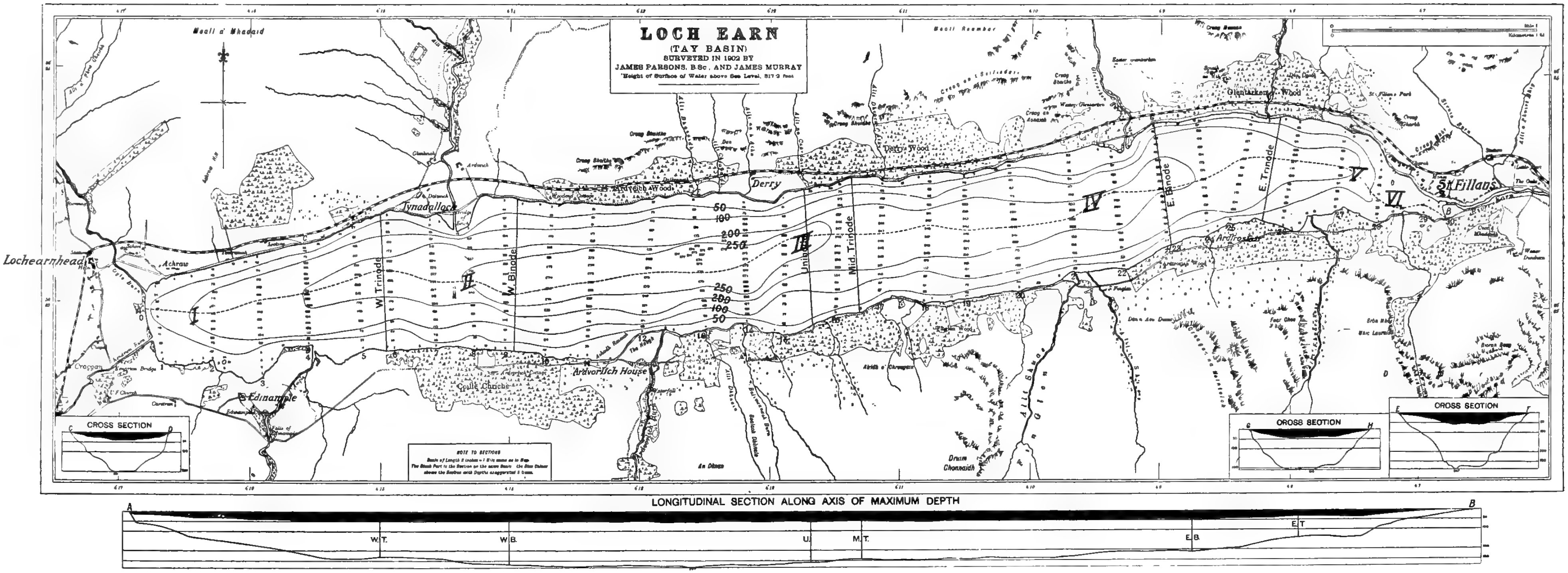
LOCH EARN
(TAY BASIN)
SURVEYED IN 1902 BY
JAMES PARSONS, B.Sc., AND JAMES MURRAY
Height of Surface of Water above Sea Level, 317·2 feet
Lochearnhead
Achraw
Edinample
Tynadalloch
Ardvorlich House
Coille Chriche
Ardvorlich Wood
Derry
Derry Wood
Glentarken Wood
Ardtrostan
St Fillans
Meall a' Mhadaid
Meall Reamhar
Drum Chonnaidh
W. Trinode
W. Binode
Uninode
Mid. Trinode
E. Binode
E. Trinode
I
II
III
IV
V
VI
50
100
200
250
CROSS SECTION
C
D
E
F
G
H
NOTE TO SECTIONS
LONGITUDINAL SECTION ALONG AXIS OF MAXIMUM DEPTH
A
B
W.T.
W.B.
U.
M.T.
E.B.
E.T.

Fig. 1.

Part III. p. 850, from which it will be seen that the loch is about $5\frac{1}{2}$ miles in length, with a very uniform basin, free from any sudden shallows, and also of fairly uniform breadth. It was decided to observe at five stations along the loch, each station being at a distance of about $1\frac{1}{2}$ miles from the next one, marked I. to V. on the sketch map fig. 1. To facilitate observation a boat was moored at each station, communication between this boat and the shore being kept up by means of a second boat. Each boat was provided with a strong sounding machine, specially designed for the work, the nature of which will be seen from the accompanying illustrations. It consisted simply of a zinc drum mounted at the end of a plank 5 feet long, which was fastened athwart the boat so that the drum projected over the side. The plank formed a convenient seat for the observer, and the whole arrangement worked satisfactorily. The sounding wire consisted of a $\frac{3}{16}$-inch circumference flexible steel rope on which lead marks, numbered consecutively, were sweated at intervals of a metre. Negretti and Zambra deep-sea reversing thermometers were used, and with one or two exceptions were found to work satisfactorily. The messengers used were of the Macdonald pattern, and my good opinion of them was confirmed.

FIG. 2.

In addition to the deep-sea thermometers a host of meteorological instruments were employed, three thermographs, two rain-gauges, wet and dry bulb thermometers, air-sling thermometers, and most important of all, a Dines recording anemograph.

The principal meteorological station was at Tighnadalloch, a farm-house about $1\frac{1}{2}$ miles from Lochearnhead, and it was here that the anemograph was erected.

For each station four observers* were allotted, while to another observer was

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* Mr HERBERT BELL, M.A., B.Sc., Edinburgh, was in charge of Station No. I.; Mr W. M'CLELLAND, Edinburgh, of No. II.; Mr A. J. ROSS, M.A., Killin, of No. III.; Mr W. WATSON, M.A., B.Sc., Edinburgh, of No. IV.; and Mr W. MALLOCH, Perth, of No. V. The other observers were:—Messrs R. K. BUTCHART, W. INNES, T. G. IRONSIDE, M.A., B.Sc., W. LIDDELL, W. G. M'EWAN, J. MACKIE, M.A., B.Sc., D. MACOWAN, M.A., B.Sc., JOHN MARSHALL,

deputed the charge of the current-meters to which reference will be made later. The author endeavoured to keep a general superintendence over the whole work, and thus, in all, twenty-two observers were employed, all of whom entered enthusiastically into the work, and to whose collaboration and especially to those in charge of the various stations a very large part of the success of the expedition was due.

At first the intention was to make regular hourly observations at each station, each observation consisting of the observation of temperature at eight or nine different depths, occupying say 45 minutes; as most of the observers had to live at some distance from the work, and as many were not expert in the management of boats, this programme was found a little severe. Observations were therefore made every other hour, and the preliminary observations made it appear that such observations were sufficiently close. Nevertheless, hourly observations were kept up, as a rule, during daylight at three of the stations.

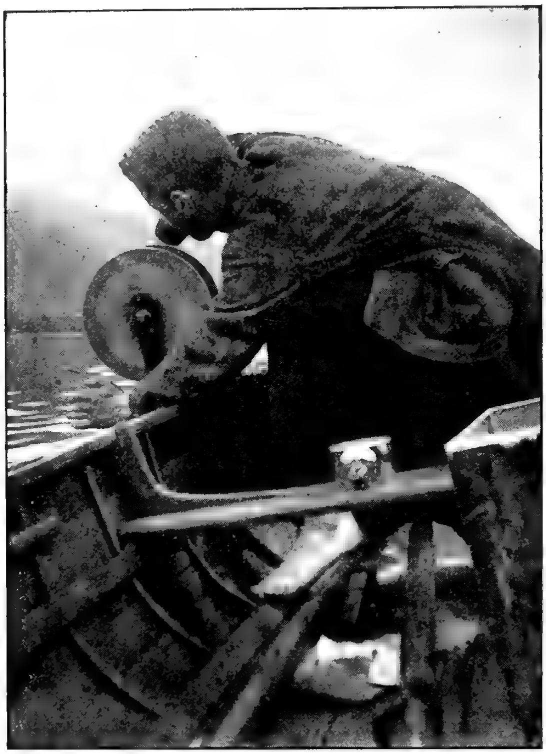

Fig. 3.—Mr Young operating sounding machine.

Fig. 4.—Mr Paske reading thermometer.

Interruptions of the work were happily few—one or two breaks were caused by bad weather, others, unfortunately, by the loss of thermometers through the wire rope

James Mechie, C. W. B. Normand, M.A., B.Sc., V. E. Paske, E. G. Ritchie, G. Shearer, T. M. Steven, J. G. Sutherland, M.A., and A. W. Young. Sir John Murray lent several reversing thermometers, and a current-meter; the Director of the Meteorological Office, thermographs, sunshine recorder, and parts of anemograph; Professor Niven, Aberdeen, the anemograph; the Scottish Meteorological Office, rain-gauges and thermometer screens. Dr W. S. Bruce also kindly offered the use of a reversing thermometer.

fraying by constant use, and breaking. But considering the arduous nature of the work, especially during the nights, it says much for the enthusiasm of the observers that the interruptions were so few.

Current Observations.

Two Ekman current-meters were available for the work, and, as already stated, these were in the charge of one of the observers. Observations with these were subsidiary to the main observations, and were not commenced until the temperature observations were in full swing, by which time the winds were light and variable and not favourable for producing currents. The observations which were made are given in Table I. appended to this paper, but it has not been possible to draw any clear conclusions from them.

The current-meters used were not supposed to be accurate for currents of less than 3 cm. per second, but, except at the surface, it was rare to find currents of this velocity recorded. Observations were made at Station I. from 7th to 14th August. Apart from the surface observations, there were only four occasions on which currents of greater velocity than 2 cm. per second were observed, and three of these were on the same day, viz., 12th August. On the other occasion the velocity was only in excess of 2 cm. per second by a very small amount, and the directions recorded for currents at different depths were very various.

Observations were made at Station III. from 15th to 20th August, and the currents observed there were much stronger. The observations on the 18th were the most interesting, and on this day a strong west wind began to blow. At the surface there was a westerly current of 12 cm. per second, while at 7 fathoms (12·8 metres) there was an easterly current of 7·8 cm. per second, and again at 10 fathoms (18·3 metres) a westerly current of about 4 cm. per second. These observations afford a good example of a current below the discontinuity in the same direction as the surface current, and observations on other days show the same thing.

At Station V. observations were made from 22nd to 27th August, but except on the 25th, a day of strong west winds, little information was obtained. On that day the strongest currents observed (only 4·5 cm. per second) were at a depth of 9 fathoms (16·5 metres) and in an easterly direction. The currents at other depths were too feeble for any importance to be attached to them.

As might have been expected, the current velocities recorded were much feebler at the ends of the loch than at the centre, for the current-meters only recorded horizontal velocities, and at the ends the currents have vertical components, and vortices are almost certain to be formed. The observations, however, suggest that the currents in lochs are not so simple as has been supposed, and there is considerable scope for their investigation.

TEMPERATURE OBSERVATIONS.

Table II. contains nearly all the temperature observations which were made, and as they were all made within four weeks, it will be evident that the number of observations made daily was very considerable. Temperature-depth diagrams were drawn by the observers from day to day, so that the author was able to keep in touch with what was going on and to direct attention to any peculiarities which were observed. Of course, in any investigation of lake temperatures it is of the greatest importance to have a record of the meteorological conditions, and especially of the state of the winds. The Dines anemograph was, therefore, a great acquisition. The upper portion of fig. 15 shows (1) the direction of winds during the month, and (2) the wind pressure as estimated from the anemograph records, and it will be convenient to refer to this diagram in what follows. The following table gives the number of hours' sunshine recorded, while fig. 5 gives the thermograph record taken at Tighnadalloch, which is fairly typical for the loch :—

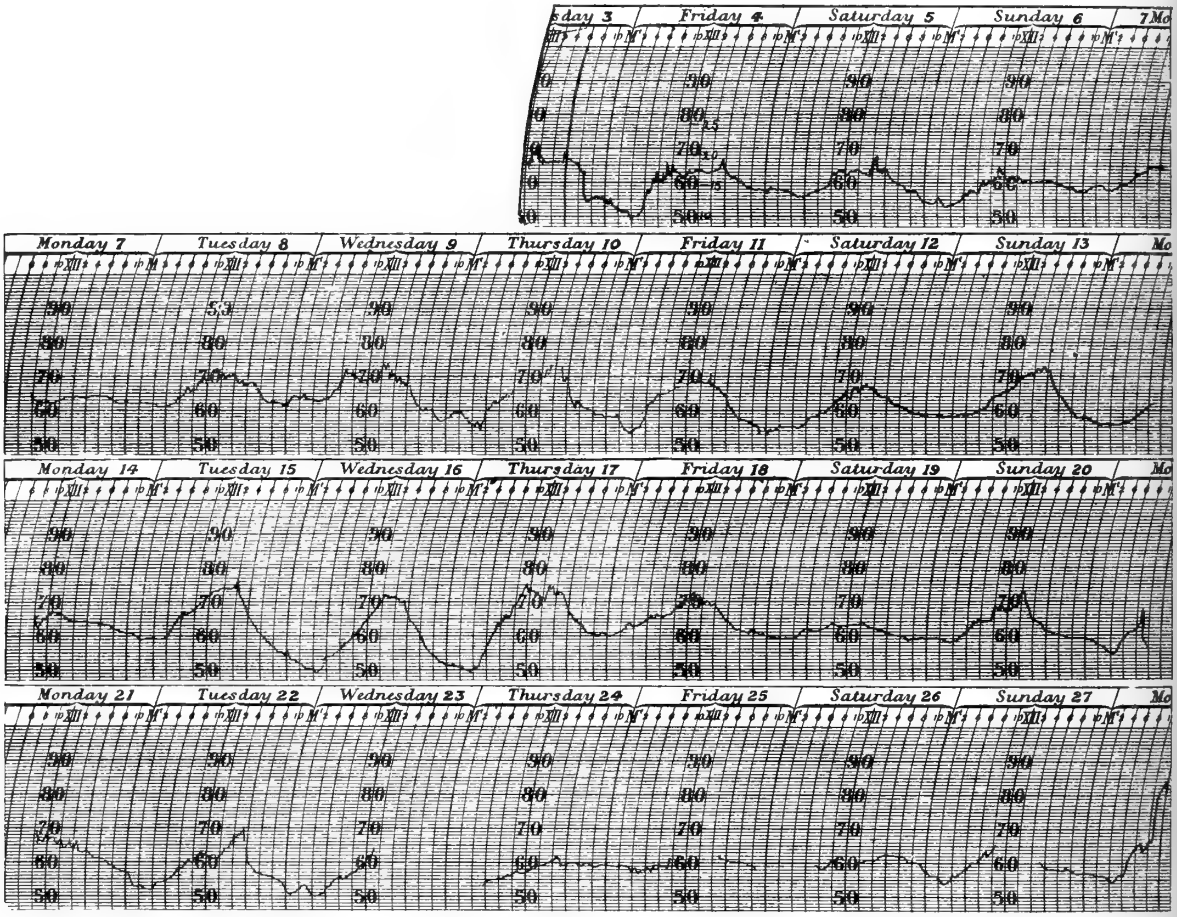

FIG. 5.—Thermograph record from Tighnadalloch.

NUMBER OF HOURS' SUNSHINE.

August 3	3¾ hours	August 16	6 hours
,, 4	2½ ,,	,, 17	5¼ ,,
,, 5	2 ,,	,, 18	5¼ ,,
,, 6	2½ ,,	,, 19	0 ,,
,, 7	2 ,,	,, 20	2 ,,
,, 8	8 ,,	,, 21	4¼ ,,
,, 9	12¼ ,,	,, 22	3¾ ,,
,, 10	13 ,,	,, 23	4½ ,,
,, 11	12¾ ,,	,, 24	0 ,,
,, 12	2¾ ,,	,, 25	2¼ ,,
,, 13	9¼ ,,	,, 26	0 ,,
,, 14	¾ ,,	,, 27	2 ,,
,, 15	11½ ,,	,, 28	8½ ,,

Discussion of the observations will best centre round typical diagrams. Fig. 6 consists of the temperature-depth curves drawn from the observations at alternate hours at the five stations, from noon on 5th August to noon on 6th August.* Reference to fig. 15 will show that at noon on the 5th the wind changed from east to west, and we find that at that time there is the temperature distribution associated with an east wind, *i.e.*, a much sharper temperature discontinuity at the west end than at the east. With the change of wind the distribution gradually changes to a west wind type, with a sharp discontinuity at the east end. It is very interesting to compare the curves for Stations I. and V., and to see how the types gradually change. The type at 12 noon on the 5th at Station I. is practically the same as that at Station V. on the 6th, while the type at Station V. at noon on the 5th is practically the same as at Station I. at noon on the 6th. The curves for Station II. are similar to those at Station I., and those at Station IV. follow the Station V. curves, while at Station III. the type does not change much.

Fig. 7 * shows a reversal of this on 10th and 11th August, as the wind changed from west to east about 9 p.m. on the 10th. In a similar manner fig. 8 * (7th August) shows the type of curves to be found with a steady west wind of no great strength, the principal points to be noted being the sharper discontinuity and higher surface temperature at the lee end of the loch, *i.e.* the east end. The effect of the direction of the wind in determining the temperature distribution in a lake must be clearly kept in view before it is possible to understand the nature of the variations which are observed. The object of these diagrams is to show this effect and to illustrate how rapidly the effect of a change in the direction of the wind makes itself felt.

Fig. 9 * shows the result of observations at Station III., from 12th to 23rd August, and during the whole of this period there was an absence of strong winds and a great deal of sunshine. The raising of the surface temperature and the slackening of the discontinuity in temperature will be observed. Had the winds been strong, there

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* See explanation of diagrams, p. 652.

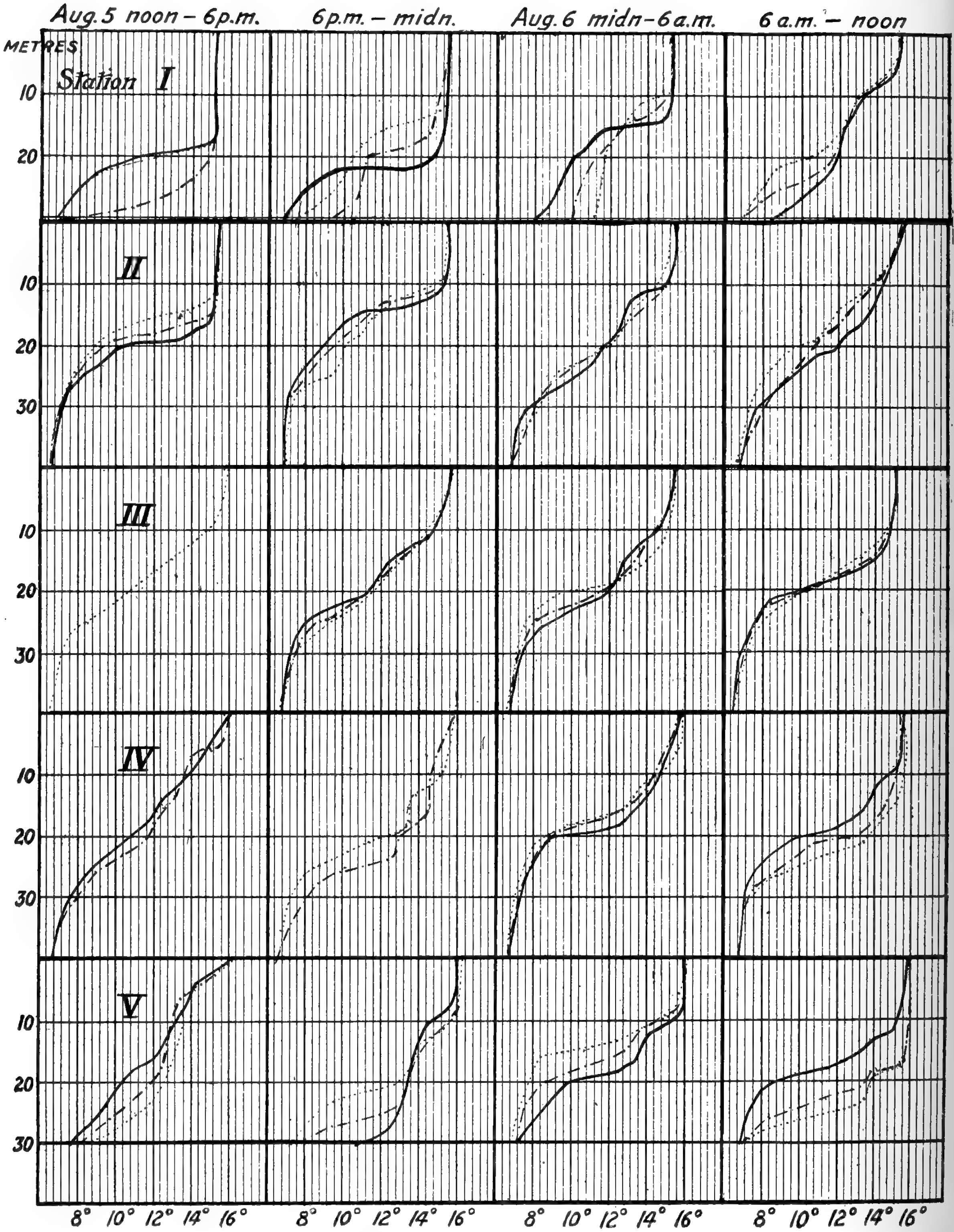

FIG. 6.—Temperature-depth diagrams, August 5th–6th.

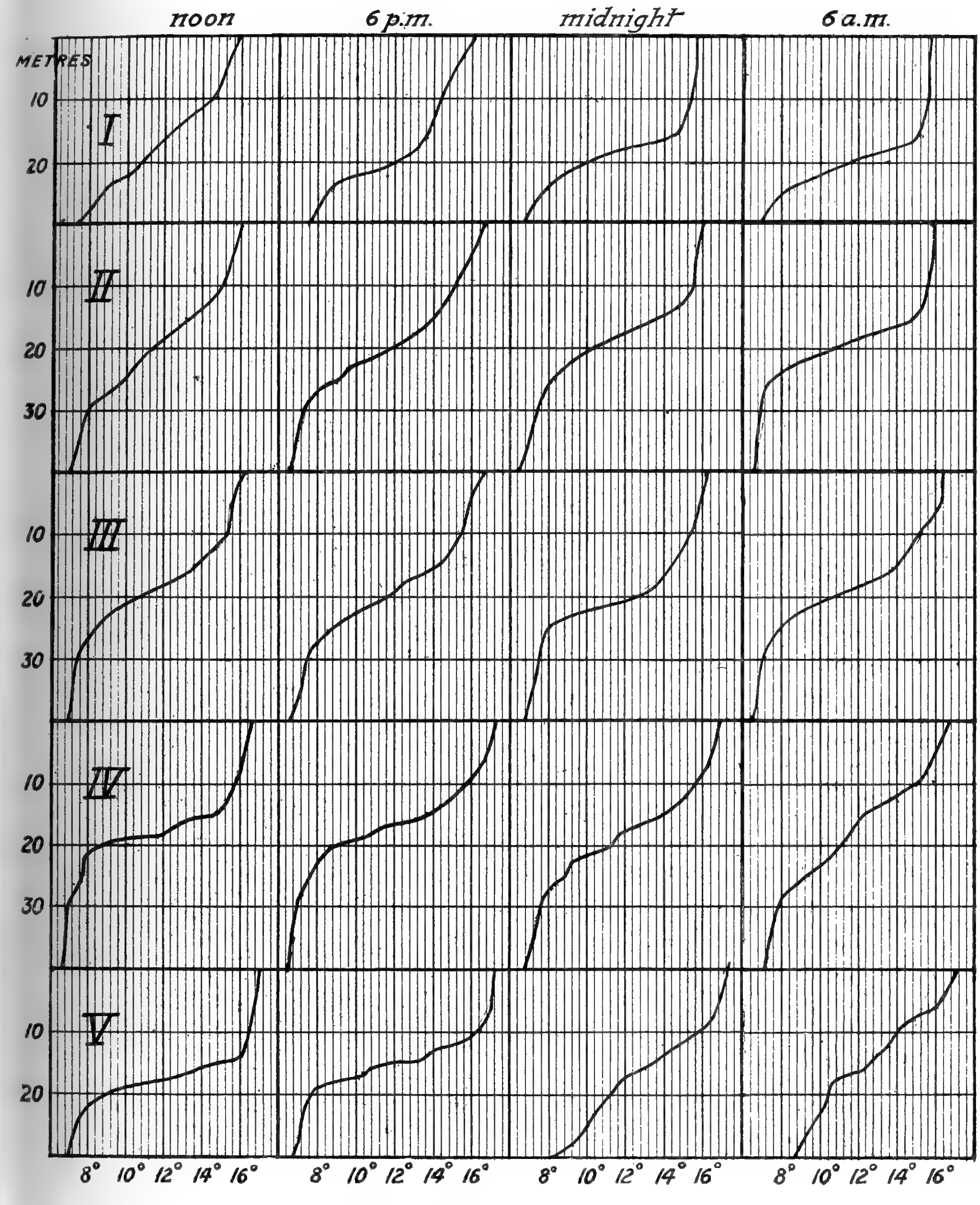

Fig. 7.—Temperature-depth diagrams, August 10th–11th.

would not have been so high a rise in surface temperature, and the discontinuity would have become more abrupt. Otherwise the curves are very similar, and, as will be explained later, the observations during this period were somewhat monotonous.

Fig. 10 * is drawn from observations at Station V., on 24th and 25th August, and shows the effect of the very strong west winds which commenced on the afternoon of the 24th. A sharp discontinuity is produced—there being at 7 p.m. on the 25th a fall in temperature of 7° C. in two metres. The last curve on this diagram shows, for comparison, the observations at Station I. at 11 p.m. on the 25th, there being an almost complete absence of discontinuity.

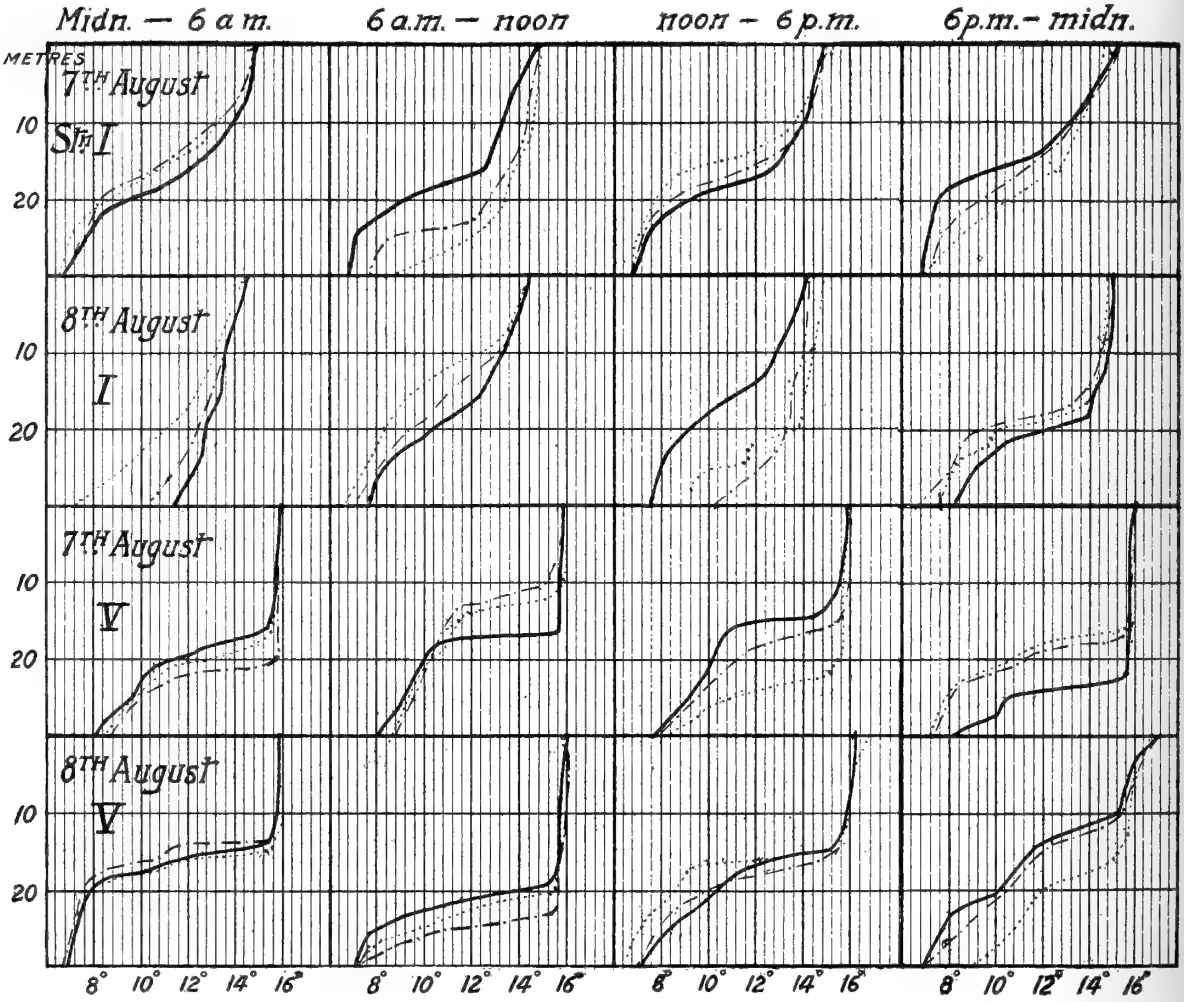

FIG. 8.—Temperature-depth diagrams, August 7th–8th.

Perhaps a clearer idea of the changes which occur will be gained by an examination of figs. 11–15,* which represent for each station the fluctuation of level of various isotherms throughout the month. It will be seen at once that in the earlier part of the month there was a well-marked oscillation of the isotherms, and a comparison of the

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* See explanation of diagrams, p. 652.

curves for the various stations shows that on the whole the phase of the oscillations at Stations I. and II. is the same, but directly opposed to the phase of the oscillations at Stations IV. and V. At Station III. the oscillations are different in character—being of much shorter period—in fact, the long-period oscillations so clearly marked at the other stations cannot be traced at Station III.

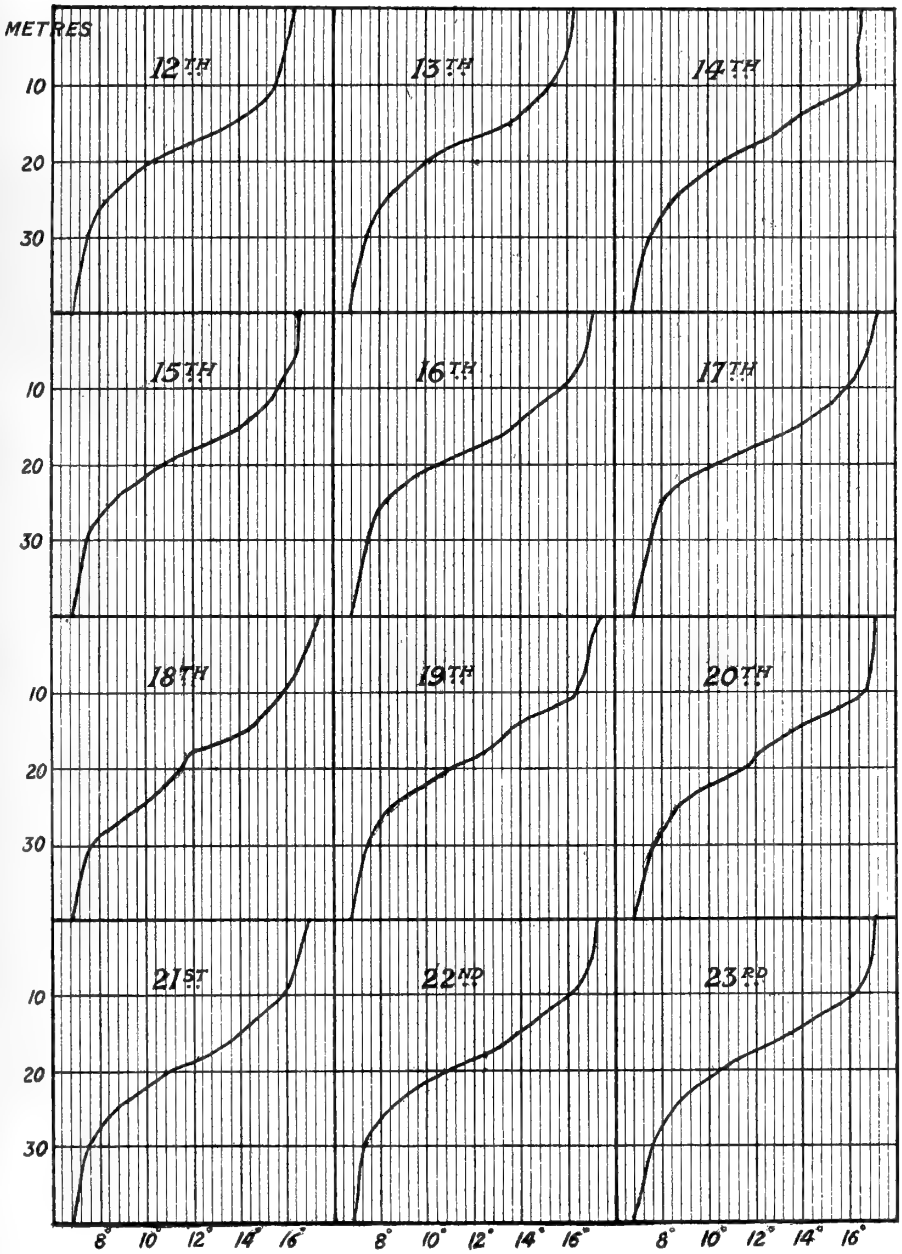

Fig. 9.—Temperature-depth diagrams for Station III. for 1 a.m., August 12th–23rd.

This is very clear evidence that the seiche theory of the oscillations is the correct one, the absence of the long-period oscillations at Station III. being due to the proximity of the uninode. In fig. 16 * the sixteen diagrams show cross sections of the loch, the depth scale being greatly exaggerated. The blackened portion shows the area between the isotherms for 9° C. and 11° C. (*i.e.* in the neighbourhood of the discontinuity), for successive hours, on 9th August from 1 a.m. to 4 p.m. The period of the oscillation is about 15 hours, and so the diagram covers a complete period. The gradual alteration in the tilt of the isotherms can be easily followed. It is difficult to get an accurate determination of the period of the oscillation, and, indeed, as the distribution of temperature is always varying slightly, the period cannot be absolutely uniform. The curves for Station V. are purer than at Station I., as westerly winds prevailed. Station V. being the leeward end of the loch during west winds, the discontinuity was usually well marked, which is probably the reason for the greater purity of the curves. At Station V. from noon on 6th August to 7 a.m. on the 10th (91 hours) there were six complete oscillations, giving a period of 15·17 hours for each oscillation. Or we may take the Station I. curves, and we find that from 7 p.m. on the 6th to 8 a.m. on the 9th (61 hours) there were four oscillations giving a period of 15·25 hours, and we may take 15·2 hours as being approximately the period of the oscillations at this time. It is difficult to obtain a determination of the period later in the month, but at Station V. there are four fairly regular oscillations from 2 a.m. on the 14th to 10 a.m. on the 16th, which gives a period of 14 hours—very appreciably less. As

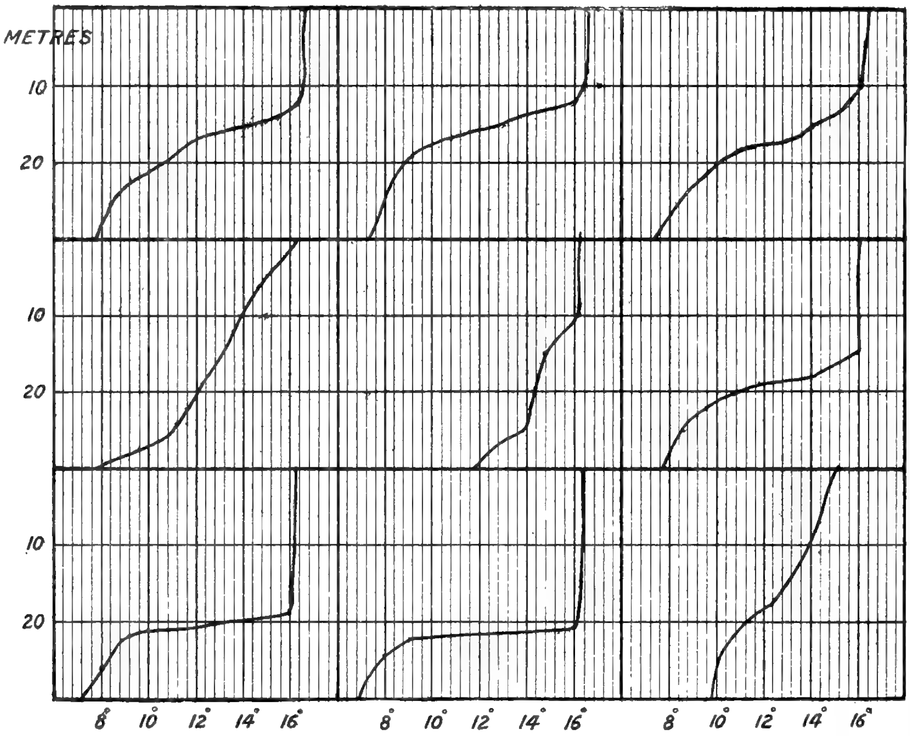

FIG. 10.—Temperature-depth diagrams, August 24th–25th.

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* See explanation of diagrams, p. 652.

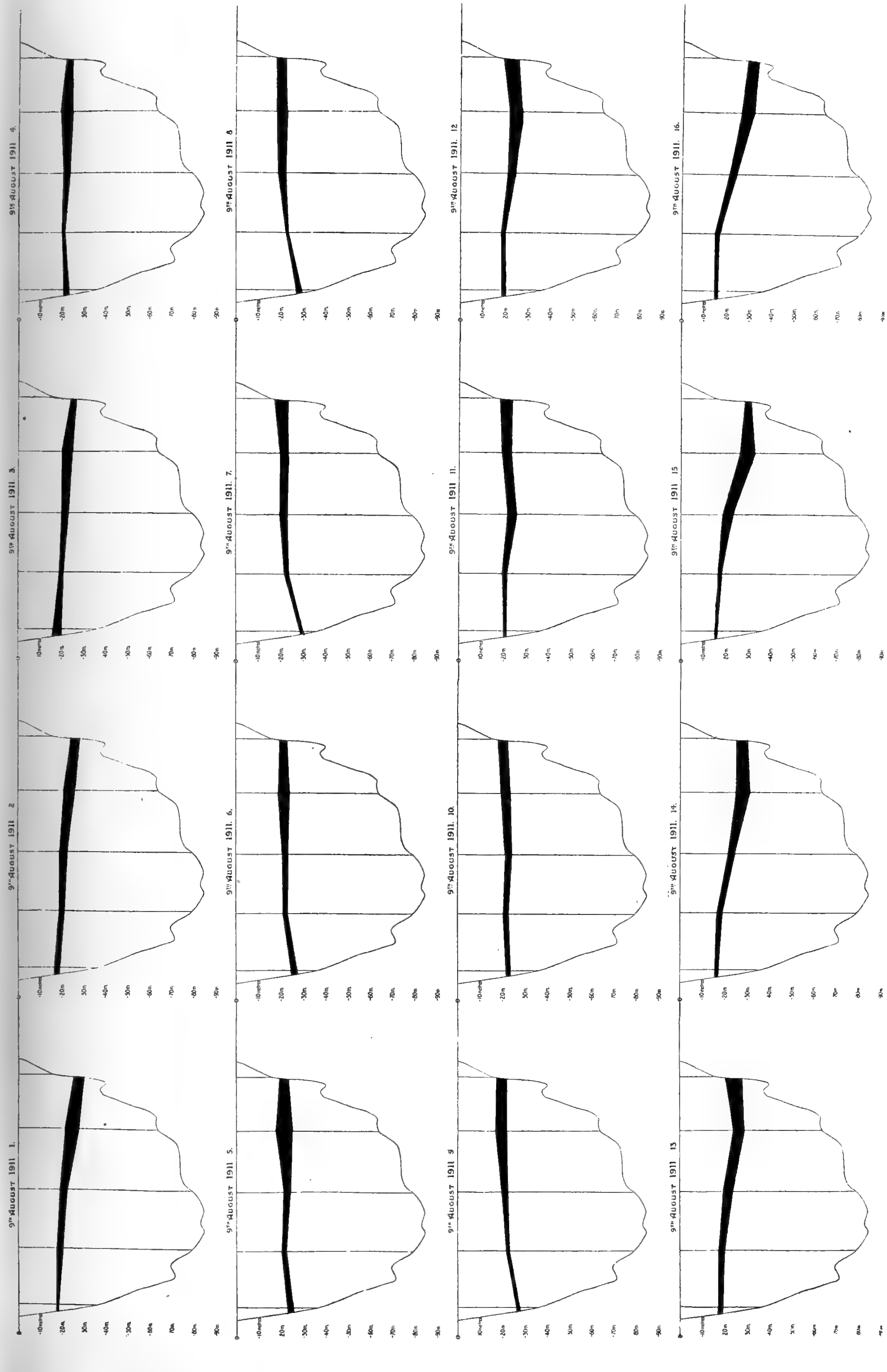

FIG. 16.—Longitudinal sections of loch. Successive position of isotherms, 9°–11°.

will be seen later, the theory of the oscillations accounts for this discrepancy by taking into account the raising of the surface temperature.

The Station III. curve, from 8th to 10th August, gives a fairly pure example of the binodal seiche from which a period of 8·2 hours is obtained.

For a study of the effect of meteorological conditions the diagrams in figs. 11–15 are not very satisfactory, and accordingly the observations for Station I. are represented in a more convenient form in fig. 17*, which shows the relative positions of the various isotherms throughout the month.

We shall first consider the effect of a change in the direction of the wind. The loch runs nearly due east and west, so that it is the easterly or westerly components of winds which are of chief importance from the point of view of temperature seiches.

About 4 a.m. on 5th August the wind changed from a westerly to an easterly direction, but returned to a westerly direction at noon. The Station I. thermometer was not working satisfactorily on 4th and 5th August, but the diagrams in fig. 7 show that the west wind, enduring for eight hours, was sufficient to establish a typical east wind distribution, and that within eight or nine hours after the change back to a west wind we again have a west wind distribution, although the winds were very moderate in strength. In the afternoon of the 6th, during a lull of the wind, there was for a very short time an easterly breeze, but it was too short in duration and too light to produce any noticeable effect. Thereafter, until midnight between 8th and 9th August, the wind was westerly, then, for nine or ten hours, there was an easterly wind, but not very strong. Its effect is, however, at once seen on all the isotherms higher than 11° C. (see fig. 17). The surface isotherms at Station I. sink, indicating the accumulation of warm water at the lee end of the loch. There is also noticeable a slight decrease in the amplitude of the oscillations. But about noon on 9th August the wind was blowing strongly from the west, and the change of wind, in this case, was so timed as to considerably increase the amplitude of the oscillation. But this increase was of short duration, for about 8 p.m. on 10th August the direction of the wind again changed to the east. This wind was of considerable strength, and commenced when the isotherms at Station I. should have been nearly at their lowest. The effect of the wind was to bring the isotherms close together and to prevent them rising, and in this way the oscillation which was in progress was practically damped out.

Thereafter, until 17th August, the wind was easterly, but was generally light. On the 17th there was a change to westerly winds, but, except for short periods, the winds were light and had little effect on the general distribution, although there is an appreciable lessening of the depth at which the higher isotherms are found. On 19th August the wind again changed from west to east, and the effect is at once seen on the surface isotherms, and a small oscillation which was in progress was damped out and the isotherms brought closer together. From 22nd to 24th August the wind was rather variable in direction, yet was never strong; but on the

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* See explanation of diagrams, p. 652.

afternoon of the 24th a strong west wind began to blow, and continued for the rest of the month, and this wind was strong enough to start an oscillation.

It was hoped that it would be possible to obtain fairly definite information as to the effect of variations in the strength of the wind, but this unfortunately was not the case. Some general conclusions can, however, be drawn. Thus on 5th August a wind of from 10 to 15 miles per hour, blowing for eight hours, was sufficient to change the distribution of temperature from a west wind type to an east wind type, and again, on 14th August, a wind of this strength suddenly arising and enduring for about thirteen hours, nearly the period of the oscillation, was sufficient to start a small oscillation. Then again the curve for 9° C. in fig. 17, from 17th to 20th August, seems to show an oscillation with a period which is far from uniform, but is much longer than fifteen hours. These oscillations are forced, as the following table will show, it being remembered* that at Station I. an east wind tends to raise the bottom isotherms and a west wind to lower them. Reference to fig. 15 will show that there were alternately calms and winds of moderate strength.

Direction of Wind.	Duration of Wind.	Remarks on Isotherm for 9° C. at Station I.
West.	Noon on 17th—3 a.m. on 18th.	Minimum about 9 p.m. on 17th.
,,	5 a.m.—9 p.m. on 18th.	,, 6 p.m. on 18th.
East.	8 a.m.—midnight on 19th.	Maximum at midnight, 19th–20th.
,,	4 p.m. on 20th—6 a.m. on 21st.	,, about midnight, 20th–21st.

The oscillations observed are, therefore, probably forced, while during periods of calm from 9 p.m. on 18th to 8 a.m. on 19th (11 hours), and from 3 a.m. to 4 p.m. on 20th (13 hours), we see the natural period for the loch trying to assert itself.

Further examples of the effect of variations in the strength of the wind might be multiplied, but one other example is sufficient. We have seen that the strong wind which sprang up on the 24th seemed likely to start an oscillation, but this oscillation lasted only a very short time. The wind moderated very considerably about 1 a.m. on the 26th, to rise again in strength at noon, and this increase in the strength of the wind, without any change in direction, was so timed as to damp down the oscillation which had just been started.

It was, perhaps, a misfortune that during the larger portion of the month the oscillations were so small, but the presence of a large oscillation during the whole period of oscillation would have masked the smaller embroideries which the observations show. The observations were not arranged specially for the examination of these embroideries, and it would be desirable, for the more complete investigation of them,

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[*] See "Temperature of Scottish Lakes," *Bathymetrical Survey of Scottish Lochs*, vol. i. p. 122.

to observe at closer intervals of time, and also at shorter distances along the loch. Figs. 7–11 show that though the temperature-depth curves follow a definite type there are many irregularities—double discontinuities and the like—which can only be investigated in this way, and for the elucidation of which recording instruments would be invaluable. Towards the end of the month an effort was made, by concentrating the observers at Stations III. and V., to follow some of these smaller variations, but these small variations seemed at that time to have almost disappeared, and a number of accidents occurred which made this series of observations of little value.

Before work was discontinued, observations were made at the point marked VI. on the sketch map simultaneously with observations at Station V., during a strong west wind—so strong that both boats dragged their anchors. These observations were made from 6 a.m. to 6 p.m., on 29th August, during which a small oscillation was in progress The depth of water at Station VI. was only about 12 metres, and always about 2 metres or so above the bottom there was a sudden fall in temperature, the temperature found at 12 metres being the same as was found at about 24 metres at Station V. Whether this was due to the high wind or not, cannot be said, as similar observations were not made during a calm. It is very probable, however, that it was the result of the high wind, and indicated that warm surface water was being forced downwards by the high wind.

Viewed as a whole, the results of the investigation may be summarised as follows:—

It has been proved beyond all possible doubt that what we have called Temperature Seiches do exist, and that they are truly of the nature of a standing boundary wave.

Examples of the effect of winds, both in starting and in damping oscillations already in progress, have been given, with an indication that even a wind of very moderate strength will start oscillations, and examples of oscillations forced by wind have also been obtained.

The observations suggest the lines on which the investigation of lake temperatures may most profitably proceed in the future, viz. the investigation of the short-period oscillations, analogous to "vibrations" at the free surface of the loch, most of them probably due to travelling boundary waves, some due to standing waves of high nodality, and some perhaps due to transverse oscillations.

Before passing to the more technical part of this paper, I should like to record my indebtedness to all the observers who assisted in the work, and particularly to those in charge of the various stations. But for the energy with which they all carried on the work, which was frequently of an uninteresting as well as of an arduous and uncomfortable nature, the expedition would have been a failure. I should also like to acknowledge the courtesy shown by proprietors along the loch shore for facilities for landing boats, etc.; also to many of those in the district who in various ways, such as rescuing shipwrecked observers, helped on the work.

HYDRODYNAMICAL THEORY OF TEMPERATURE OSCILLATIONS.

In the discussion of the "Hydrodynamical Theory of Temperature Oscillations," which appeared in the *Transactions*, vol. xlvii., Part IV. p. 628, the following assumptions were made: (1) That the amplitude of the oscillation was small, (2) that there was no transverse motion of water particles, and (3) that there was an abrupt discontinuity in temperature at a certain depth, above and below which there was uniform temperature. In what follows, this last assumption is removed and the case of oscillations in a liquid of gradually varying density is considered. In such a case irrotational motion is not possible, but as the amplitudes with which we are dealing are small, and the velocity of water particles is slow, we shall only be neglecting very small quantities if we assume that the motion is irrotational.

We have seen (*ibid.*, p. 633) that by imposing a condition that at any given depth there is no horizontal motion, an infinite number of modes of oscillation is possible. Let us then consider a transverse vertical section of the lake at a horizontal distance x, from a plane perpendicular to the axis of the lake, which we shall call the plane of origin. As before, the axis of the lake is taken as following the average line of greatest depth. Assume now that at a certain level there is no horizontal motion, which is equivalent to assuming that above and below this level the motion of the water particles is in opposite directions. Let the area of the whole cross-section be $\{A'(x)+A(x)\}$, $A'(x)$ being the area of the section above the level at which there is no horizontal motion, which we shall call the boundary, and $A(x)$ the area of the section below the boundary. Further consider $A'(x)$ split up into thin laminæ $A'_1(x)$, $A'_2(x)$, $A'_3(x)$ . . . and $A(x)$ into $A_1(x)$, $A_2(x)$, $A_3(x)$. . . . The volume of slices S′ and S above and below the boundary, with thickness dx at the point under consideration, will then be respectively $\Sigma A'_1(x)dx$ and $\Sigma A_1(x)dx$.

Suppose that, after a time, the slices S′ and S have moved into new positions, so that the distances of the various laminæ from the plane of origin are $(x-\xi'_1)$, $(x-\xi'_2)$, $(x-\xi'_3)$ . . . for those above the boundary, and $(x+\xi_1)$, $(x+\xi_2)$, $(x+\xi_3)$ . . . for those below. Then the thickness of the various laminæ in their new positions, above and below the boundary respectively, must be $dx\left(1-\frac{\partial\xi'_n}{\partial x}\right)$ and $dx\left(1+\frac{\partial\xi_n}{\partial x}\right)$. The volume of the slice will then be

$$\Sigma A'_1(x-\xi'_1)dx\left(1-\frac{\partial\xi'_1}{\partial x}\right)$$

and of S

$$\Sigma A_1(x+\xi_1)dx\left(1+\frac{\partial\xi_1}{\partial x}\right).$$

It follows from the assumption that there is no transverse motion, that the change of level of any lamina is the same throughout its whole breadth. Let ζ'_1, ζ'_2, ζ'_3 . . . ζ_1, ζ_2, ζ_3 . . . be the difference between the change of level of successive laminæ, as S′ and S move to the new position, so that $\Sigma\zeta'_1=\Sigma\zeta_1=\zeta$, where ζ is the change of level at the boundary. When there is such a rise, ζ, at the boundary, the change of volume of any lamina, $A'_n(x)$, above the boundary is $-b'_n(x)\zeta'_n\left(1-\frac{\partial\xi'_n}{\partial x}\right)$, and of any lamina $A_n(x)$ below the boundary is $b_n(x)\zeta_n\left(1+\frac{\partial\xi_n}{\partial x}\right)$; $b'_n(x)$ and $b_n(x)$ being respectively the breadth of the laminæ $A'_n(x)$ and $A_n(x)$.

The equations of continuity for the various laminæ are then of the form

$$A'_n(x)dx=\{A'_n(x-\xi'_n)-b'_n(x)\zeta'_n\}dx\left(1-\frac{\partial\xi'_n}{\partial x}\right) \quad . \quad . \quad . \quad (1'),$$

and

$$A_n(x)dx=\{A_n(x+\xi_n)-b_n(x)\zeta_n\}dx\left(1+\frac{\partial\xi_n}{\partial x}\right) \quad . \quad . \quad . \quad (1).$$

That is

$$\zeta'_n b'_n(x)=-A'_n(x)\Big/\left(1-\frac{\partial\xi'_n}{\partial x}\right)+A'_n(x-\xi'_n) \quad . \quad . \quad . \quad (2'),$$

$$\zeta_n b_n(x)=A_n(x)\Big/\left(1+\frac{\partial\xi_n}{\partial x}\right)+A_n(x+\xi_n) \quad . \quad . \quad . \quad . \quad (2),$$

or neglecting quantities of the second order

$$\zeta'_n=-\frac{1}{b'_n(x)}\frac{\partial}{\partial x}\{A'_n(x)\xi'_n\} \quad . \quad . \quad . \quad . \quad (3'),$$

$$\zeta_n=\frac{1}{b_n(x)}\frac{\partial}{\partial x}\{A_n(x)\xi_n\} \quad . \quad . \quad . \quad . \quad (3).$$

Neglecting vertical accelerations (*i.e.* assuming $\left(\frac{h}{2l}\right)^2$ small, and the amplitude of the oscillation also small) and considering only horizontal acceleration, the differences between the pressures on the two sides of the various laminæ in their disturbed positions will simply be due to the difference in density between successive laminæ and the change in their relative levels, *e.g.* for the lamina $A'_n(x)$, $\rho'_n\zeta'_n$ per unit area of the whole lamina, where ρ'_n is the difference between the density of that lamina and the adjoining lamina, the resultant pressure for S′ being $g\Sigma\rho'_n\zeta'_n$ per unit area, and for S, $g\Sigma\rho_n\zeta_n$ per unit area; g being the acceleration due to gravity.

The equation of motion for all the laminæ, as a whole, then becomes

$$\frac{1}{A'(x)^2}\Sigma R'_n A'_n(x)dx\left(1-\frac{\partial\xi'_n}{\partial x}\right)\frac{\partial^2}{\partial t^2}\{A'_n(x)\xi'_n\}+\frac{1}{A(x)^2}\Sigma R_n A_n(x)dx\left(1+\frac{\partial\xi_n}{\partial x}\right)\frac{\partial^2}{\partial t^2}\{A_n(x)\xi_n\}$$
$$=-g\,dx(\Sigma\rho'_n\zeta'_n+\Sigma\rho_n\zeta_n) \quad . \quad . \quad . \quad . \quad (4),$$

where $R'_1, R'_2, R'_3 \ldots R_1, R_2, R_3 \ldots$ represent the density of successive laminæ.

But if the various laminæ are to remain in contact we must have

$$\frac{\partial^2}{\partial t^2}\{A'_n(x)\xi'_n\}=-\frac{\partial^2}{\partial t^2}\{A_n(x)\xi_n\}=\frac{\partial^2 u}{\partial t^2} \quad . \quad . \quad . \quad (5),$$

where u is a function depending on the contour of the lake and the horizontal displacement of the water particles.

Equation (4) may then be written as follows, after substituting for ζ'_n and ζ_n from equations (3′) and (3)

$$\left\{\Sigma \mathrm{R}'_n\left(1-\frac{\partial \xi'_n}{\partial x}\right)\mathrm{A}'_n(x)\Big/\mathrm{A}'(x)^2+\Sigma \mathrm{R}_n\left(1+\frac{\partial \xi_n}{\partial x}\right)\mathrm{A}_n(x)\Big/\mathrm{A}(x)^2\right\}$$

$$=g\left[\Sigma\rho'_n b'_n(x)\frac{1}{b'_n(x)}\frac{\partial}{\partial x}\left\{\frac{1}{b'_n(x)}\frac{\partial}{\partial x}(\mathrm{A}'_n(x)\xi'_n)\right\}+\Sigma\rho_n b_n(x)\frac{1}{b_n(x)}\frac{\partial}{\partial x}\left\{\frac{1}{b_n(x)}\frac{\partial}{\partial x}(\mathrm{A}_n(x)\xi_n)\right\}\right] \qquad (6),$$

$$=g\left[\Sigma\rho'_n b'_n(x)\frac{\partial^2\{\mathrm{A}'_n(x)\xi'_n\}}{\partial\{\int b'_n(x)dx\}^2}+\Sigma\rho_n b_n(x)\frac{\partial^2\{\mathrm{A}_n(x)\xi_n\}}{\partial\{\int b_n(x)dx\}^2}\right] \quad . \quad . \quad . \quad . \quad . \qquad (7).$$

But, as we are assuming that the motion is irrotational, we must have

$$\frac{\partial^2\{\mathrm{A}'_n(x)\xi'_n\}}{\partial\{\int b'_n(x)dx\}^2}=\frac{\partial^2\{\mathrm{A}'_r(x)\xi'_r\}}{\partial\{\int \mathrm{B}(x)dx\}^2}=\frac{\partial^2\{\mathrm{A}_r(x)\xi_r\}}{\partial\{\int \mathrm{B}(x)dx\}^2}=\frac{\partial^2\{\mathrm{A}_n(x)\xi_n\}}{\partial\{\int b_n(x)dx\}^2}=\frac{\partial^2 u}{\partial v^2} \quad . \quad . \qquad (8),$$

when $\mathrm{A}'_r(x)$ and $\mathrm{A}_r(x)$ are the laminæ adjacent on either side of boundary, $\mathrm{B}(x)$ is the breadth of $\mathrm{A}'_r(x)$ and $\mathrm{A}_r(x)$ at the boundary and $v=\int\mathrm{B}(x)dx$.

We may, therefore, neglecting quantities of the second order, write equation (7) in the following form :—

$$\frac{\partial^2 u}{\partial t^2}\left\{\frac{\Sigma\mathrm{R}'_n\mathrm{A}'_n(x)}{\mathrm{A}'(x)^2}+\frac{\Sigma\mathrm{R}_n\mathrm{A}_n(x)}{\mathrm{A}(x)^2}\right\}=g\frac{\partial^2 u}{\partial v^2}\{\Sigma\rho'_n b'_n(x)+\Sigma\rho_n b_n(x)\} \quad . \quad . \qquad (9),$$

or

$$\frac{\partial^2 u}{\partial t^2}=g\frac{\{\Sigma\rho'_n b'_n(x)+\Sigma\mathrm{R}_n b_n(x)\}}{\Sigma\mathrm{R}'_n\mathrm{A}'_n(x)/\mathrm{A}'(x)^2+\Sigma\mathrm{R}_n\mathrm{A}_n(x)/\mathrm{A}(x)^2}\frac{\partial^2 u}{\partial v^2} \quad . \quad . \quad . \qquad (10),$$

$$=g\sigma(v)\frac{\partial^2 u}{\partial v^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (11),$$

which is the same in form as the equation arrived at in our preliminary discussion, and as before, we find that the theory depends on the differential equation

$$\frac{\partial^2\mathrm{P}}{\partial v^2}+\frac{n^2\mathrm{P}}{g\sigma(v)}=0 \quad . \quad . \quad . \quad . \quad . \quad . \qquad (12),$$

$$\text{where } u=\Sigma\mathrm{P}\sin n(t-\tau) \quad . \quad . \quad . \quad . \qquad (13),$$

and where P is a function of v alone and τ is constant. Thus the methods used by Professor CHRYSTAL,* in his discussion of the ordinary seiche, are available here also. For the evaluation of the periods of oscillation possible in any lake with a known density distribution we must proceed to evaluate $\sigma(v)$ at a number of positions. This may be greatly simplified by assuming $\frac{\Sigma\mathrm{R}'_n\mathrm{A}'_n(x)}{\mathrm{A}'(x)^2}=\frac{1}{\mathrm{A}'(x)}$ and $\frac{\Sigma\mathrm{R}_n\mathrm{A}_n(x)}{\mathrm{A}(x)^2}=\frac{1}{\mathrm{A}(x)}$. The error in making this assumption is small, as R_n and R'_n are in nature always near unity, and it is only where their differences are concerned that we need take them into consideration.

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* "The Hydrodynamical Theory of Seiches," *Trans. Roy. Soc. Edin.*, xli. (iii.) p. 599.

Making this assumption, we have

$$\sigma(v)=\frac{\Sigma\rho'_n b'_n(x)+\Sigma\rho_n b_n(x)}{\dfrac{1}{\mathrm{A}(x)}+\dfrac{1}{\mathrm{A}'(x)}} \quad . \quad . \quad . \quad . \qquad (14).$$

If there is an abrupt temperature discontinuity with uniformity of density of ρ' above, and ρ below, this expression reduces to $\dfrac{\mathrm{B}(x)(\rho-\rho')}{\dfrac{1}{\mathrm{A}(x)}+\dfrac{1}{\mathrm{A}'(x)}}$, which is the form obtained in our preliminary investigation.

There remains the consideration of the depth at which the boundary should be taken.

Theoretically, an infinite number of modes of oscillation is possible, but in practice we find that only one period occurs, or at least that the oscillations which occur in any loch have very nearly the same period. There is, therefore, an element of doubt as to the depth at which the boundary should be taken. So long as the motion of the water particles is irrotational there must be slip at the boundary, and the physical difficulty to such a slip can be overcome by assuming the formation of a thin vortex sheet at the boundary, and, as the velocities are all small, such a sheet might be so thin as to be negligible for the purposes of this discussion. If we consider a body of water of gradually varying temperature, in which the isotherms have, from any cause, been inclined from the horizontal, but are now at liberty to return to the horizontal position, the force which is acting at any point is proportional to the rate of change of density at that point. Accordingly, if slip of one layer of water over another is to take place anywhere, it is most likely to occur where the density gradient is greatest.

Very often, in nature, there is a considerable distance through which the density gradient is at a maximum, and in such a case probably the exact depth at which slip takes place may be determined by the viscosity of the water, and as the viscosity of water decreases more rapidly as the temperature rises, it is likely that if there is any distance through which the density gradient is at a maximum, the slip will occur where the maximum gradient commences.

The foregoing theory does not attempt to be a rigorous mathematical treatment of the problem of standing waves in a heavy liquid of gradually varying density, and its usefulness will depend on the degree of accuracy with which it fits in with observed facts, but before applying the theory to the calculation of the periods of Loch Earn it will be well to summarise the assumptions made. Perhaps the greatest error is in the supposition that the motion is irrotational and that the effect of vortices, which are certain to be formed at the boundary, is negligible. We should expect the theory to give too short a period for the oscillation on this account. It is also assumed that the amplitude of the seiche is small compared with the depth of the lake, but this assumption is also wide of the mark, for the amplitudes which we find are often very large; on this account, also, the observed period should be greater than the calculated period. There is also uncertainty as to the depth at which the boundary should be chosen, and, as will have been seen from the discussion of the temperature observations, the temperature distribution at different points in the loch may be widely different, and the boundary may in reality not be a plane, but may be at different depths below the surface, its depth at any point depending on the temperature distribution at that point.

Calculation of the Period for Loch Earn.

To apply the theory in its most elaborate form to the calculation of periods it would have been necessary to take into account all the local variations of distribution, but it was felt that this was a refinement which the approximate character of the theory, and of the data at our disposal, would not warrant. Accordingly an average distribution for the whole loch was obtained by taking the mean for several depths of all the observations made at each station at 1 p.m. on 8th August. This hour was chosen because, from an inspection of the observations, it appeared that the discontinuity was nearly horizontal at that time. In taking the means, the observations at Stations I. to V. were only given half the weight of those at other stations. In fig. 18 are shown temperature-depth curves for the five stations, the heavy line showing the mean distribution of temperature for the whole loch, arrived at in this way. In the diagram

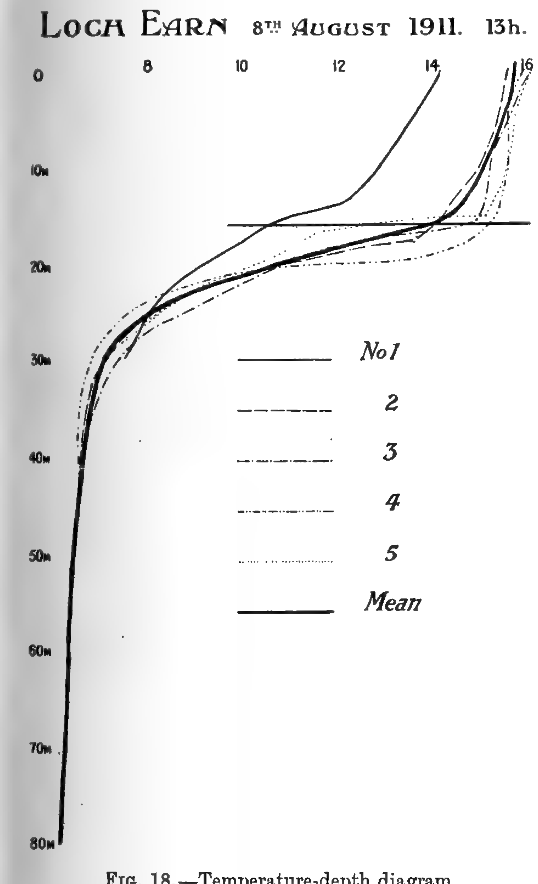

Fig. 18.—Temperature-depth diagram, 8th August, 1 p.m.

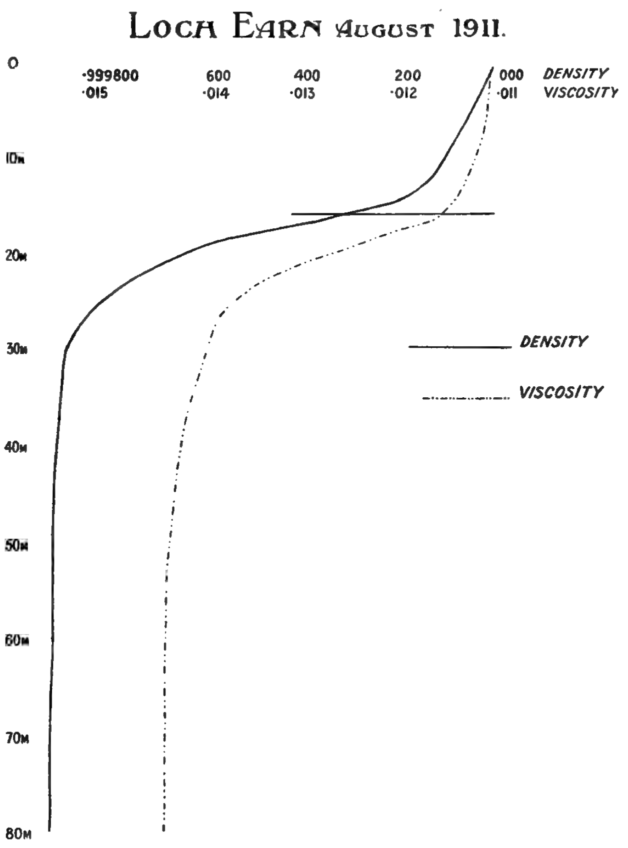

Fig. 19.—Density and viscosity diagram, 8th August, 1 p.m.

the depth of 16 metres is shown by a horizontal line. The next diagram (fig. 19) shows the density and viscosity distribution, corresponding to the mean temperature distribution, the depth of 16 metres being again marked by a horizontal line. The density gradient from 15 metres to 18 metres is pretty uniform, and, for the purposes of calculation, 16 metres was taken as the depth of the boundary. If the suggestion made in page 648 were carried out, the depth would have been taken at 15 metres; but as the difference in viscosity between 15 metres and 16 metres was so slight, there did not seem to be much justification for taking a less depth than 16 metres.

The next step in the calculation was the construction of the $\sigma(v)$ curve for the loch, and this was rather a laborious process. Cross sections were drawn for each point at which a sounding line had been made by the lake survey—28 in all—and the breadth of each cross section, at depths at intervals of a metre, was tabulated. By summing the breadths thus tabulated a good approximation to the areas of the cross section above and below the boundary was obtained, and from this $\frac{1}{A(x)}+\frac{1}{A'(x)}$ was calculated. Each breadth was then multiplied by the difference in density of the water at that depth, and at the depth of the succeeding metre. By summing the values so obtained, an approximation to $\Sigma\rho'_n b'_n(x)+\Sigma\rho_n b_n(x)$ was obtained for each cross section.

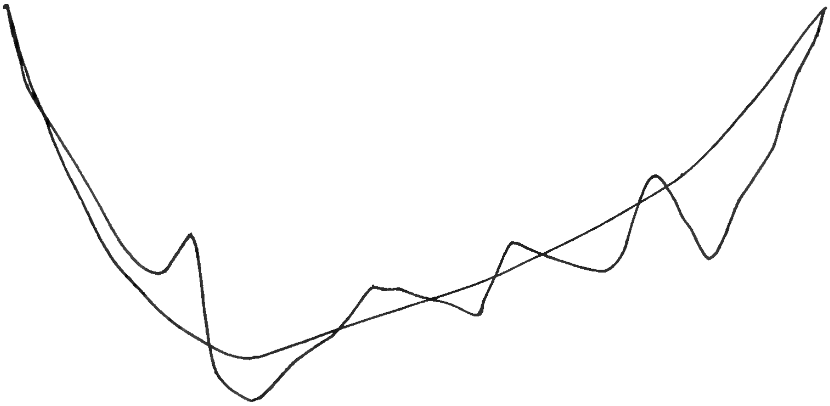

FIG. 20.—$\sigma(v)$ curve and biparabolic approximation.

The area, measured by planimeter along a 16-metre contour line drawn on the map, between successive cross sections, was then plotted against the values obtained for $\dfrac{\Sigma\rho'_n b'_n(x)+\Sigma\rho_n b_n(x)}{\dfrac{1}{A'(x)}+\dfrac{1}{A(x)}}$, the resulting curve, shown in fig. 20, being analogous to Professor CHRYSTAL'S seiche $\sigma(v)$ curve.

The method of least squares was employed to obtain an approximation to this curve by means of two parabolæ, just as was done by Professor CHRYSTAL and the author* in the case of ordinary seiches in Loch Earn. The details of the calculation are shown in the following table:—

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* *Trans. Roy. Soc. Edin.*, xli. (iii.) p. 823.

H, calculated by method of least squares $= 3{\cdot}632 \times 10^5$.

No. of Sounding Line.	v Unit 48010. sq. ft.	σ Unit $1{\cdot}016 \times 10^7$. cub. ft.	No. of Sounding Line.	v Unit 48010. sq. ft.	σ Unit $1{\cdot}016 \times 10^7$. cub. ft.	No. of Sounding Line.	v Unit 48010. sq. ft.	σ Unit $1{\cdot}016 \times 10^7$. cub. ft.
0	515	·00000	10	0	·04104	20	722	·02728
1	514	·00007	11	65	·03707	21	814	·01780
2	472	·00839	12	154	·03434	22	870	·02118
3	432	·01178	13	238	·02894	23	929	·02522
4	368	·01669	14	323	·02980	24	995	·02030
5	308	·02289	15	373	·02993	25	1047	·01567
6	260	·02590	16	455	·03180	26	1111	·00665
7	195	·02716	17	528	·02450	27	1149	·00356
8	132	·02349	18	591	·02570	28	1168	·00000
9	87	·03761	19	654	·02704			

Proceeding in exactly the same way as in the previous Loch Earn calculations, a period of 14·99 hours was obtained, which is remarkably close to the observed period of 15·2 hours.

A further calculation was made on the assumption that the boundary should have been taken at a depth of 17 metres, and this gave a period of 14·7 hours. The calculation for a 15-metre boundary was not made, but inspection of the other calculations makes it probable that a figure of about 15·3 metres would be obtained, so that the period as calculated from the theory is well within the experimental limits of accuracy.

As stated on page 640, the period of the oscillation on 15th August was about 14 hours. The reason for this is, doubtless, to be found in the higher surface temperature, and a very rough calculation of the period to be expected with the temperature distribution at that time gave 13·8 hours.

A calculation of the binodal period under the same conditions gives 8·44 hours, whereas the observed period was 8·2 hours. The observed ratio of the uninodal period to the binodal, $\frac{15{\cdot}2}{8{\cdot}2}$ (*i.e.* 1·85), is greater than in the case of the ordinary seiche, when it was $\frac{14{\cdot}5}{8{\cdot}1}$ (*i.e.* 1·79), though theoretically the ratio should be nearly the same, viz. $\frac{14{\cdot}99}{8{\cdot}44}$ (*i.e.* 1·78). The reason of the discrepancy is probably that, with the higher nodalities, the assumptions on which the theory is based are not so accurate as they are for the ordinary seiche.

Before the theory was developed the period of the oscillations was calculated by the method used for the Madüsee, and which gave quite good results in that case. But the period which the calculation gave was about 16 hours, and it was this discrepancy which suggested the extension of the theory. The reason of the agreement, which was obtained in the case of the Madüsee, is that the discontinuity was much sharper than in Loch Earn, and the conditions more nearly approximated to a sudden discontinuity in temperature. But in Loch Earn the discontinuity was seldom very sudden, and at the surface there was often a considerable temperature gradient. The temperature at the surface will be seen to be very important, and a first approximation to the period may be obtained by assuming there is a sudden discontinuity, above which all the water has the surface temperature, and below the bottom temperature. In the foregoing calculation for Loch Earn, the surface temperature was taken as 15·7°—if it had been taken as 15·5° the calculated period would have been greater by about one per cent., which shows how responsive the period of the oscillation is to a small change in the density distribution of the loch.

EXPLANATION OF DIAGRAMS.

1. Sketch map of Loch Earn showing position of the observation stations. The nodal lines are those determined by Professor CHRYSTAL and the author for the ordinary seiche. Contour lines are drawn for 50, 100, 200, and 250 feet.

2. Boat moored, fore and aft, at Station I., showing sounding drum for thermometers in bow, and two drums for current-meters at stern.

3. Mr YOUNG winding up thermometer, showing method of using sounding machine.

4. Mr PASKE reading thermometer. Observe lead marks on the sounding wire.

5. This is a reproduction of the thermograph record at Tighnadalloch, which was of the ordinary Richard pattern. It was situated in the open in a very roughly fashioned screen.

6. This diagram shows temperature-depth diagrams for each station, from noon on 5th August to noon on the 6th. The first horizontal line of diagrams refers to Station I., the second to Station II., and so forth. The first vertical column gives curves drawn from observations between noon and 6 p.m. on the 5th. The continuous curve refers to observations made between noon and 1 p.m., the broken line to observations between 2 and 3 p.m., and the dotted line to observations between 4 and 5 p.m. The second vertical column similarly gives curves for observations between 6 p.m. and midnight, for alternate hours; the third column for observations up to 6 a.m. on the 6th, and the fourth column for observations up to noon. The temperature scale in each case is horizontal and the depth scale is vertical.

7. This diagram is drawn in exactly the same way as the preceding one, for the period from noon on 10th to noon on 11th August, but the curves at each station are only for the hours noon to 1 p.m. and 6 to 7 p.m. on the 10th, and for midnight to 1 a.m. and 6 to 7 a.m. on the 11th.

8. This diagram is drawn in the same way as No. 6, save that the first horizontal line refers to observations on the 7th at Station I., the second to observations on the 8th at Station I., the third to observations on the 7th at Station V., and the fourth to observations on the 8th at Station V.

9. This diagram is drawn in the same manner as the preceding ones, but each curve represents the observations between midnight and 1 a.m. at Station III., on successive days from 12th to 23rd August.

10. The first 8 curves on this diagram represent the observations at Station V. at six-hour intervals, on 24th and 25th August. The ninth curve is from observations at Station I. between 11 p.m. and midnight on the 25th.

11. This diagram shows the variation in depth of isotherms for 10°, 12°, 14°, 16°, and 17°, at Station I. throughout the month, the time scale being horizontal and the depth scale vertical.

12–14. These diagrams show similarly the variations in level of isotherms for 8°, 10°, 12°, and 14°, at Stations II., III., and IV. respectively.

15. This diagram shows the variation in level of isotherms for 10°, 12°, and 14°, at Station V., and also the wind pressure throughout the month (measured vertically in kilograms per square metre), drawn by taking hourly means from the anemograph records. The line at the top of the diagram indicates the direction of the wind.

16. Each of the sixteen portions of this diagram represents a longitudinal section of the loch, the depth scale being greatly exaggerated. The blackened portion represents the space between 9° and 11° isotherms, for successive hours, from 1 a.m. to 4 p.m. on 9th August.

17. This diagram shows the variation in level of isotherms for 7°, 9°, 11°, 13°, 15°, and 17°, at Station I. throughout the month. It differs from fig. 12 in that the relative position of the isotherms is shown, and the depth scale is much greater.

18. This shows, by means of the ordinary temperature-depth diagram, the distribution at each of the stations, as shown by the observations made from noon to 1 p.m. on 8th August. The heavy black line is drawn from the mean of these observations, and is supposed to represent the average distribution of temperature over the whole loch.

19. This diagram shows the density and viscosity distribution, corresponding to the average temperature distribution of the preceding diagram.

20. The normal $\sigma(v)$ curve is shown by the irregular line, the biparabolic approximation by the smooth line.

EXPLANATION OF TABLES.

Table I.—Current Observations. The first three columns give particulars of the date of the observations, the depth at which they were made, and their duration. The fourth column gives actual directions recorded, in degrees West of North. A number prefixed to a direction indicates that there were two determinations of that direction, *e.g.* 2 N. 270 W. means that the current-meter during the observation twice indicated a current of N. 270° W., *i.e.* due East. The fifth column gives the average direction in degrees East or West of North obtained from the various determinations of direction for each observation. The last column gives the velocity of the current in centimetres per second calculated from the calibration formulæ supplied with the instruments.

Table II.—Temperature Observations. The date of the observations is shown in the margin. The hour of observation is shown at the top of each page, the hours being numbered consecutively from 1 to 24. The observations indicated as made at hour 1 were made during the hour from midnight to 1 a.m., those indicated as made at hour 24 were made between 11 p.m. and midnight, and so forth. The depth of observation is indicated at the left of each page.

TABLE I.

CURRENT-METER OBSERVATIONS TAKEN ON LOCH EARN, AUGUST 1911.

STATION I.

Date.	Depth.	Duration of Experiment.	Direction Indications.	Average Current.	
				Direction.	Velocity.
	fathoms.	minutes.			cms. p. sec.
11.8.11	0	31	2 N. 230 W. 4 N. 240 W. 1 N. 250 W.	N. 124 E.	4·38
–	2	31	1 N. 200 W. 1 N. 250 W.	N. 135 E.	1·19
	4	31	none.	-	2·03
–	6	31	none.	–	0·95
–	8	30	1 N. 340 W.	N. 20 E.	1·11
–	10	44	1 N. 180 W.	N. 180 W.	0·57
–	12	30	1 due N. 2 N. 70 W. 1 N. 340 W. 2 N. 350 W.	N. 17 W.	1·38
–	13	40	none.	–	0·73
–	15	97	1 N. 180 W. 1 N. 320 W.	N. 110 E.	0·59
12.8.11	0	31	1 N. 310 W.	N. 50 E.	2·10
–	1	35	1 N. 60 W.	N. 60 W.	0·78
–	2	32	none.	–	0·93
–	3	33	1 N. 350 W.	N. 10 E.	0·69
–	3	33	1 N. 350 W.	N. 10 E.	1·01
–	4	31	1 N. 110 W.	N. 110 W.	1·34
–	5	100	1 N. 30 W. 3 N. 80 W. 1 N. 100 W. 1 N. 130 W. 1 N. 60 W. 4 N. 90 W. 2 N. 120 W.	N. 89 W.	2·29
–	6	31	1 N. 60 W. 1 N. 90 W.	N. 75 W.	1·83
–	6·5	11	1 N. 130 W.	N. 130 W.	1·50
–	7	22	1 N. 230 W. 1 N. 240 W. 2 N. 270 W.	N. 108 E.	3·32
–	7	21	1 N. 90 W. 1 N. 120 W.	N. 105 W.	0·93
–	8	32	1 N. 20 W. 1 N. 40 W.	N. 30 W.	1·64
–	9	30	none.	–	0·62
–	10	98	1 due N. 1 N. 200 W. 1 N. 240 W. 1 N. 290 W. 2 N. 180 W. 1 N. 220 W. 1 N. 250 W. 1 N. 310 W.	N. 112 E.	2·15
–	11	31	none.	–	–
–	12	31	1 N. 10 W. 1 N. 80 W.	N. 45 W.	2·78
–	13	39	none.	–	–
–	14	32	1 N. 170 W.	N. 170 W.	1·18
–	15	32	none.	–	0·67
–	0	30	1 N. 240 W. 1 N. 270 W. 1 N. 260 W. 3 N. 290 W.	N. 87 E.	3·64
13.8.11	0	30	1 N. 240 W. 1 N. 260 W. 1 N. 270 W.	N. 103 E.	2·27
–	1	30	2 N. 240 W.	N. 120 E.	0·72
–	2	32	1 N. 210 W.	N. 150 E.	0·95
–	3	33	none.	–	0·54
–	4	34	none.	–	0·88
–	5	32	none.	–	0·67
–	6	32	1 due N.	due N.	1·13
–	8	30	none.	–	0·97
–	9	86	1 N. 180 W.	N. 180 W.	0·87
–	10	51	none.	–	0·89
–	11	27	1 N. 160 W.	N. 160 W.	0·65
–	12	31	1 N. 160 W.	N. 160 W.	1·12
–	15	31	none.	–	–
14.8.11	0	86	none.	–	0·84
–	2	35	1 N. 20 W.	N. 20 W.	1·47
–	6	28	none.	–	0·90
–	14	125	1 due N. 1 N. 340 W.	N. 10 E.	1·01
–	15	136	none.	–	0·53

TABLE I.—*continued.*

CURRENT-METER OBSERVATIONS TAKEN ON LOCH EARN, AUGUST 1911.

STATION III.

DATE.	DEPTH.	DURATION OF EXPERIMENT.	DIRECTION INDICATIONS.	AVERAGE CURRENT.	
				DIRECTION.	VELOCITY.
	fathoms.	minutes.			cms. p. sec.
14.8.11	0	15	2 N. 260 W. 4 N. 240 W.	N. 113 W.	4·65
14.8.11 15.8.11	25	1098	1 N. 150 W.	N. 150 W.	0·50
14.8.11 15.8.11	40	1097	1 N. 20 W.	N. 20 W.	0·80
15.8.11	0	95	1 N. 20 W. 1 N. 60 W. 1 N. 90 W. 3 N. 130 W. 1 N. 50 W. 1 N. 80 W. 1 N. 100 W. 2 N. 140 W. 1 N. 150 W.	N. 102 W.	1·97
–	5	20	1 N. 80 W.	N. 80 W.	0·88
–	10	29	2 N. 220 W.	N. 140 E.	2·03
–	15	28	1 N. 10 W. 1 N. 190 W.	N. 100 W.	1·74
–	20	88	1 N. 290 W. 1 N. 320 W. 1 N. 330 W.	N. 47 E.	1·21
15.8.11 16.8.11	25	1000	1 due N. 1 N. 190 W. 1 N. 220 W. 1 N. 320 W. 1 N. 130 W. 2 N. 200 W. 1 N. 230 W. 1 N. 340 W.	N. 157 E.	0·93
15.8.11 16.8.11	40	1025	1 due N. 1 N. 220 W. 2 N. 240 W. 2 N. 350 W. 2 N. 210 W. 2 N. 230 W. 1 N. 260 W.	N. 129 E.	0·62
16.8.11	0	31	1 N. 160 W. 1 N. 170 W. 1 N. 180 W.	N. 170 W.	1·53
–	1	35	1 N. 120 W.	N. 170 W.	0·87
–	3	75	2 N. 180 W. 4 N. 200 W. 1 N. 220 W. 2 N. 190 W. 5 N. 210 W.	N. 159 E.	4·82
–	3	30	none.	–	0·52
–	4	34	none.	–	–
–	5	50	none.	–	0·64
–	7	69	none.	–	0·52
–	10	81	none.	–	–
–	11	34	none.	–	–
–	14	73	1 N. 10 W.	N. 10 W.	0·90
–	16	53	1 N. 40 W.	N. 40 W.	0·86
–	18	67	none.	–	0·81
–	20	36	none.	–	0·82
–	0	17	4 N. 240 W. 2 N. 250 W.	N. 117 E.	5·28
16.8.11 17.8.11	25	1013	1 N. 340 W. 1 N. 350 W.	N. 15 E.	0·52
16.8.11 17.8.11	40	1003	1 due N. 1 N. 20 W.	N. 10 W.	0·82
17.8.11	0	74	none.	–	0·00
–	3	31	3 N. 70 W.	N. 70 W.	2·48
–	7	224	1 N. 90 W. 5 N. 250 W. 1 N. 270 W. 3 N. 240 W. 4 N. 260 W.	N. 119 E.	1·35
–	9	35	1 N. 270 W. 1 N. 280 W.	N. 85 E.	2·14
–	10	232	1 N. 250 W. 7 N. 270 W. 3 N. 260 W. 3 N. 280 W.	N. 92 E.	1·22
–	12	32	none.	–	0·53
–	15	33	none.	–	0·00
–	0	35	4 N. 50 W. 4 N. 60 W. 5 N. 70 W.	N. 61 W.	9·79
17.8.11 18.8.11	25	826	1 N. 180 W. 3 N. 240 W. 2 N. 260 W. 1 N. 300 W. 1 N. 230 W. 2 N. 250 W. 2 N. 270 W. 2 N. 310 W.	N. 102 E.	1·09
17.8.11 18.8.11	40	828	none.	–	0·54
18.8.11	0	35	4 N. 80 W. 3 N. 90 W. 2 N. 100 W.	N. 88 W.	12·10
–	2	26	1 N. 40 W. 2 N. 70 W. 1 N. 60 W. 1 N. 150 W.	N. 78 W.	7·12

TABLE I.—*continued.*

CURRENT-METER OBSERVATIONS TAKEN ON LOCH EARN, AUGUST 1911.

STATION III.—*continued.*

DATE.	DEPTH.	DURATION OF EXPERIMENT.	DIRECTION INDICATIONS.	AVERAGE CURRENT.	
				DIRECTION.	VELOCITY.
	fathoms.	minutes.			cms. p. sec.
18.8.11	4	33	1 N. 230 W. 1 N. 270 W. 1 N. 240 W. 1 N. 280 W.	N. 105 E.	2·27
–	6	41	1 N. 220 W. 1 N. 250 W. 2 N. 290 W. 3 N. 310 W. 1 N. 230 W. 2 N. 280 W. 3 N. 300 W. 1 N. 320 W.	N. 75 E.	4·63
–	7	39	1 N. 240 W. 3 N. 260 W. 3 N. 280 W. 1 N. 300 W. 1 N. 250 W. 2 N. 270 W. 2 N. 290 W.	N. 96 E.	7·83
–	8	39	1 N. 190 W. 1 N. 200 W. 1 N. 240 W.	N. 150 E.	1·51
–	9	26	1 N. 50 W.	N. 50 W.	1·38
–	10	45	1 N. 50 W. 2 N. 80 W. 3 N. 150 W. 2 N. 60 W. 1 N. 100 W.	N. 98 W.	3·30
–	12	38	1 N. 40 W. 1 N. 60 W. 1 N. 90 W. 3 N. 50 W. 1 N. 80 W. 1 N. 120 W.	N. 67 W.	3·83
–	13	27	1 N. 100 W. 3 N. 160 W.	N. 145 W.	2·54
–	14	54	2 N. 50 W. 1 N. 80 W. 1 N. 330 W. 1 N. 70 W. 1 N. 150 W.	N. 122 W.	2·34
–	15	41	1 N. 50 W. 1 N. 170 W.	N. 110 W.	1·17
–	16	88	1 N. 150 W. 1 N. 180 W.	N. 165 W.	1·07
–	17	19	1 N. 110 W. 1 N. 150 W.	N. 130 W.	1·50
–	18	57	1 N. 160 W.	N. 160 W.	1·12
–	20	40	1 N. 210 W. 1 N. 230 W.	N. 140 W.	1·45
–	0	16	1 N. 30 W. 1 N. 40 W.	N. 35 W.	3·24
18.8.11 19.8.11	35	992	1 N. 20 W. 1 N. 60 W. 1 N. 50 W. 2 N. 160 W.	N. 90 W.	0·56
18.8.11 19.8.11	25	1000	1 N. 20 W. 2 N. 160 W. 2 N. 180 W. 1 N. 50 W. 1 N. 170 W.	N. 131 W.	0·89
19.8.11	0	33	1 N. 230 W. 2 N. 250 W. 1 N. 270 W. 1 N. 300 W. 2 N. 240 W. 4 N. 260 W. 1 N. 280 W.	N. 79 E.	4·94
–	2	27	2 N. 270 W. 1 N. 280 W. 1 N. 310 W.	N. 78 E.	2·35
–	4	47	none.	–	0·56
–	6	34	2 N. 70 W. 4 N. 80 W. 3 N. 90 W.	N. 81 W.	4·14
–	8	28	1 N. 70 W. 1 N. 90 W. 1 N. 80 W. 1 N. 110 W.	N. 87 W.	2·19
–	10·5	77	1 due N.	due N.	0·91
–	12	34	1 N. 340 W.	N. 20 E.	1·01
–	14	34	1 N. 150 W.	N. 150 W.	0·57
–	16	49	none.	–	0·51
–	18	73	none.	–	0·54
–	20	159	1 N. 150 W.	N. 150 W.	0·90
19.8.11 20.8.11	25	999	1 N. 10 W. 1 N. 160 W. 1 N. 70 W. 1 N. 170 W.	N. 102 W.	0·85
19.8.11 20.8.11	35	1016	1 N. 30 W. 1 N. 160 W. 1 N. 140 W.	N. 110 W.	0·53
20.8.11	0	202	1 N. 260 W. 1 N. 280 W. 2 N. 270 W. 1 N. 300 W.	N. 84 E.	1·11
–	8	213	1 N. 250 W. 3 N. 270 W. 4 N. 260 W. 4 N. 280 W.	N. 92 E.	7·97
–	13	195	1 N. 320 W.	N. 40 E.	0·89
–	20	183	none.	–	0·51
28.8.11	0	37	2 N. 50 W. 3 N. 60 W. 6 N. 70 W.	N. 64 W.	5·39
–	8	74	none.	–	0·88
–	10	65	1 N. 30 W. 1 N. 260 W. 1 N. 330 W.	N. 33 E.	1·11
–	20	37	2 N. 40 W. 3 N. 90 W.	N. 70 W.	1·07

TABLE I.—*continued.*

CURRENT-METER OBSERVATIONS TAKEN ON LOCH EARN, AUGUST 1911.

STATION V.

DATE.	DEPTH.	DURATION OF EXPERIMENT.	DIRECTION INDICATIONS.	AVERAGE CURRENT.	
				DIRECTION.	VELOCITY.
	fathoms.	minutes.			cms. p. sec.
21.8.11 22.8.11	17	952	1 N. 130 W.	N. 130 W.	0·51
22.8.11	0	31	1 N. 210 W. 2 N. 220 W. 1 N. 270 W.	N. 130 E.	2·25
–	2	57	1 N. 20 W. 1 N. 40 W.	N. 30 W.	0·91
–	4	56	none.	–	0·00
–	6	128	none.	–	0·00
–	12	98	none.	–	0·00
–	17	204	none.	–	0·51
22.8.11 23.8.11	17	955	none.	–	0·50
23.8.11	0	74	1 N. 230 W. 2 N. 250 W.	N. 117 E.	1·43
–	3	65	none.	–	0·65
–	6	80	1 N. 200 W. 1 N. 220 W. 1 N. 230 W.	N. 143 E.	1·15
–	9	126	1 N. 10 W.	N. 10 W.	0·93
–	13	83	none.	–	0·89
–	15	142	1 N. 120 W.	–	0·82
–	17	258	1 N. 310 W.	N. 50 E.	0·53
–	0	43	1 N. 130 W. 4 N. 150 W. 3 N. 140 W. 5 N. 160 W.	N. 150 W.	4·95
23.8.11 24.8.11	17	804	1 N. 200 W.	N. 160 E.	0·51
23.8.11 24.8.11	10	797	none.	–	0·81
24.8.11	0	35	1 N. 160 W. 1 N. 200 W.	N. 180 W.	1·13
–	3	141	1 N. 20 W.	N. 20 W.	0·84
–	4	35	1 N. 320 W.	N. 40 E.	2·99
–	6	427	none.	–	0·51
–	8	47	1 N. 10 W. 2 N. 340 W. 1 N. 350 W.	N. 10 E.	1·94
–	9	304	1 due N. 1 N. 50 W. 1 N. 10 W. 1 N. 120 W.	N. 45 W.	1·01
–	14	401	none.	–	0·51
–	17	417	1 due N. 1 N. 200 W. 1 N. 260 W. 1 N. 170 W. 2 N. 230 W. 1 N. 290 W.	N. 111 E.	1·21
–	0	31	2 N. 10 W. 1 N. 80 W. 1 N. 160 W. 1 N. 50 W. 1 N. 130 W.	N. 73 W.	2·94
25.8.11	0	45	1 N. 20 W. 1 N. 120 W. 1 N. 150 W. 1 N. 50 W. 1 N. 130 W.	N. 94 W.	2·69
–	3	107	1 due N. 2 N. 90 W. 1 N. 130 W. 1 N. 70 W. 1 N. 110 W. 1 N. 210 W.	N. 100 W.	1·74
–	5	107	1 N. 240 W. 2 N. 270 W. 1 N. 320 W. 1 N. 340 W. 1 N. 250 W. 3 N. 310 W. 3 N. 330 W. 2 N. 350 W.	N. 52 E.	2·87
–	7	50	1 N. 260 W. 2 N. 290 W. 2 N. 320 W. 1 N. 280 W. 1 N. 310 W. 2 N. 330 W.	N. 57 E.	2·93
–	9	49	1 N. 170 W. 2 N. 200 W. 3 N. 220 W. 2 N. 270 W. 2 N. 190 W. 1 N. 210 W. 2 N. 240 W. 1 N. 310 W.	N. 135 E.	4·50
–	10	35	1 N. 170 W. 2 N. 240 W. 1 N. 300 W. 1 N. 330 W. 1 N. 200 W. 1 N. 270 W. 1 N. 320 W. 1 N. 340 W.	N. 92 E.	3·92
–	10	569	1 N. 40 W. 1 N. 170 W. 2 N. 340 W. 1 N. 120 W. 1 N. 190 W.	N. 160 E.	2·11
–	10·5	40	1 N. 160 W. 1 N. 220 W. 1 N. 270 W. 3 N. 210 W. 1 N. 250 W.	N. 141 E.	2·80
–	11	36	1 N. 200 W. 1 N. 210 W. 1 N. 290 W. 1 N. 300 W.	N. 110 E.	2·92
–	12	31	1 N. 340 W.	N. 20 E.	1·42
–	12	25	1 N. 140 W. 1 N. 350 W.	N. 115 E.	2·03
–	13	28	1 N. 350 W.	N. 10 E.	1·30
–	14	40	1 due N. 1 N. 10 W.	N. 5 W.	1·28
–	14	46	1 N. 180 W. 1 N. 350 W.	N. 95 E.	1·85
–	15	49	1 N. 180 W. 1 N. 210 W.	N. 165 E.	1·27
	16	571	2 due N. 3 N. 20 W. 1 N. 70 W. 1 N. 100 W. 2 N. 10 W. 1 N. 60 W. 1 N. 90 W. 1 N. 150 W. 2 N. 160 W.	N. 62 W.	1·13
–	17	57	2 N. 140 W. 2 N. 150 W. 1 N. 310 W.	N. 178 W.	1·58
–	17	42	1 N. 150 W. 1 N. 190 W. 1 N. 300 W. 1 N. 160 W. 1 N. 250 W.	N. 150 E.	1·85
–	0	45	none.	–	1·44
–	0	21	1 N. 30 W.	N. 30 W.	2·42
27.8.11	0	41	1 N. 130 W. 1 N. 140 W. 1 N. 150 W.	N. 140 W.	2·31
–	7·5	33	1 N. 10 W. 1 N. 70 W. 1 N. 80 W.	N. 53 W.	2·10
–	9	38	none.	–	0·81
–	10·5	54	1 due N.	due N.	0·90
–	12	116	2 N. 330 W.	N. 30 E.	0·68
–	14	131	none.	–	0·00
–	17	165	none.	–	0·00

TABLE II.

OBSERVATIONS AT STATION I.

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 6, 1911.	0	15·4	–	15·3	–	15·3	–	15·3	–	15·3	15·3	15·3	15·4	15·4	–	15·4	15·1	15·0	15·3	15·4	15·2	15·2	–	15·1	–
	6	–	–	–	–	–	–	15·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·2	–	15·2	–	15·2	–	13·3	–	13·0	12·9	12·8	12·9	12·8	–	13·1	15·1	13·5	13·8	14·6	14·6	14·3	–	13·9	–
	12	–	–	–	–	13·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	14·8	–	13·2	–	13·2	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	11·3 11·1	–	12·6	–	12·4	–	–	–	12·3	12·2	12·2	12·1	12·1	–	12·6	12·4	13·0	13·4	13·6	13·5	13·4	–	13·7	–
	18	10·8	–	11·5	–	–	–	–	–	–	–	–	10·7	–	–	11·6	–	–	–	–	–	–	–	–	–
	20	10·0	–	11·1	–	11·7	–	12·1	–	11·6	11·3	10·6	9·4	9·3	–	9·7	10·6	12·6	12·9	13·3	13·3	12·7	–	11·0	–
	22	–	–	–	–	–	–	–	–	11·2	9·9	8·7	7·8	–	–	–	–	–	–	–	–	–	–	9·2	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·6	–	–	–	–	–	–	–
	24	–	–	10·6	–	–	–	10·8	–	9·2	7·9	8·1	7·6	7·6	–	7·7	8·2	12·9	12·2	12·7	12·2	11·8	–	8·3	–
	25	9·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	26	–	–	–	–	–	–	9·9	–	–	–	–		7·1	–	–	–	9·7	11·1	11·9	11·0	10·8	–	–	–
	28	–	–	–	–	–	–	9·2	–	–	–	–	–	–	–	–	–	–	9·6	10·4	10·2	9·6	–	–	–
	30	8·1	–	10·0	–	11·1	–	8·5	–	6·9	6·9	7·0	7·0	6·9	–	6·9	6·9	7·7	8·8	9·2	9·8	8·6	–	6·8	–
AUGUST 7, 1911.	0	14·9	14·9	14·8	14·7	14·7	14·7	14·8	–	14·8	14·8	14·8	14·8	–	14·9	14·8	14·4	15·3	15·2	15·2	15·2	15·2	–	14·6	
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	13·9	13·5	13·5	13·6	13·6	13·8	13·3	–	14·2	14·3	14·6	14·4	–	14·1	14·1	13·9	13·7	13·2	13·1	13·3	13·4	–	13·6	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	12·1	12·8	–	–	–	–	–	–	–	–	–	12·4	11·9	10·7	11·4	–	–	–	–	–
	16	12·1	12·1	10·6	10·8	9·9	11·6	12·6	–	13·8	13·8	13·7	13·8	–	12·6	12·1	11·4	8·9	8·9	9·4	10·5	11·4	–	12·8	–
	18	10·7	10·3	9·5	9·1	–	9·2	11·1	–	–	–	–	–	–	11·3	10·2	8·8	–	–	–	–	–	–	–	–
	19	–	–	–	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	9·7	9·3	8·8	8·2	8·2	8·1	9·2	–	12·8	13·4	13·4	12·9	–	9·1	8·4	7·6	7·6	7·7	7·5	7·7	9·2	–	10·2	–
	22	8·4	8·3	7·9	7·6	7·6	–	8·3	–	12·3	–	–	12·0	–	–	–	–	–	–	–	–	–	–	–	–
	24	7·9	7·8	7·7	7·3	7·1	7·4	7·2	–	9·7	12·6	12·6	10·7	–	7·6	7·3	7·2	7·1	7·1	7·1	7·4	7·7	–	8·4	–
	26	–	–	–	–	–	–	–	–	–	12·1	11·2	8·6	–	–		–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	10·5	9·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	6·8	6·8	6·8	6·8	6·7	6·8	6·9	–	7·8	9·6	8·3	7·8	–	6·9	6·8	7·0	6·8	6·8	6·8	6·9	7·2	–	7·2	–
	32	–	–	–	–	–	–	–	–	–	–	7·7	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 8, 1911.	0	14·6	–	14·5	–	14·4	14·4	14·4	–	14·4	14·4	14·3	14·4	14·2	–	14·2	14·6	14·8	14·9	15·0	15·0	14·9	–	14·8	15·0
	6	–	–	–	–	13·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	13·7	–	13·5	–	13·3	13·3	13·4	–	13·3	13·2	12·8	12·4	13·0	–	14·1	14·2	14·3	14·6	14·8	14·6	14·4	–	14·6	14·6
	12	–	–	–	–	–	–	–	–	–	12·2	11·1	11·8	–	–	–	–	–		–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	11·4	10·7	9·8	10·6	12·2	–	–	–	–	–	–	–	–	–	–	–
	16	13·3	–	12·9	–	12·4	12·4	12·2	–	10·7	10·4	9·3	9·5	10·7	–	13·4	13·7	13·8	13·9	14·1	14·2	14·0		14·0	14·1
	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·0	13·2	12·2	–	12·8	12·6
	20	12·8	–	12·4	–	11·0	10·9	10·4	–	9·8	8·8	8·3	8·3	9·3	–	13·3	–	13·7	13·7	11·8	10·0	9·1	–	9·9	10·2
	22	–	–	–	–	–	9·6	9·5	–	8·7	–	–	–	–	–	–	–	–	11·8	10·1	–	8·4	–	9·6	9·1
	24	12·6	–	11·8	–	9·6	8·3	8·4	–	8·6	7·9	7·9	7·8	–	–	12·8 12·9	12·8	13·2	11·6	9·3	8·6	8·2	–	8·2	8·5
	26	12·1	–	11·2	–	8·9	–	–	–	–	–		–	–	–	–	12·6	10·2	9·4	–	–	–	–	–	–
	28	11·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·6		–	–	–	–	–	–
	30	11·4	–	10·4	–	7·3	7·5	7·9	–	7·1	7·0	6·9	7·2	7·6	–	10·2	11·1	8·8	9·2	8·3	7·2	6·7	–	7·5	7·2
AUGUST 9, 1911.	0	15·1	–	15·0	–	15·0	–	–	15·1	15·2	15·4	15·5	15·6	15·7	–	15·7	15·7	15·9	15·8	15·7	15·5	15·2	15·3	–	15·5
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	14·6	–	14·8	–	15·0	–	–	15·0	15·1	15·2	15·2	15·3	15·3	–	15·2	15·1	15·1	15·1	15·2	15·2	15·1	15·0	–	15·1
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·4	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	14·4	13·1	14·6	14·9	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	12·4	12·6	12·8	14·7	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·2	11·5	10·3	10·3	–	11·7	–	–	–
	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·9	9·6	11·2	11·3	13·6	–	–
	16	14·3	–	13·2 13·4	–	14·8	–	–	14·9	15·0	15·1	15·1	15·1	14·5 12·8	–	9·3	10·3	8·4	8·6	8·6	10·3	10·8	–	–	14·9
	17	–	–	–	–	–	–	–	–	–	–	15·1	–	–	–	–	–	–	–	–	–	–	10·7	–	–
	18	10·2	–	13·3 9·6	–	–	–	–	–	–	–	9·6 10·6	11·6	9·6	–	8·3	–	–	7·8	8·2	8·9	9·6	–	–	–
	20	9·1	–	9·1	–	14·6	–	–	14·9	15·0	14·1	11·3	9·6	7·9	–	7·6	7·4	9·8	7·3	7·4	8·4	9·1	10·3	–	13·3
	22	–	–	–	–	14·6 14·7	–	–	14·9	14·7	10·6	8·7	–	–	–	–	–	–	–	–	–	–	–	–	12·0
	24	8·1	–	8·1	–	10·0	–	–	14·8	11·6	8·8	8·2	7·3	7·2	–	7·1	7·1	7·2	–	–	–	–	–	–	11·0
	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	–
	26	–	–	–	–	–	–	–	12·1	9·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	10·2	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·3	–	7·4	–	7·7	–	–	8·5	7·7	7·4	7·1	6·8	6·8	–	6·6	6·7	6·7	6·8	–	6·8	6·9	6·9	–	10·0

Table II.—*continued.*

OBSERVATIONS AT STATION I.—*continued.*

I PTH. M RES.	HOUR OF OBSERVATION.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	–	15·4	15·2	15·1	–	15·2	15·3	15·2	–	15·3	15·6	15·8	15·8	–	15 9	15·9	16·1	16·0	16·1	16·1	16·0	–	15·6	15·6	*AUGUST* 10, 1911.
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	14·4	14·4	14·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	15·1	15·0	14·2	–	13·6	13·8	13·8	–	13·4	13·3	14·4	14·7	–	15·1	15·1	14·9	14·5	14·4	14·9	14·4	–	15·1	15·4	
	–	–	13·7	13·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	·	–	
	–	13·7	12·6	12·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	13·2	12·2	12·3	–	12·2	12·2	12·2	–	11·6	12·1	11·2	12·1	–	14·3	14·3	14·0	13·3	13·7	13·7	13·3	–	14·4	14·4	
	–	–	–	–	–	–	–	–	–	–	10·9	–	–	–	–	13·9	–	12·7	–	12·3	12·2	–	13·3	13·5	
	–	11·7	11·5	11·6	–	11·4	11·4	11·0	–	9·6	9·6	9·4	10·7	–	13·3	13·2	12·5	12·2	12·1	11·2	11·1	–	11·6	11·2	
	–	–	–	11·2	–	10·6	10·1	9·2	–	8·5	8·5	8·3	10·1	–	–	–	11·0	9·9	9·6	–	–	–	–	–	
	–	10·9	10·8	10·3	–	9·3	8·9	8·4	–	7·8	7·8	7·8	8·9	–	12·3	12·2	9·7	9·1	8·8	9·4	9·4	–	9·3	8·7	
	–	–	–	–	–	8·7	–	–	–	–	–	–	–	–	12·2	10·4	–	–	–	–	–	–	–	–	
{	–	10·6	9·3	8·5	–	7·3	7·2	7·3	–	7·2	7·2	7·3	7·4	–	11·2	8·3 8·4	8·1	7·8	7·7	7·5	7·7	–	7·2	6·8	
	–	15·7	–	15·7	15·7	15·7	–	15·7	15·7	16·0	16·1	16·1	16·0	–	16·4	16·6	16·6	16·4	16·4	16·4	16·4	–	16·4	15·9	*AUGUST* 11, 1911.
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	15·4	–	15·6	–	15·6	–	15·6	15·6	15·7	15·6	15·7	15·7	–	16·1	16·1	16·1	16·2	16·4	16·3	16·3	–	16·4	15·9	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·6	
{	–	14·8	–	15·1	15·4	15·4	–	15·3	14·8	14·0	14·3	14·8 15·0	15·6	–	15·7	15·8	16·1	16·2	16·3	16·3	16·3	–	16·4	13·5	
	–	–	–	–	–	–	–	–	–	–	–	12·5	13·0	–	–	–	–	–	–	–	–	–	–	–	
	–	12·1	–	13·0	13·0	14·4	–	–	–	11·2	10·9	10·1	10·3	–	15·4	15·7	–	16·2	16·2	–	–	–	11·2	10·4	
	–	–	–	–	–	12·6	–	–	–	–	9·7	–	–	–	12·3	15·6	–	–	–	–	–	–	–	–	
	–	10·0	–	10·2	10·7	11·0	–	12·4	9·9	9·6	9·3	8·9	9·4	–	9·9	11·3	14·7	12·1	14·2	16·1	15·8	–	10·6	10·6	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·5	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–		9·2	9·9	9·4	9·3	9·4	8·9	–	–	–	
	–	7·9	–	7·9	8·3	8·4	–	9·1	8·2	8·1	7·9	7·7	7·7	–	7·8	8·1	8·3	8·3	8·4	8·4	8·2	–	9·8	9·2	
	–	6·8	–	6·8	7·1	7·2	–	7·1	7·4	7·4	7·2	7·2	7·1	–	7·0	7·2	7·1	6·9	7·0	·7·1	6·9	–	8·4	8·0	
	–	16·4	–	16·4	–	16·2	16·2	16·2	–	16·3	16·3	16·3	16·4	–	16·6	16·6	16·7	16·6	16·7	16·7	16·6	–	16·5	16·6	*AUGUST* 12, 1911.
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	16·3	–	16·4	–	16·2	16·2	16·2	–	16·2	16·2	16·2	16·2	–	16·3	16·4	15·4	16·5	16·5	16·6	16·5	–	16·5	16·5	
	–	–	–	–	–	–	–	–	–	·	–	–	–	–	–	–	–	–	–	–	16·1	–	–	–	
	–	–	–	16·1	–	16·1	–	–	–	–	–	–	–	–	–	–	16·4	15·7	15·7	14·3	13·6	–	16·3	16·5	
	–	–	–	11·9	–	13·2	–	–	–	–	–	·	–	–	–	–	–	–	13·0	–	–	–	–	–	
	–	13·2	–	11·2	–	11·1	14·2	16·1	–	–	–	–	16·0	–	12·3	12·6	13·1	12·9	12·8	12·8	12·8	–	13·3	14·2	
	–	–	–	–	–	–	11·2	15·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	11·1	–	10·6	–	–	11·1	11·6	–	15·8	14·2	12·8	11·9	–	11·8	12·0	–	12·1	12·2	12·3	12·3	–	12·6	13·3	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·0	–	–	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	11·3	11·4	–	–	–	–	–	–	–	–	–	–	–	–	–	
	–	10·0	–	9·4	–	9·7	10·0	10·4	–	10·6	10·6	10·9	11·0	–	11·1	11·2	11·1	11·3	11·3	11·1	11·1	–	11·3	12·4	
	–	–	–	–	–	–	–	–	–	–	–	10·4	–	–	–	–	–	–	–	9·8	9·3	–	–	11·7	
	–	8·8	–	8·7	–	8·9	9·4	–	–	10·0	10·1	10·3	10·4	–	10·6	9·7	9·6	8·8	8·8	8·3	8·7	–	9·1	9·9	
	–	8·3	–	7·3	–	7·7	8·2	8·7	–	8·6	8·6	8·8	9·8	–	8·1	7·8	7·4	7·4	7·3	7·2	7·2	–	7·2	7·6	
	–	16·7	–	16·6	–	16·5	–	16·5	–	16·6	16·6	16·7	16·7	–	17·1	17·2	17·3	17·5	17·6	17·6	17·4	–	17·1	17·2	*AUGUST* 13, 1911.
	–	16·5	–	16·4	–	16·4	–	16·4	–	16·5	16·5	16·6	16·5	–	16·6	16·7	16·6	16·7	16·6	16·6	16·7	–	16·7	16·7	
	–	–	–	–	–	–	–	–	–	16·2	13·9	–	–	–	–	–	–	–	–	–	–	–	15·9	–	
	–	16·2	–	14·7	–	14·2	–	13·8	–	13·8	–	–	–	–	–	16·5	–	–	–	–	–	–	13·8	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·3	–	–	–	–	–	–	–	–	
	–	13·4	–	13·2	–	13·2	–	13·2	–	13·4	13·4	13·4	13·5	–	13·8	14·3	14·4	16·4	14·4	14·0	13·8	·	13·4	12·8	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	·	–	12·6	
	–	–	–	–	–	–	–		–	12·7	12·7	13·4	12·5	–	–	–	–	13·9	–	–	–	–	11·7	9·9	
	–	12·5	–	12·1	–	11·6	–	11·4	–	11·2	10·4	12·7	10·1	·	11·6	12·6	13·2	13·3	13·3	12·3	11·4	–	9·3	8·9	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·8	–	–	–	–	11·1	–	–	–	–	
	–	11·4	–	10·9	–	9·9	–	9·7	–	–	–	8·5	8·2	–	9·1	–	–	12·5	11·4	10·0	9·6	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	–	–	
	–	9·8	–	9·2		8·6	–	8·4	–	8·1	8·0	7·8	7·6	–	7·8	8·2	9·4	11·0	9·4	8·8	7·9	–	7·4	7·5	
	–	–	–	–	–		–	–	–		–	–	–	–	–	–	–	9·3	–	–	–	–	–	–	
		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	7·9	–	–	–	–	–	
	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·5	–	–	–	–	–	
	–	7·3	–	7·2	–	7·2	–	6·7	–	7·2	7·1	6·9	6·8	–	6·8	7·1	7·2	7·2	7·2	7·2	7·1	–	7·0	6·8	

TABLE II.—*continued.*

OBSERVATIONS AT STATION I.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 14, 1911.	0	–	17·1	–	16·9	–	16·7	16·7	16·8	–	16·9	17·1	16·8	17·1	–	17·2	17·2	17·2	17·2	17·2	17·2	–	17·3	–	17·4
	10	–	16·7	–	16·6	–	16·4	16·6	16·5	–	16·6	16·6	16·5	16·6	–	16·8	16·9	17·1	17·2	17·2	17·2	–	17·2	–	17·1
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	15·3	–	14·3	–	16·2	16·3	16·4	–	–	–	–	–	–	15·1	–	15·3	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14		13·7	–	13·9	–	13·9	14·2	14·7	–	14·7	–	–	–	–	13·9	–	14·1	–	–	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–
	16	–	13·0	–	13·0	–	13·3	13·5	13·8	–	14·1	13·8	13·7	16·5	–	12·7	16·9	13·3	13·7	13·7	13·8	–	13·9	–	13·7
	17	–	11·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	–	10·4	–	11·7	–	–	–	–	–	13·6	12·5	11·6	11·1	–	–	11·1	–	11·6	–	12·8	–	12·6	–	11·7
	19	–	–	–	11·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·1	–	–	–	–	–
	20	–	8·8	–	9·4	–	11·9	11·7	12·3	–	11·6	11·1	10·7	10·4	–	10·3	10·3	10·5	10·7	10·8	10·9	–	10·6	–	10·6
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	10·3	10·1	10·7	–	–	–	–	–	–	–	–	9·6	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	7·3	–	7·6	–	9·1	9·1	9·7	–	9·5	9·4	9·2	9·3	–	9·5	9·3	9·3	–	–	9·6	–	9·3	–	9·3
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·0	–	–	–	–	–	–
	30	–	6·8	–	6·8	–	7·1	7·4	7·7	–	8·2	8·3	8·0	8·3	–	8·3	8·4	8·6	8·2	–	8·3	–	8·1	–	7·9
AUGUST 15, 1911.	0	–	17·2	–	17·1	–	17·1	17·0	17·1	–	17·4	17·4	17·6	18·2	–	18·3	18·3	18·3	–	18·6	18·5	18·3	–	18·6	18·3
	10	–	17·0	–	16·8	–	16·8	16·8	16·7	–	16·9	16·9	16·8	16·8	–	16·7	16·9	16·8	–	16·7	16·7	16·3	–	16·5	16·7
	11	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	16·1	–	–	–	–	–	16·7	16·7	16·6	16·1	–	16·7	16·4	15·1	–	15·1	14·6	14·6	–	14·6	14·9
	13	–	–	–	14·2	–	–	–	–	–	15·8	16·0	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	13·7	–	13·9	–	14·1	–	14·9	14·9	14·5	14·4	–	14·2	14·4	14·1	–	14·1	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	–	13·2	–	11·8	–	12·4	12·7	12·3	–	13·8	13·9	13·9	13·9	–	13·6	13·7	13·4	–	13·8	13·3	13·3	–	13·8	14·1
	17	–	11·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	–	11·1	–	–	–	–	–	–	–	–		–	–	–	–	–	12·2	–	11·9	11·1	11·1	–	13·2	13·6
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	–	10·1	–	10·1	–	10·4	10·6	10·7	–	11·8	12·1	11·7	11·9	–	11·9	11·1	10·9	–	10·0	9·7	9·0	–	10·9	11·4
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	9·6	–	–	–	–	–	–	–	–	10·8	–	10·5	–	10·3	10·1	9·4	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	8·6	–	8·9	–	8·9	9·2	9·3	–	9·9	9·9	–	9·8	–	9·5	8·8	8·7	–	8·4	8·3	8·3	–	9·2	8·9
	25	–	–	–	–	–	–	–	–	–	–	–	9·1	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	7·7	–	7·8	–	7·7	7·3	7·4	–	7·8	7·4		7·7	–	7·2	7·2	7·2	–	7·3	7·3	7·4	–	7·7	7·2
AUGUST 16, 1911.	0	–	18·2	–	17·9	–	17·7	–	17·4	–	17·4	17·5	17·5	17·7	–	17·9	18·1	18·0	18·1	18·1	18·3	18·2	–	18·1	17·9
	10	–	15·6	–	15·0	–	14·8	–	15·0	–	15·1	–	15·0	15·2	–	16·1	16·2	16·4	16·2	16·1	16·2	16·1	–	16·5	16·6
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12		–	–	–	–	–	–	–	–	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	14·1	–	14·3	14·3	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	–	–	–	–	–	–	–	13·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	–	14·2	–	13·9	–	13·7	–	12·9	–	13·4	13·7	13·9	14·0	–	14·4	14·3	14·4	14·4	14·4	14·4	14·2	–	14·3	14·3
	17	–	–	–	–	–	13·3	–	12·6	–	12·7	–	12·9	–	–	–	–	–	–	–	–	–	–	13·2	–
	18	–	–	–	13·5	–	12·3	–	–	–	11·9	12·1	11·9	12·1	–	13·2	13·8	13·8	13·3	13·1	–	12·3	–	12·6	12·9
	19	–		–	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		11·2	–	–	11·6
	20	–	13·3	–	11·4	–	11·1	–	11·0	–	11·1	11·3	11·2	11·0	–	11·8	12·1	11·9	11·9	11·6	11·7	10·3	–	11·3	10·3
	21	–	12·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·3	–
	22	–	11·2	–	–	–	–	–	–	–	–	–	–	–	–	10·5	10·9	11·0	10·6	–	9·6	8·8	–	8·8	9·1
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	10·0	–	9·4	–	9·8	–	9·7	–	9·4	9·4	9·1	9·4	–	9·3	9·4	9·6	9·4	8·9	8·4	8·2	–	7·8	8·2
	30	–	7·8	–	7·8	–	7·8	–	8·4	–	7·8	8·2	7·8	7·9	–	7·6	7·7	7·5	7·2	7·2	7·2	7·2	–	7·4	7·3
AUGUST 17, 1911.	0	–	17·9	–	17·8	–	17·8	17·7	17·8	–	18·1	17·9	18·3	18·7	–	18·8	18·4	18·4	18·4	18·2	18·1	17·9	–	17·5	17·6
	10	–	16·6	–	16·4	–	16·1	16·1	16·0	–	16·5	16·6	16·6	16·7	–	16·4	16·0	15·6	15·0	14·9	14·9	15·0	–	14·9	14·9
	11	–	–	–	–	–	–	–	–	–	–	–	16·4	–	–	–		–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	15·6	15·5	15·9	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	15·1	15·1	–	–	–	14·4	–	–	–	–	–	–	–	–
	14	–	15·2	–	14·5	–	–		–	–	14·7	14·6	14·7	14·6	–	14·4	13·9	13·7	13·1	12·9	13·1	–	–	–	–
	15	–	–	–	–	–	–	–	–	–	14·1	14·4	14·1	13·6	–	13·4	13·3	–	–		–	–	–	–	–
	16	–	13·9	–	13·3	–	13·0	13·3	13·6	–	13·2	13·2	13·2	12·4	–	12·2	12·7	12·6	12·5	12·1	11·9	12·0	–	12·2	12·8
	17	–	–	–	–	–	–	–	–	–	12·5	12·2	12·2	11·8	–	–	–	–	–	–	–	–	–	–	–
	18	–	11·2	–	11·4	–	11·4	11·1	11·9	–	11·7	–	–	11·2	–	11·2	11·7	11·5	11·7	11·3	–	–	–	–	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	–	10·0	–	9·6	–	9·7	9·9	10·7	–	10·9	10·6	10·6	–	–	–	11·1	–	11·1	10·6	10·7	10·8	–	11·0	11·2
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	8·4	–	8·5	8·9	–	–	–	–	–	–	–	–	–	–	10·2	–	–	–	–	–	–
	24	–	8·1	–	7·6	–	8·1	8·1	8·3	–	8·8	9·0	9·3	9·3		9·3	9·6	9·8	9·7	9·6	9·5	9·5	–	9·7	10·1
	30	–	7·2	–	7·0	–	7·1	7·1	7·4	–	7·4	7·2	7·7	8·3	–	8·3	8·2	8·5	8·6	8·2	8·4	8·1	–	7·9	8·1

Table II.—*continued.*

OBSERVATIONS AT STATION I.—*continued.*

Depth. Metres.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	–	17·6	–	17·4	–	17·4	17·3	17·2	–	17·2	17·1	17·2	17·5	–	17·1	16·8	16·7	16·3	16·1	16·1	–	16·4	–	16·7	*AUGUST* 18, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·1	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	–	–	–	–	
10	–	15·2	–	15·1	–	15·4	15·3	15·3	–	15·2	15·1	15·1	15·0	–	15·1	15·1	15·0	15·1	15·0	15·1	–	15·1	–	15·6	
14	–	–	–	–	–	–	–	14·2	–	–	13·8	–	–	–	–	–	–	14·6	–	–	–	–	–	–	
16	–	13·9	–	13·7	–	13·9	13·7	13·2	–	12·8	12·4	12·4	12·3	–	12·5	13·3	13·9	–	14·5	14·4	–	14·6	–	14·8	
18	–	12·9	–	12·4	–	–	12·4	12·2	–	11·5	11·3	11·4	11·0	–	11·5	12·8	–	13·8	–	–	–	–	–	–	
20	–	12·1	–	11·8	–	11·9	11·7	11·3	–	10·4	9·7	9·2	9·1	–	10·1	11·1	12·4	12·8	–	–	–	12·4	–	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·3	–	–	–	–	–	11·1	
22	–	11·2	–	10·5	–	11·1	10·5	9·8	–	8·8	8·4	8·1	7·9	–	8·6	9·8	11·6	11·7	12·2	11·4	–	10·7	–	10·3	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·7	10·6	–	9 6	–	9·3	
24	–	10·5	–	–	–	9·7	9·1	8·4	–	8·0	7·8	7·7	7·6	–	7·6	8·1	9·8	10·8	10·8	9·7	–	9·3	–	8·7	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·4	9·2	–	–	–	–	
26	–	–	–	9·0	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	
28	–	–	–	8·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	–	8·3	–	7·8	–	7·7	7·6	7·4	–	7·3	7·2	7·1	7·0	–	6·9	7·1	7·2	7·6	7·7	7·6	–	7·5	–	7·6	
0	–	17·1	–	16·8	–	16·8	16·8	16·8	–	16·8	16·8	16·8	16·8	–	16·8	16·8	16·9	16·9	16·9	16·9	–	16·9	–	16·7	*AUGUST* 19, 1911.
10	–	15·6	–	15·8	–	16·1	16·1	16·2	–	16·3	16·3	16·4	16·7	–	16·8	16·8	16·8	16·9	16·9	16·8	–	16·9	–	16·7	
14	–	–	–	–	–	–	–	–	–	–	15·3	15·5	15·8	–	–	–	–	–	16·8	–	–	–	–	–	
15	–	–	–	–	–	–	–	–	–	–	–	15·2	–	–	–	–	–	–	–	–	–	–	–	–	
16	–	15·2	–	14·1	–	14·8	14·4	15·3	–	15·2	14·1	14·1	14·9	–	15·4	15·4	15·0	15·0	15·4	16·4	–	16·8	–	16·7	
17	–	–	–	–	–	–	13·8	–	–	–	13·6	–	13·9	–	14·1	13·9	13·5	13·5	–	–	–	15·8	–	16·6	
18	–	–	–	12·3	–	12·8	12·4	–	–	12·9	12·8	13·0	13·3	–	13·3	13·2	12·3	12·5	11·5	11·4	–	11·2	–	11·8	
19	–	–	–	–	–	12·2	–	–	–	–	–	12·2	12·4	–	12·2	11·8	10·8	11·0	–	–	–	–	–	–	
20	–	11·4	–	9·9	–	10·9	10·6	10·6	–	12·2	11·9	11 7	11·5	–	11·7	10·8	10·4	10·5	10·1	9·7	–	9·4	–	10·0	
21	–	–	–	–	–	–	–	–	–	–	10·9	–	11·2	–	10·9	–	–	–	–	–	–	–	–	–	
22	–	–	–	–	–	–	–	–	–	10·5	10·2	10·9	10·4	–	10·0	9·7	9·1	–	–	–	–	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	–	7·9	–	7·7	–	7·6	8·1	8·2	–	8·8	9·1	10·0	9·8	–	9·4	8·7	8·4	8·4	8·3	8·2	–	8·5	–	8·6	
26	–	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	
30	–	7·1	–	6·9	–	7·0	7·1	7·1	–	7·8	8·0	7·9	8·2	–	7·7	7·6	7·6	7·4	7·3	7·3	–	7·6	–	7·5	
0	–	16·7	–	16·7	–	16·7	–	16·7	–	16·9	17·1	17·1	16·9	–	17·8	17·8	18·2	17·4	17·2	–	17·2	17·1	–	17·1	*AUGUST* 20, 1911.
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·0	–	–	–	
10	–	16·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·8	–	16·7	–	–	17·1	–	17·1	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·7	–	16·7	–	–	–	–	–	
12	–	16·7	–	–	–	–	–	16·7	–	16·1	16·4	16·7	16·8	–	16·7	16·5	15·1	14·5	15·6	–	16·1	16·8	–	16·5	
13	–	–	–	–	–	16·7	–	12·5	–	13·4	13·8	16·2	16·3	–	15·4	14·5	14·1	13·4	14·6	–	14·3	14·6	–	–	
14	–	16·7	–	16·7	–	16·2	–	12·3	–	11·9	12·1	12·4	13·6	–	13·5	13·5	13·1	12·9	13·7	–	13·8	13·6	–	14·1	
15	–	16·7	–	15·0	–	12·2	–	–	–	11·4	11·6	11·9	12·6	–	12·8	12·9	–	12·8	–	–	13·1	–	–	–	
16	–	15·4	–	11·7	–	11·8	–	–	–	11·1	11·2	11·4	–	–	12·5	12·6	–	12·7	12·8	–	–	13·1	–	13·3	
17	–	–	–	11·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·4	–	–	–	
20	–	–	–	–	–	10·3	–	10·0	–	10·0	10·1	10·5	11·1	–	11·6	–	11·7	11·9	12·1	–	-	11·9	–	12·2	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·6	11·0	–	–	
22	–	8·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·9	–	10·6	
23	–	–	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·0	–	–	–	
24	–	–	–	–	–	–	–	9·4	–	9·6	9·7	–	–	–	10·7	10·8	9·9	9·8	9·9	–	-	9·6	–	9·2	
30	–	7·2	–	7·5	–	8·6	–	8·9	–	8·7	8·4	8·9	8·3	–	8·9	7·9	7·9	7·4	7·6	–	7·2	7·1	–	7·2	
0	–	17·2	–	17·2	–	17·2	–	17·2	–	17·2	17·2	16·9	17·7	–	17·7	17·6	17·6	17·4	17·4	17·4	17·4	–	17·5	17·6	*AUGUST* 21, 1911.
9	–	–	–	–	–	–	–	–	–	17·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	–	17·2	–	–	–	17·2	-	17·1	–	16·8	16·9	17·0	–	–	–	–	–	–	17·4	–	–	–	–	–	
11	–	–	–	–	–	–	–	-	–	15·0	15·3	16·8	16·8	–	17·1	17·1	17·2	17·4	–	–	–	–	–	17·2	
12	–	16·8	–	17·1	–	15·5	–	14·9	–	14·4	14·5	15·0	14·9	–	15·3	15·4	17·1	17·2	–	17·2	17·3	–	15·5	–	
13	–	14·4	–	15·0	–	14·4	–	–	–	–	–	14·4	14·5	–	14·6	14·8	15·3	16·8	15·6	–	–	–	-	14·6	
14	–	14·2	–	14·2	–	14·2	–	14·2	–	–	–	–	–	–	–	–	14·7	14·9	14·6	–	14·8	–	14·4	–	
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	–	14·4	–	–	–	14·2	
16	–	13·6	–	–	–	–	–	13·5	–	–	–	–	–	–	–	–	–	14·3	14·4	–	14·3	–	14·2	–	
17	–	–	–	–	–	–	–	–	–	12·8	13·4	·13·3	–	–	–	–	–	–	–	–	–	–	–	–	
18	–	–	–	13·3	-	12·7	–	12·4	–	12·2	12·7	12·8	12·9	–	13·3	—	-	13·9	13·8	13·7	13·9	–	–	13·6	
19	–	–	–	12·8	–	–	–	–	–	11·2	11·4	11·6	12·1	–	12·9	13·2	13·3	–	–	–	–	–	11·8	–	
20	–	11·9	–	11·7	–	11·5	–	10·6	–	10·1	10·4	10·4	10·8	–	10·9	11·7	13·0	13·2	13·2	–	–	–	–	12·8	
21	–	–	–	11·1	–	–	–	–	–	8·9	–	–	10·4	–	9·9	10·6	11·7	–	–	–	10·6	–	–	–	
22	–	10·1	–	9·9	–	10·0	–	9·9	–	8·7	–	–	–	–	–	10·0	10·3	12·8	–	10·1	–	–	9·1	8·8	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·4	9·6	9·9	–	–	–	–	–	
24	–	8·9	–	8·6	–	–	–	–	–	–	–	8·1	–	–	8·2	–	–	8·9	–	–	–	–	–	8·1	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·1	–	–	–	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	–	8·0	–	-	–	
30	–	7·3	–	7·4	–	7·4	–	7·2	–	7·1	7·1	7·1	7·2	–	7·2	7·2	7·2	7·4	7·6	7·3	7·6	–	7·5	7·3	

Table II.—*continued.*

OBSERVATIONS AT STATION I.—*continued.*

	Depth. Metres.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 22, 1911.	0	–	17·4	–	17·4	–	17·3	–	17·4	–	17·5	17·5	17·2	17·8	–	17·7	17·8	18·1	17·9	17·7	17·8	–	17·6	–	17·4
	8	–	–	–	17·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	17·3	–	17·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	17·2	–	15·6	–	15·6	–	16·7	–	17·3	17·2	17·2	17·2	–	17·2	–	–	17·2	17·2	17·2	–	–	–	–
	11	–	15·7	–	–	–	–	–	15·4	–	–	17·1	16·1	15·3	–	16·9	16·9	17·2	17·0	16·7	16·7	–	17·2	–	17·3
	12	–	14·9	–	14·6	–	14·6	–	14·9	–	15·8	15·2	15·0	15·0	–	15·4	15·5	15·2	15·3	15·0	15·0	–	16·0	–	17·2
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	14·6	–	15·0	–	15·3
	14	–	14·4	–	–	–	–	–	–	–	14·8	14·7	–	–	–	–	–	–	14·5	–	–	–	14·9	–	15·0
	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·8	13·9	13·9	–	14·4	–	–
	16	–	13·9	–	13·9	–	13·6	–	13·8	–	–	14·0	14·1	13·6	–	13·9	13·7	13·8	12·7	12·5	12·5	–	13·9	–	14·4
	17	–	13·3	–	13·3	–	12·4	–	12·3	–	–	13·6	12·1	11·7	–	12·4	12·4	11·9	11·7	11·5	11·5	–	12·7	–	13·0
	18	–	11·6	–	12·2	–	11·4	–	11·2	–	12·5	12·1	11·7	11·7	–	11·8	11·7	11·6	–	–	–	–	11·9	–	11·9
	19	–	10·6	–	11·7	–	–	–	–	–	–	–	–	–	–	–	11·4	–	–	–	–	–	–	–	–
	20	–	9·9	–	10·4	–	10·8	–	10·4	–	11·4	11·2	–	–	–	–	–	–	10·4	10·3	10·3	–	10·7	–	10·9
	21	–	–	–	9·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	8·1	–	8·7	–	9·2	–	9·6	–	9·9	–	9·7	9·6	–	9·7	9·4	9·6	9·1	9·1	9·1	–	9·4	–	9·7
	30	–	7·4	–	7·8	–	7·8	–	8·9	–	8·3	8·9	8·6	8·9	–	8·3	8·1	8·0	7·8	7·8	7·8	–	8·2	–	8·3
AUGUST 23, 1911.	0	–	17·5	–	17·4	–	17·4	17·4	17·4	–	17·4	17·5	17·5	18·0	–	17·8	17·7	17·8	–	17·6	17·5	–	17·2	17·2	17·1
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·2	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·1	17·1
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·0	16·6	15·8
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	15·2
	10	–	–	–	–	–	–	–	17·2	–	17·2	17·2	–	–	–	–	–	–	–	–	15·7	–	15·2	15·0	–
	11	–	17·2	–	17·1	–	17·1	17·0	15·6	–	–	16·9	17·2	17·3	–	–	–	–	–	15·3	15·1	–	14·9	–	–
	12	–	–	–	15·2	–	15·8	15·2	–	–	15·4	15·8	16·3	16·9	–	17·2	17·2	16·4	–	15·0	14·9	–	14·6	14·5	–
	13	–	16·7	–	14·9	–	–	–	14·9	–	–	–	15·3	15·3	–	16·1	15·3	15·2	–	14·6	–	–	–	–	–
	14	–	–	–	–	–	14·7	14·7	–	–	14·9	–	–	–	–	15·1	15·1	14·9	–	–	–	–	13·9	14·1	13·9
	15	–	14·4	–	14·3	–	–	–	14·4	–	–	–	–	–	–	–	–	14·6	–	13·9	13·1	–	12·9	13·3	12·9
	16	–	–	–	–	–	–	–	–	–	14·4	14·2	13·9	14·2	–	–	–	14·1	–	12·2	12·2	–	11·8	12·2	12·3
	17	–	13·3	–	12·7	–	13·6	12·8	12·2	–	13·7	12·6	12·6	13·4	–	14·2	14·2	12·5	–	11·4	11·4		–	–	–
	18	–	11·7	–	–	–	12·2	11·9	11·4	–	12·2	11·8	11·4	11·8	–	13·1	12·7	11·2	–	–	–	–	11·1	10·7	–
	19	–	–	–	10·9	–	–	–	–	–	–	–	–	–	–	11·4	11·0	10·7	–	–	–	–	–	–	–
	20	–	10·6	–	–	–	10·9	10·7	–	–	10·4	–	–	–	–	–	10·3	–	–	–	–	–	10·3	–	10·7
	21	–	–	–	–	–	–	–	10·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	–	9·6	–	9·3	–	–	9·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	9·4	–	8·9	–	8·9	8·9	9·0	9·2	–	9·1	8·9	8·7	–	8·4	8·9	–	–	–	9·8
	29	–	–	–	7·9	–	–	7·8	7·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	7·9	–	–	–	7·9	–	–	–	7·8	7·6	7·6	7·6	–	7·8	7·8	7·8	–	7·7	8·3	–	7·7	8·1	8·3
AUGUST 24, 1911.	0	–	17·1	–	–	–	17·0	–	17·1	–	17·1	16·9	16·9	16·8	–	17·0	16·9	16·8	–	16·9	16·8	–	16·8	16·8	16·8
	7	–	17·1	–	17·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	16·1	–	17·1	–	16·8	–	16·8	–	16·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	15·4	–	16·2	–	15·7	–	15·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–	15·8	–	15·3	–	15·6	–	16·8	–	–	–	–	–	–	–	–	–	–	–	–	–	16·7
	11	–	–	–	–	–	–	–	–	–	–	16·8	16·9	–	–	17·0	–	–	–	–	–	–	16·8	16·7	15·8
	12	–	–	–	–	–	–	–	–	–	16·7	16·4	–	–	–	–	–	–	–	–	–	–	16·5	15·3	14·9
	13	–	–	–	–	–	–	–	–	–	15·8	–	16·9	16·9	–	17·0	–	–	–	–	–	–	15·6	14·7	13·3
	14	–	14·2	–	14·9	–	14·4	–	14·4	–	15·3	–	–	–	–	–	–	–	–	16·9	16·8	–	14·4	13·6	11·9
	15	–	13·9	–	–	–	–	–	–	–	–	15·1	15·3	–	–	16·9	17·0	–	–	16·8	15·8	–	12·8	12·6	10·1
	16	–	13·7	–	–	–	13·9	–	13·8	–	14·6	–	–	15·0	–	16·9	17·0	–	–	15·0	14·5	–	10·8	10·4	9·7
	17	–	13·3	–	–	–	13·4	–	13·5	–	–	13·7	13·7	–	–	16·4	16·9	16·9	–	14·2	12·8	–	9·2	–	8·4
	18	–	13·1	–	13·9	–	13·1	–	13·2	–	13·5	–	–	–	–	13·9	14·6	14·5	–	13·1	11·5	–	8·6	–	–
	19	–	12·6	–	13·3	–	12·8	–	–	–	–	12·8	12·6	–	–	12·7	13·7	13·4	–	12·5	10·9	–	–	–	–
	20	–	12·1	–	12·9	–	12·8	–	12·6	–	12·5	–	–	11·9	–	–	12·6	–	–	11·7	9·7	–	8·1	8·1	7·6
	21	–	–	–	–	–	–	–	–	–	–	11·8	10·9	–	–	–	12·0	11·9	–	10·4	–	–	–	–	–
	22	–	–	–	–	–	–	–	–	–	11·9	11·1	–	–	–	10·2	–	–	–	9·4	8·2	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	10·9	–	9·4	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	10·6	–	11·1	–	10·6	–	10·5	–	10·3	–	–	–	–	–	9·6	9·0	–	–	–	–	–	–	–
	25	–	–	–	–	–	–	–	–	–	–	8·5	–	7·9	–	7·9	–	–	–	–	–	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	–	8·2	–	7·8	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	8·4	–	8·9	–	8·7	–	7·8	–	7·6	7·6	7·3	7·2	–	7·2	7·3	7·2	–	7·2	7·2	–	7·2	7·2	7·1

TABLE II.—*continued.*

OBSERVATIONS AT STATION I.—*continued.*

AUGUST 25, 1911.

DEPTH. METRES.	HOUR OF OBSERVATION.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	–	16·7	16·8	16·7	–	16·7	–	16·5	–	16·6	16·5	16·4	16·2	–	15·5	14·9	15·0	15·0	15·1	15·2	15·1	–	15·1	15·2
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·1
4	–	–	–	–	–	–	–	–	–	–	15·3	15·3	14·8	–	14·8	14·9	14·3	14·9	–	–	–	–	15·1	14·9
5	–	–	–	–	–	–	–	–	–	–	15·0	–	–	–	–	14·8	14·1	–	14·9	14·7	14·7	–	–	14·9
6	–	–	–	–	–	–	–	–	–	–	14·7	14·4	–	–	–	14·0	13·9	–	–	–	–	–	15·1	14·8
7	–	–	–	–	–	16·7	–	16·4	–	15·5	14·4	–	–	–	–	–	–	–	–	–	–	–	14·8	–
8	–	–	16·7	16·6	–	16·3	–	16·4	–	14·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	16·7	16·1	15·0	–	15·6	–	–	–	13·9	–	–	–	–	–	–	–	–	–	–	–	–	14·1	–
10	–	14·8	14·8	–	–	14·6	–	15·9	–	13·9	–	13·7	13·7	–	13·7	13·8	13·9	13·9	13·9	13·9	13·9	–	–	–
11	–	14·4	14·4	14·4	–	13·9	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	13·6	13·9	–	–	–	–	14·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·7	13·8
13	–	12·9	13·2	13·1	–	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	–	12·1	12·4	–	–	–	–	13·6	–	13·0	13·1	12·9	12·8	–	–	12·9	13·1	13·3	–	–	–	–	13·7	–
15	–	10·9	11·9	11·8	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	–	–	11·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	13·6
17	–	10·0	10·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·3	–	–	–
18	–	–	–	9·7	–	10·9	–	–	–	–	–	–	–	–	–	–	11·8	12·4	12·4	–	–	–	11·9	12·8
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·9	12·1	11·4	–	–	–
20	–	8·3	9·4	9·2	–	9·8	–	11·8	–	12·1	11·9	11·9	12·0	–	11·6	10·9	10·6	11·1	11·1	11·2	–	–	11·7	11·9
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·8	10·6	–	10·7	–	10·9	10·8	–	–	–
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·6	9·7	9·8	–	–	–	9·4	–	–	–
24	–	–	–	–	–	–	–	10·8	–	–	–	11·1	11·0	–	8·8	–	8·3	9·8	10·2	9·6	8·6	–	9·9	9·9
26	–	–	–	–	–	–	–	–	–	–	–	9·6	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	–	–	–	–	8·9	9·0	–	–	–	–	–	–	–	–	–	–	–
30	–	7·2	7·4	7·4	–	8·1	–	10·0	–	11·2	11·1	9·0	8·2	–	7·7	7·3	7·4	7·8	7·9	7·9	7·6	–	7·8	7·7
32	–	–	–	–	–	–	–	–	–	11·2	10·0	8·1	–	–	–	–	–	7·6	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	10·9	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	9·2	–	9·2	8·6	7·8	7·8	–	7·5	7·2	7·2	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

AUGUST 26, 1911.

DEPTH. METRES.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	15·6	15·4	15·7	15·7	–	15·6	–	15·7	15·8	15·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	15·0	15·1	15·7	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	15·0	–	15·4	15·7	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	15·6	–	–	–	15·7	15·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	14·7	–	–	–	–	–	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	15·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	15·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	14·3	–	14·4	14·8	–	–	–	–	15·5	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
12	–	14·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
14	13·8	–	–	14·1	–	–	–	–	14·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
16	13·4	–	13·5	–	–	14·1	–	–	–	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	12·8	13·1	13·1	13·3	–	13·7	–	14·2	12·9	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	12·1	–	–	13·4	–	13·6	12·5	11·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	12·3	11·8	11·4	11·9	–	12·2	–	12·7	11·0	10·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
21	–	–	11·1	11·3	–	11·4	–	11·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
22	10·2	10·2	–	–	–	–	–	10·9	9·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
23	–	–	–	–	–	11·0	–	9·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
24	8·8	8·9	9·2	9·6	–	10·0	–	9·7	8·6	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	7·2	7·6	7·6	7·5	–	7·8	–	7 6	7·6	7·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	7·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
35	–	–	7·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 4, 1911.	0	15·4	15·0	15·3	15·4	15·5	15·0	15·4	15·0	15·4	15·2	15·7	15·8	15·8	15·5	15·6	15·5	15·5	15·5	15·5	–	–	–	15·5	15·5
	6	15·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	14·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	13·8	14·2	14·0	14·5	14·7	14·5	14·2	14·5	14·8	14·2	14·6	14·4	14·2	14·3	14·3	14·3	14·4	14·5	14·8	–	–	–	14·8	–
	12	13·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·2
	14	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·0	–
	16	12·5	–	13·3	13·5	13·4	13·3	13·7	13·3	13·6	14·1	13·5	13·4	13·0	12·8	13·0	12·5	12·6	12·8	13·5	–	–	–	–	–
	18	11·8	–	–	–	–	–	–	–	–	–	–	–	11·5	11·5	11·2	11·1	–	11·8	12·4	–	–	–	–	–
	20	11·3	11·2	12·0	13·0	12·5	12·7	13·1	12·9	13·4	13·0	11·3	11·0	10·5	10·7	10·2	10·6	10·0	11·0	11·5	–	–	–	12·1	–
	22	–	–	–	–	–	–	–	13·0	12·3	11·8	10·7	9·8	9·9	9·5	9·8	9·5	9·7	9·0	10·2	–	–	–	10·5	–
	24	–	–	10·3	–	10·4	11·0	10·5	11·2	12·2	11·5	10·0	9·1	8·9	9·0	9·0	8·5	8·7	8·7	9·1	–	–	–	–	9·6
	26	–	8·8	–	10·0	–	–	–	12·2	11·3	10·8	9·0	8·2	8·0	8·0	7·8	8·0	8·0	8·5	8·5	–	–	–	9·0	–
	28	–	–	8·8	–	8·7	8·2	9·9	9·8	10·4	10·5	8·5	7·5	7·7	–	–	–	7·6	8·0	–	–	–	–	–	8·0
	30	7·6	7·5	7·8	8·2	8·0	8·0	9·5	9·7	10·5	9·0	7·5	7·4	7·6	7·5	7·3	7·4	7·4	8·0	7·5	–	–	–	7·1	–
	36	–	7·0	7·3	7·2	7·2	8·0	–	–	–	–	–	7·1	–	–	–	–	–	–	–	–	–	–	7·0	–
	38	–	–	–	–	–	–	8·0	8·5	8·0	7·7	8·3	–	–	–	–	–	–	–	–	–	–	–	–	6·8
	40	–	6·8	6·8	7·0	7·0	7·9	–	–	–	–	–	6·8	7·7	–	6·6	–	6·8	–	–	–	–	–	6·7	–
	42	–	–	–	–	–	–	7·0	7·7	7·3	7·2	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	50	–	–	–	–	–	–	–	–	–	–	–	6·5	6·5	6·4	–	6·4	–	6·5	–	–	–	–	–	–
AUGUST 5, 1911.	0	15·5	15·5	15·6	15·3	15·6	15·6	15·5	15·6	15·6	15·5	15·5	15·5	15·5	15·5	15·5	15·5	15·5	15·6	15·5	15·5	15·5	–	15·4	–
	9	–	–	–	–	–	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	14·5	15·0	15·1	15·0	15·0	15·0	15·3	15·4	15·4	15·5	–	15·4	15·4	15·4	15·5	15·4	15·5	15·4	15·4	15·3	15·3	–	15·0	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·2	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	–	–	14·4	–	13·8	–
	13	–	–	–	–	–	14·4	–	–	–	–	–	–	–	–	–	–	–	–	14·2	13·1	12·0	–	12·5	–
	14	–	–	–	–	–	–	–	–	–	15·4	15·1	–	–	–	–	–	–	13·8	–	10·9	11·2	–	12·2	–
	15	–	–	14·0	13·9	13·8	13·9	–	–	–	14·4	14·9	15·3	15·3	15·4	15·2	15·2	13·4	11·6	10·5	10·7	11·2	–	11·7	–
	16	13·0	–	–	–	–	–	13·8	13·7	13·9	13·9	14·7	15·0	15·1	15·3	14·5	13·3	–	10·7	–	10·3	–	–	–	–
	17	–	13·0	–	–	–	13·2	–	–	–	–	13·6	13·8	14·2	13·7	12·8	10·7	–	10·1	9·9	9·9	–	–	–	–
	18	–	–	–	–	–	–	12·0	12·2	12·8	12·9	13·0	13·7	14·0	12·8	11·0	10·0	–	9·5	–	–	–	–	10·8	–
	19	–	–	–	–	–	–	–	–	–	10·6	12·3	12·0	11·8	10·2	9·6	9·2	–	–	–	–	–	–	–	–
	20	11·0	–	11·3	11·0	10·5	10·5	10·6	10·7	10·5	9·6	10·2	10·7	10·1	9·5	9·2	8·7	8·9	9·1	9·1	9·2	9·5	–	10·0	–
	21	–	–	–	–	–	–	–	–	10·2	9·3	9·5	–	–	–	9·0	–	–	–	–	–	–	–	–	–
	22	–	10·0	–	–	–	8·8	–	8·7	8·6	–	9·3	–	9·0	–	–	8·3	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	9·8	–	8·5	–	–	–	8·3	8·4	8·0	–	8·3	8·7	8·8	8·4	8·2	–	–	–	–	–	–	–	–	–
	25	–	–	–	7·8	8·0	8·2	–	–	–	–	–	–	–	–	–	–	7·9	–	–	–	7·9	–	9·6	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·8	–	–	–	–	–	–	8·0	–
	27	–	–	–	–	–	–	–	–	–	–	–	–	7·5	–	–	–	–	–	–	–	–	–	–	–
	28	8·2	9·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·5	–
	30	–	–	–	7·2	7·2	7·2	7·2	7·5	–	7·4	–	–	7·2	7·0	–	–	7·2	–	7·0	–	7·0	–	7·2	–
	35	–	–	–	–	7 0	–	–	–	–	–	–	–	–	–	–	–	6·9	–	–	–	6·7	–	–	–
	36	–	–	–	–	–	–	–	–	–	–	–	9·0	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	6·7	–	–	6·6	–	6·8	–	6·7	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–
	45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–
	50	–	–	–	–	–	–	–	6·5	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·0	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·2	–
AUGUST 6, 1911.	0	15·5	–	15·5	–	15·2	–	15·5	15·5	15·3	15·3	15·4	15·3	15·5	15·5	15·5	15·5	15·5	15·5	15·3	15·3	15·3	–	15·5	–
	5	–	–	–	–	–	–	–	–	–	–	–	15·0	15·0	–	–	–	–	–	–	–	–	–	–	–
	10	15·1	–	15·0	–	14·6	–	14·4	14·4	13·9	13·7	13·5	13·5	13·5	13·7	14·0	14·3	14·5	14·5	14·6	–	14·8	–	15·1	–
	12	13·2	–	–	–	–	–	–	–	–	–	–	–	13·0	–	–	–	–	–	–	14·4	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	–	–	–	–	–	–	–	–	–
	14	12·8	–	–	–	–	–	13·5	13·4	–	12·8	12·0	–	–	–	–	–	–	13·5	13·5	13·7	13·7	–	–	–
	15	–	–	13·1	–	13·1	–	13·2	13·2	–	–	–	11·7	11·9	12·1	12·9	–	–	–	–	–	–	–	15·0	–
	16	12·7	–	–	–	–	–	13·0	–	12·1	11·6	11·5	–	–	–	–	–	–	–	13·2	13·2	–	–	–	–
	17	–	–	–	–	–	–	12·5	–	11·5	–	–	–	–	–	12·1	–	–	–	–	–	–	–	–	–
	18	12·6	–	12·7	–	–	–	12·2	12·0	11·0	–	11·2	–	11·1	11·0	–	–	12·2	–	13·0	–	12·9	–	12·5	–
	19	–	–	–	–	–	–	12·6	–	–	11·1	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	11·5	–	–	–	12·0	–	11·8	11·0	10·8	10·2	10·3	10·0	9·9	9·5	10·9	11·2	11·8	11·4	11·8	12·1	–	–	11·5	–
	21	–	–	–	–	–	–	11·0	–	–	–	9·7	–	–	9·2	–	–	–	–	–	–	–	–	–	–
	22	–	–	11·3	–	–	–	10·7	10·7	10·2	9·3	9·0	–	–	9·1	–	–	10·3	10·9	–	11·6	11·7	–	10·6	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	7·8	8·5	–	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	10·0	9·5	9·5	8·7	–	–	–	–	9·4	–	9·5	10·2	–	10·8	10·8	–	10·2	–
	25	10·3	–	11·0	–	9·3	–	–	–	–	–	–	7·8	7·7	–	8·2	–	–	–	9·9	–	–	–	–	–
	26	–	–	–	–	–	–	–	9·0	–	–	8·0	–	–	–	–	–	8·6	9·3	–	–	8·5	–	7·7	–
	27	–	–	8·5	–	8·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	8·0	–	8·0	–	–	–	–	–	–	–	8·0	–	8·2	7·9	–	–	–
	30	7·7	–	8·2	–	8·2	–	7·7	7·7	7·8	7·5	7·2	7·2	–	8·4	7·3	7·2	7·6	7·7	7·5	–	7·4	–	7·4	–
	34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–
	35	–	–	–	–	7·2	–	–	–	–	–	–	6·9	–	–	–	–	–	–	7·2	–	–	–	–	–
	40	–	–	–	–	6·8	–	–	–	–	–	–	6·8	–	–	7·0	6·8	–	–	–	6·7	–	–	–	–
	50	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–	6·5	6·5	–	–	–	–	–	7·0	–
	60	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–
	70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	6·2	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	15·3	–	15·2	–	15·2	–	15·5	15·3	15·2	15·3	15·4	15·4	15·2	15·3	15·2	15·2	15·1	15·1	15·0	15·0	15·0	–	15·2	–	*AUGUST* 7, 1911.
10	14·4	–	14·2	–	13·7	–	14·7	15·0	15·0	15·1	15·2	15·0	15·0	14·5	–	13·5	13·7	13·7	13·5	–	13·5	–	14·7	–	
12	–	–	13·4	–	13·5	–	–	–	–	–	–	–	–	–	13·8	13·4	–	–	13·4	13·2	–	–	–	–	
13	–	–	–	–	–	–	–	–	14·7	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	–	
14	–	–	12·8	–	13·2	–	–	–	–	–	–	–	–	13·3	13·3	–	12·0	12·4	12·3	–	13·0	–	–	–	
15	12·8	–	–	–	–	–	13·5	13·5	13·5	13·6	13·8	–	–	–	–	–	–	–	–	–	–	–	13·0	–	
16	–	–	–	–	–	–	–	–	–	–	–	13·3	–	–	–	–	–	–	11·4	11·3	–	–	–	–	
17	–	–	11·4	–	11·7	–	–	13·1	–	–	–	–	–	–	–	–	–	11·3	–	–	–	–	12·7	–	
18	11·1	–	10·1	–	10·5	–	–	–	12·9	–	–	13·0	13·0	11·7	11·4	10·8	10·4	10·0	10·3	10·0	10·6	–	–	–	
19	–	–	–	–	–	–	–	12·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20	9·3	–	8·9	–	8·7	–	10·8	–	12·2	12·4	12·2	12·5	11·9	10·8	9·4	–	8·6	8·7	9·2	–	10·2	–	11·7	–	
21	–	–	–	–	–	–	–	11·8	–	–	–	–	–	–	–	8·3	–	–	–	–	–	–	–	–	
22	7·8	–	–	–	–	–	–	–	–	–	–	–	10·0	9·0	8·2	–	8·2	8·0	–	8·3	–	–	11·4	–	
23	–	–	–	–	–	–	–	9·8	10·2	–	–	–	–	–	–	7·6	–	–	–	–	–	–	11·0	–	
24	7·4	–	–	–	7·8	–	–	–	–	–	–	9·3	9·5	8·3	8·0	–	–	–	–	–	–	–	–	–	
25	–	–	7·6	–	–	–	7·8	8·3	–	–	8·5	–	–	–	–	–	–	–	–	–	8·1	–	9·6	–	
26	–	–	–	–	–	–	–	–	–	–	–	8·1	7·8	7·5	–	–	7·5	7·5	–	7·7	–	–	–	–	
27	–	–	–	–	–	–	–	–	8·2	–	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	
30	7·0	–	–	–	–	–	7·2	7·5	7·4	7·2	7·2	7·4	7·3	7·0	–	–	7·1	–	7·0	7·1	7·5	–	8·0	–	
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·9	–	–	–	–	–	–	–	–	
34	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	6·7	–	–	–	–	–	–	–	–	–	
35	–	–	6·7	–	–	–	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	
36	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
40	6·5	–	–	–	–	–	–	6·7	–	6·6	–	–	6·6	–	–	–	6·5	–	–	6·6	6·7	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	6·3	–	6·4	–	–	–	–	–	6·5	–	–	–	
55	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	
0	15·4	–	15·5	–	15·4	–	14·7	14·8	14·8	14·8	14·9	15·1	15·6	15·6	15·5	15·5	15·7	15·6	15·5	15·5	15·5	–	15·0	–	*AUGUST* 8, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·0	–	15·0	–	15·0	–	14·5	13·8	14·6	13·3	14·3	14·4	15·6	14·7	14·7	–	15·5	15·2	15·4	15·6	15·0	–	14·5	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	14·7	–	–	15·3	–	–	–	–	–	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	–	–	13·0	–	–	13·0	13·0	13·4	14·3	14·6	–	–	–	–	–	–	–	–	–	–	
15	14·5	–	14·5	–	13·0	–	–	–	11·5	–	–	–	–	–	–	–	14·5	14·7	14·8	14·0	14·5	–	–	–	
16	–	–	–	–	–	–	–	11·3	–	–	–	–	–	–	14·4	–	–	–	–	–	–	–	12·4	–	
17	–	–	–	–	–	–	–	–	–	–	11·2	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	–	–	–	–	–	–	11·3	–	–	10·4	–	11·4	13·6	13·7	13·3	13·1	14·0	13·2	13·1	12·5	–	–	10·7	–	
19	–	–	–	–	–	–	–	–	9·6	–	10·6	–	–	–	–	–	–	–	–	–	–	–	–	–	
20	13·0	–	12·0	–	11·0	–	–	9·5	–	9·5	–	10·4	11·4	11·3	11·2	11·4	13·0	12·5	12·2	11·6	11·2	–	9·5	–	
22	–	–	–	–	–	–	9·5	8·6	–	–	–	9·0	9·6	9·4	10·0	10·7	11·8	11·6	–	–	10·0	–	8·0	–	
23	–	–	–	–	–	–	–	–	8·2	–	8·8	–	–	–	–	–	–	–	10·6	–	–	–	–	–	
24	–	–	–	–	–	–	–	8·2	–	8·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	12·5	–	10·0	–	9·5	–	–	–	7·8	–	–	–	8·3	–	–	–	9·2	9·3	9·3	9·7	8·5	–	–	–	
26	–	–	–	–	–	–	8·0	7·9	–	–	–	8·2	–	7·8	8·3	9·0	–	–	–	–	–	–	7·5	–	
27	–	–	–	–	–	–	–	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	9·2	–	–	–	–	–	–	–	–	7·6	7·5	–	–	–	–	–	8·5	8·5	8·9	–	–	–	7·1	–	
30	–	–	–	–	8·0	–	7·4	7·2	–	–	–	7·3	7·2	7·3	7·8	7·8	7·9	7·7	8·6	8·1	7·5	–	7·0	–	
31	–	–	8·5	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
32	–	–	–	–	–	–	7·2	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	
35	8·4	–	–	–	7·6	–	–	6·9	–	6·9	6·9	–	–	–	–	–	–	–	7·2	–	–	–	–	–	
36	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	
40	7·5	–	7·7	–	7·0	–	6·7	–	–	–	–	–	–	–	–	–	7·0	–	7·0	7·7	6·7	–	–	–	
50	–	–	7·0	–	–	–	6·5	–	–	–	–	–	–	–	–	–	–	–	6·6	6·5	6·5	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	6·5	–	–	–	–	–	
80	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	6·2	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 9, 1911.	0	15·5	–	–	15·5	15·5	–	15·7	15·7	15·7	15·8	15·8	15·9	16·0	16·1	16·1	16·4	16·4	16·2	16·1	16·0	16·0	–	15·7	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	15·8	–	–	–	–
	9	15·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–	15·5	15·3	–	15·5	15·6	15·6	–	–	15·6	15·7	15·6	15·6	15·2	15·0	15·0	15·0	15·0	15·0	–	15·0	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	–	–	–	–	–
	13	13·4	–	–	14·3	15·0	–	15·4	–	–	15·5	15·5	–	–	–	–	–	12·8	–	13·3	–	14·7	–	14·7	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·8	–	–	–	–	–
	15	13·0	–	–	14·0	14·5	–	14·8	15·0	–	–	–	15·0	15·0	13·7	13·0	10·3	10·2	10·8	11·4	12·6	13·5	–	13·8	–
	18	11·0	–	–	13·5	13·8	–	14·0	–	14·8	14·6	14·4	13·8	10·5	9·4	9·2	8·7	9·2	–	10·1	–	11·7	–	12·7	–
	19	–	–	–	13·0	–	–	–	–	–	14·5	13·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	9·5	–	–	9·7	11·8	-	13·1	13·5	14·2	13·3	10·0	9·0	9·0	8·7	8·5	8·4	9·0	8·5	9·7	10·0	10·8	–	11·6	–
	21	–	–	–	–	–	–	12·7	12·9	11·5	10·3	9·2	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	9·7	10·8	10·0	9·3	8·6	–	–	8·2	–	–	–	–	–	–	–	–	–	–
	23	–	–	–	8 3	8·8	–	9·3	9·0	–	7·1	–	8·2	8·0	–	–	8·0	–	–	–	9·2	–	–	10·6	–
	25	8·1	–	–	8·0	8·0	–	–	8·4	7·9	–	8·0	8·0	7·6	8·0	8·1	7·7	–	7·7	–	8·4	9·3	–	10·3	–
	28	–	–	–	–	–		7·3	–	–	–	–	7·6	7·4	7·5	7·5	7·5	–	–	–	7·7	-	–	7·8	–
	30	7·2	–	–	7·5	7·2	–	–	7·4	7·3	–	7·0	7·2	7·2	7·3	7·2	7·2	7·1	7·2	7·2	7·5	7·7	–	–	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–
	40	6·6	–	–	6·6	6·7	–	–	–	–	6·5	–	–	–	–	6·6	–	6·5	6·6	–	–	6·8	–	–	–
	50	6·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–
	77	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 10, 1911.	0	15·9	–	15·6	–	16·0	–	15·5	15·5	15·6	15·7	15·8	15·8	15·8	15·9	16·5	16·0	16·3	16·4	16·6	16·3	16·1	–	16·1	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·5	15·5	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·0	–	15·0	–	–	–	15·0	15·0	14·9	14·6	15·0	15·0	15·1	15·0	14·8	15·0	15·2	15·2	15·3	15·0	–	–	15·5	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	–	14·6	–	–	–
	13	14·9	–	15·0	–	15·4	–	13·4	13·2	–	13·2	13·5	14·0	–	13·8	–	14·8	15·1	–	–	15·0	–	–	15·0	–
	15	–	–	13·5	–	13·0	–	–	12·0	11·6	12·3	12·5	13·5	13·2	13·5	13·5	14·1	14·5	14·4	–	13·8	14·0	–	14·2	–
	18	13·2	–	–	–	11·5	–	10·7	10·5	10·6	11·0	11·3	12·1	--	12·6	–	13·0	13·2	13·2	13·0	–	11·7	–	11·5	–
	20	12·2	–	–	–	10·7	–	10·2	10·2	10·2	10·0	10·5	11·4	11·4	11·9	11·2	12·1	12·3	–	11·9	10·5	10·2	–	10·3	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·2	–	–	–	–	–	–
	23	10·7	–	10·0	–	–	–	9·0	9·5	9·0	9·2	9·5	–	–	10·3	–	10·5	10·7	10·2	9·5	–	9·1	–	–	–
	25	10·0	–	9·0	–	9·3	–	8·7	8·7	8·5	8·7	9·2	9·2	9·7	9·2	9·4	9·7	9·7	–	9·0	8·9	8·5	–	8·2	–
	26	–	–	–	–	–	–	–	–	–	–	9·0	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	8·4	–	8·4	–	8·0	–	7·8	–	7·8	–	–	–	–	–	–	8·2	–	7·5	7·2	–	–	–
	30	8·2	–	–	–	8·0	–	7·7	7·5	7·5	7·7	–	7·5	7·9	7·5	7·7	7·6	7·7	–	7·4	7·2	7·1	–	7·6	–
	33	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·1	–	–	–	–	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	–	–	–
	38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–
	40	–	–	–	–	6·8	–	–	–	–	7·0	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–
	50	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 11, 1911.	0	16·0	–	16·0	–	15·9	–	15·9	–	16·1	16·2	16·3	16·4	16·5	16·4	16·4	16·5	16·5	16·5	16·4	16·4	16·5	–	16·6	–
	5	–	–	–	–	–	–	15·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·6	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	16·3	–	–	–	–	–	–	–	–	–	–
	10	15·5	–	15·4	–	15·6	–	15·7	–	15·7	15·9	15·8	15·8	16·0	–	16·3	16·3	16·4	16·4	16·4	16·4	16·3	–	16·2	–
	13	14·8	–	15·0	–	15·2	–	15·3	–	–	–	–	15·4	–	15·7	–	–	15·7	–	–	–	–	–	15·9	–
	15	13·4	–	14·0	–	14·5	–	14·8	–	14·7	14·9	14·5	14·7	15·2	15·4	14·8	15·2	15·5	15·4	15·7	15·2	16·2	–	15·7	–
	16	–	-	–	–	–	–	–	–	–	–	–	–	12·8	–	13·2	–	–	15·1	–	–	–	–	13·4	–
	17	–	–	–	–	–	–	–	–	–	–	12·9	–	–	12·0	12·2	–	14·1	14·0	–	13·9	14·0	–	11·7	–
	18	11·8	–	12·7	–	13·7	–	12·8	–	11·2	–	10·5	10·5	10·2	10·1	12·0	12·4	12·4	11·9	12·8	13·4	12·0	–	11·4	–
	19	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	10·4	–	10·5	–	10·4	–	10·7	–	10·2	9·4	8·6	8·6	9·0	9·7	–	10·1	10·4	10·6	10·6	11·4	–	–	10·4	–
	23	–	–	8·8	–	9·2	–	–	–	8·4	–	7·9	7·7	7·9	–		9·2	–	–	10·0	9·6	9·8	–	–	–
	25	8·3	-	7·9	–	8·3	–	7·4	–	8·0	7·8	7·4	7·4	–	7·6	8·2	8·2	–	9·0	9·6	–	9·2	–	8·7	–
	28	–	–	–	–	–	–	–	–	7·2	–	-	–	7·1	–	–	7·8	7·7	–	–	7·8	–	–	–	–
	30	7·4	–	7·3	–	7·3	–	7·1	–	7·1	7·0	7·0	6·9	6·8	–	7·2	7·2	–	–	7·9	–	7·6	–	7·7	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	7·2	–	7·1	–	–	–	–
	40	6·6	–	–	–	–	–	–	–	–	6·6	6·6	–	–	6·5	–	–	–	–	6·8	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	77	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·7	16·7	16·6	16·5	16·6	–	16·3	16·3	16·3	16·2	16·2	16·4	16·4	16·3	16·4	16·5	16·5	16·6	16·6	16·6	16·5	–	16·2	–	*AUGUST 12, 1911.*
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	16·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	16·5	16·3	16·5	16·5	16·5	–	16·2	16·2	–	16·1	16·1	16·2	16·2	16·2	16·2	16·3	16·4	16·3	16·0	15·3	16·0	–	16·2	–	
13	–	16·2	13·7	14·5	14·0	–	14·1	13·7	14·9	14·5	–	14·5	14·3	14·0	13·8	13·9	–	14·0	13·9	14·0	16·0	–	–	–	
14	–	–	12·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	12·5	12·0	12·1	12·5	12·2	–	12·3	12·2	13·0	13·2	13·5	13·4	13·3	13·2	13·3	13·1	13·2	13·0	13·0	13·1	13·2	–	15·3	–	
18	11·4	10·4	10·8	–	11·0	–	11·5	11·4	11·9	12·2	12·4	12·4	12·3	12·2	12·1	12·0	–	11·6	11·5	11·5	11·5	–	12·3	–	
20	10·0	9·5	–	10·0	10·0	–	10·7	10·7	11·0	–	11·9	11·6	11·8	11·6	10·8	11·2	11·0	11·0	10·7	10·6	10·9	–	11·1	–	
23	–	–	–	–	–	–	10·0	10·0	10·1	10·7	10·7	10·8	10·0	9·7	9·8	9·8	–	–	10·0	9·2	–	–	9·4	–	
25	8·5	8·3	8·3	8·5	–	–	–	9·3	–	–	9·4	–	–	–	–	–	8·9	–	–	–	8·4	–	8·2	–	
28	8·2	–	–	–	–	–	8·0	–	–	9·0	9·0	9·0	8·3	8·2	8·1	8·2	–	8·2	8·2	8·0	–	–	7·4	–	
30	–	–	–	–	–	–	–	–	8·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
33	–	–	–	–	–	–	–	7·7	–	7·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
35	7·2	7·3	7·2	7·2	7·2	–	7·2	–	–	–	–	7·2	–	–	–	–	7·2	7·2	7·2	7·2	7·1	–	7·0	–	
38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
40	–	–	–	–	–	–	–	–	7·0	–	7·0	–	6·8	6·9	6·8	6·8	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
80	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·3	–	16·3	–	16·5	–	16·4	16·4	16·4	16·4	16·4	16·6	16·6	16·6	17·0	16·9	16·8	16·8	16·7	16·7	16·7	–	16·7	–	*AUGUST 13, 1911.*
10	16·3	–	16·3	–	16·3	–	16·3	16·3	16·3	16·3	16·3	16·4	16·3	16·5	16·5	16·5	16·6	16·6	16·7	16·5	16·5	–	16·4	–	
13	14·2	–	15·0	–	14·4	–	14·5	14·3	14·3	14·3	14·3	14·5	14·4	15·0	15·3	15·4	–	–	–	–	–	–	14·2	–	
15	13·6	–	13·7	–	–	–	14·0	13·8	13·4	13·8	14·0	13·9	14·0	14·1	14·3	14·5	14·5	14·7	14·8	15·0	14·7	–	13·5	–	
16	–	–	–	–	13·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	13·0	–	13·3	–	12·9	–	12·1	12·1	12·2	12·3	12·3	12·5	12·6	13·0	13·5	13·8	–	13·9	13·8	–	–	–	12·2	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·1	–	–	–	–	–	
20	11·6	–	11·9	–	11·7	–	11·1	10·6	10·1	10·3	10·4	10·4	10·6	11·3	11·6	–	12·5	12·6	12·3	12·1	11·5	–	10·0	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·6	–	–	–	11·0	–	–	–	–	
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·2	–	–	–	–	
23	–	–	9·9	–	–	–	8·4	8·3	8·3	8·3	8·2	8·3	–	8·7	9·5	9·8	–	9·6	9·7	9·0	–	–	8·5	–	
25	8·5	–	9·0	–	8·5	–	7·8	7·8	7·5	7·4	7·5	8·0	7·8	7·8	8·1	–	8·2	8·4	8·0	7·6	7·7	–	8·0	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·5	7·5	–	–	–	–	–	–	–	–	
30	7·5	–	7·4	–	7·4	–	–	–	–	–	–	7·0	7·0	7·3	–	–	7·2	–	–	7·2	7·0	–	–	–	
35	–	–	–	–	–	–	6·8	–	6·8	6·8	–	–	–	7·0	7·0	7·0	6·9	6·9	6·8	–	6·9	–	–	–	
40	6·8	–	–	–	6·7	–	–	6·6	–	–	6·6	–	–	–	–	–	6·7	–	–	6·7	6·7	–	6·7		
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	
77	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·7	–	16·7	–	16·5	–	16·6	16·6	16·6	16·6	16·7	–*	–	–	16·8	16·7	16·6	16·5	16·5	16·5	16·5	–	16·8	–	*AUGUST 14, 1911.*
10	16·5	–	–	–	16·5	–	16·5	16·5	16·5	16·5	16·5	–	–	–	16·4	16·4	16·4	16·4	16·5	16·5	16·5	–	16·5	–	
13	14·2	–	14·1	–	14·6	–	15·6	16·5	15·6	15·1	14·6	–	–	–	–	13·9	14·9	14·6	14·8	15·5	15·7	–	15·0	–	
15	13·6	–	13·6	–	13·8	–	14·0	14·0	14·2	14·3	14·0	–	–	–	12·9	13·5	13·4	13·3	13·6	13·5	13·5	–	14·0	–	
18	10·0	–	10·9	–	11·5	–	12·7	12·5	12·9	12·3	12·3	–	–	–	–	11·2	11·0	11·4	11·5	11·4	11·8	–	12·1	–	
20	9·3	–	10·0	–	10·0	–	10·8	11·3	11·5	11·2	–	–	–	–	10·4	10·1	–	10·4	10·9	10·9	11·0	–	10·9	–	
23	8·2	–	8·5	–	9·1	–	9·7	–	10·0	–	–	–	–	–	–	9·1	9·0	9·4	9·7	9·6	9·3	–	–	–	
25	7·8	–	–	–	8·2	–	–	9·5	–	–	–	–	–	–	8·5	8·4	–	8·7	–	8·8	8·7	–	–	–	
28	–	–	–	–	7·5	–	8·2	–	8·2	8·1	–	–	–	–	–	–	–	–	8·1	–	–	–	8·1	–	
30	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	–	–	–	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	
35	7·0	–	–	–	–	–	7·3	7·3	7·4	7·5	–	–	–	–	7·1	7·0	7·0	7·0	–	–	–	–	7·5	–	
38	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·8	–	–	–	–	–	
40	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	6·6	–	–	–	–	
0	16·5	–	16·4	–	16·4	–	16·4	16·5	16·5	17·2	17·3	17·4	17·9	18·2	18·4	18·4	18·3	17·6	17·1	16·9	16·8	–	17·1	–	*AUGUST 15, 1911.*
10	16·5	–	16·4	–	16·4	–	16·4	16·4	16·4	16·4	16·4	16·5	16·4	16·4	16·5	16·5	16·6	16·5	16·5	16·3	16·4	–	16·0	–	
13	15·4	–	14·4	–	14·2	–	14·5	–	–	14·7	–	14·8	14·8	–	–	15·0	14·7	14·6	14·3	14·6	14·0	–	14·5	–	
15	13·4	–	13·2	–	13·5	–	13·8	13·9	13·9	13·9	14·1	14·3	14·3	14·2	14·0	14·1	13·9	13·7	13·7	14·0	13 8	–	14·1	–	
18	11·3	–	11·2	–	11 2	–	–	11·7	–	12·6	12·8	12·4	12·5	–	12·6	12·1	11·9	11·8	11·2	11·8	11·8	–	12·6	–	
20	10·4	–	9·8	–	9·8	–	10·2	10·8	10·9	10·8	11·1	11·5	11·3	11·0	10·7	10·5	10·6	10·6	10·5	10·6	10·9	–	11·1	–	
23	9·2	–	9·0	–	8·5	–	–	8·9	–	–	9·7	9·8	9·7	–	9·3	8·8	9·0	8·7	8·7	9·0	9·7	–	–	–	
25	7·9	–	7·9	–	8·1	–	7·9	8·2	8·2	8·3	8·5	8·4	–	8·4	8·3	8·2	8·4	8·2	8·2	8·2	8·6	–	8·8	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	7·6	–	7·7	–	–	–	–	–	–	–	–	–	
30	–	–	–	–	–	–	7·2	–	7·3	–	7·4	–	–	7·6	–	–	–	–	–	–	–	–	–	–	
35	6·9	–	6·8	–	6·8	–	–	6·9	6·9	–	–	6·9	–	7·0	7·1	7·1	7·1	7·1	7·0	7·0	7·1	–	7·4	–	
40	–	–	–	–	–	–	6·6	–	6·6	–	6·6	–	6·6	6·9	–	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	6·8	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

* Thermometer lost; three hours' delay.

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 16, 1911.	0	17·6	–	17·5	–	17·2	–	16·5	16·6	16·8	17·0	17·1	17·3	17·4	17·7	18·2	18·4	18·2	18·2	18·1	17·6	17·1	–	–	–
	10	16·9	–	16·7	–	16·1	–	14·9	15·1	14·9	15·1	15·1	15·5	16·1	16·3	16·4	16·4	18·1	17·9	16·5	16·5	16·5	–	–	–
	13	14·8	–	14·8	–	14·8	–	14·2	14·3	14·2	–	14·4	14·6	14·8	15·1	15·1	15·1	16·9	15·1	15·1	15·2	14·9	–	–	–
	15	14·6	–	14·6	–	14·3	–	13·7	13·8	13·8	14·1	14·0	14·2	14·5	14·6	14·6	14·8	14·9	14·8	14·4	14·4	14·5	–	–	–
	18	13·2	–	12·1	–	12·6	–	12·4	12·2	12·1	12·4	12·4	12·6	12·9	12·9	13·1	13·3	13·2	13·2	13·2	13·2	12·7	–	–	–
	20	11·7	–	–	–	–	–	11·6	11·3	11·1	11·1	11·0	11·4	12·1	11·8	11·7	12·3	11·9	–	11·5	10·9	–	–	–	–
	23	9·9	–	10·8	–	10·3	–	–	9·9	9·4	9·3	9·8	9·9	10·4	9·8	9·8	9·8	9·9	9·8	9·4	–	9·3	–	–	–
	25	–	–	–	–	–	–	8·8	–	8·5	8·6	8·7	8·7	8·6	8·5	8·6	8·9	–	–	–	8·7	–	–	–	–
	28	8·7	–	8·4	–	7·7	–	7·9	7·6	–	7·7	–	–	–	–	–	–	7·7	7·7	7·7	–	7·7	–	–	–
	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	35	7·7	–	7·5	–	7·3	–	–	6·8	7·1	–	7·1	–	7·0	7·2	–	7·1	7·2	7·2	7·1	7·1	7·1	–	–	–
	40	–	–	–	–	–	–	6·9	–	–	6·9	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–
	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 17, 1911.	0	17·3	–	16·7	–	16·9	–	16·9	17·0	17·1	17·5	17·6	17·7	18·2	18·7	18·7	18·6	18·2	18·4	17·9	17·8	17·7	–	17·3	–
	5	17·0	–	16·7	–	16·9	–	–	–	–	–	–	–	–	–	–	–	17·1	17·1	16·8	16·9	16·9	–	–	–
	10	16·5	–	16·3	–	16·8	–	16·9	17·0	16·9	16·4	16·3	16·5	15·9	16·4	16·5	15·4	15·3	15·2	15·3	15·0	15·1	–	15·2	–
	13	14·8	–	–	–	15·0	–	14·8	–	–	15·1	14·8	14·7	14·6	14·7	14·6	14·5	–	–	14·4	–	–	–	14·4	–
	15	14·1	–	14·1	–	13·9	–	14·2	14·2	14·2	–	–	13·8	–	13·8	13·7	13·8	13·5	13·7	13·6	13·2	13·2	–	13·7	–
	17	–	–	–	–	–	–	–	12·9	12·4	12·5	12·9	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	12·1	–	11·1	–	11·1	–	11·9	11·9	11·4	–	12·0	11·8	12·4	12·1	12·4	12·2	–	12·2	11·7	11·7	–	–	12·3	–
	20	10·3	–	10·0	–	10·1	–	10·3	10·3	10·4	10·7	10·8	11·1	11·1	11·4	11·2	11·5	10·9	11·0	11·1	–	11·1	–	11·7	–
	23	–	–	–	–	–	–	9·0	9·2	9·1	–	9·7	10·1	10·4	10·7	10·1	–	–	–	9·4	–	–	–	10·4	–
	25	8·3	–	8·1	–	–	–	8·6	8·4	8·5	8·8	8·7	–	–	–	–	8·8	8·7	8·8	9·1	–	9·2	–	9·0	–
	28	–	–	–	–	–	–	–	–	–	–	–	8·7	8·6	8·7	8·3	–	–	–	–	–	–	–	–	–
	30	7·4	–	7·3	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	7·8	–	–	–
	35	–	–	–	–	–	–	7·2	–	–	7·3	–	7·6	7·5	7·5	7·6	7·5	7·4	7·3	–	–	7·4	–	7·6	–
	40	6·8	–	7·1	–	–	–	–	7·1	7·1	–	7·1	–	–	–	–	–	–	–	–	–	7·2	–	–	–
	60	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	81	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–
AUGUST 18, 1911.	0	16·8	–	16·8	–	17·1	–	17·2	17·1	17·1	17·1	17·1	17·1	17·1	17·1	16·8	16·8	16·8	16·7	16·7	16·7	16·7	–	17·5	–
	3	–	–	–	–	–	–	–	–	–	–	–	–	16·6	–	–	–	–	–	–	–	–	–	–	–
	5		–	–	–	–	–	–	–	–	–	–	–	16·3	16·5	16·6	16·6	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–	–	–
	10	15·4	–	15·4	–	15·5	–	15·7	15·6	15·4	15·4	15·4	15·4	15·2	15·2	15·1	15·3	15·6	15·6	15·7	15·6	15·8	–	16·1	–
	13	14·2	–	14·8	–	14·8	–	14·7	14·8	14·8	14·6	14·3	14·2	–	–	–	–	14·6	14·7	14·9	14·9	–	–	15·4	–
	15	13·3	–	13·9	–	–	–	14·3	14·3	13·8	14·2	13·5	13·2	13·5	13·9	14·3	14·5	14·4	14·4	–	14·8	15·0	–	14·8	–
	18	12·6	–	12·6	–	12·7	–	12·7	12·3	12·3	12·1	11·5	11·7	11·8	–	12·6	12·9	12·7	12·8	13·2	13·7	13·6	–	13·7	–
	19	–	–	–	–	–	–	–	–	11·8	–	–	–	–	–	–	–	–	–	–	–	–	–	12·6	–
	20	11·2	–	11·6	–	11·6	–	11·9	11·0	–	10·5	10·4	10·1	9·9	10·3	10·8	11·4	10·9	11·6	12·6	12·4	12·1	–	–	–
	23	9·8	–	10·2	–	10·2	–	9·3	9·3	9·2	9·2	8·7	–	–	–	–	–	8·9	9·3	9·6	9·9	9·7	–	9·8	–
	25	9·3	–	–	–	8·8	–	–	–	–	–	–	7·9	7·8	8·1	–	8·2	8·2	–	8·7	8·7	8·7	–	–	–
	28	–	–	8·2	–	–	–	8·2	7·7	7·6	7·6	7·7	–	–	–	–	–	–	7·6	7·6	–	7·7	–	7·7	–
	30	–	–	–	–	–	–	–	–	–	–	–	7·3	–	7·3	7·4	7·3	–	–	–	–	–	–	–	–
	35	7·2	–	–	–	7·3	–	7·1	7·1	7·1	7·1	7·2	–	7·1	7·1	–	–	7·1	–	7·1	–	7·1	–	7·1	–
	40	–	–	7·1	–	–	–	–	–	–	–	–	6·9	–	6·9	6·9	6·9	–	6·9	–	7·0	–	–	–	–
	50	–	–	–	–	6·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–
AUGUST 19, 1911.	0	17·1	–	17·1	–	17·1	–	17·1	17·2	17·2	17·1	17·1	17·0	17·0	16·8	16·9	16·9	17·0	16·9	16·9	16·9	16·9	–	16·8	–
	5	–	–	16·6	–	–	–	16·6	16·6	–	–	16·6	–	–	–	–	–	–	16·9	–	–	–	–	16·8	–
	10	15·9	–	15·7	–	15·6	–	15·9	15·9	15·9	16·4	16·4	16·4	16·5	16·8	16·9	16·8	16·8	–	16·9	16·9	16·9	–	16·7	–
	13	14·9	–	–	–	–	–	–	–	–	15·4	–	15·7	15·5	–	15·9	15·8	15·9	16·2	16·3	16·5	16·8	–	–	–
	15	14·7	–	14·9	–	14·2	–	14·8	14·8	14·7	14·8	14·9	15·0	14·8	15·3	15·2	14·9	15·1	15·1	15·2	14·9	15·1	–	15·4	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	14·0	–	13·9	–	–	–	12·9	13·3	14·1	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	–	13·2	–	–	–	11·8	–	11·3	–	–	–	–
	18	12·6	–	12·6	–	12·5	–	–	12·9	–	12·6	12·6	12·9	12·9	12·3	11·8	12·4	11·5	11·0	11·0	11·0	11·0	–	11·1	–
	19	–	–	–	–	11·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	10·4	–	10·9	–	11·0	–	10·9	10·9	11·2	11·4	11·1	11·4	11·4	11·2	–	10·6	10·8	10·3	–	–	–	–	10·3	–
	23	8·8	–	9·0	–	9·2	–	–	9·6	–	9·3	9·3	9·2	–	9·2	9·3	9·3	9·2	–	8·8	–	9·2	–	–	–
	25	8·2	–	8·1	–	8·4	–	8·7	8·7	8·5	–	–	8·4	8·4	8·3	–	–	8·7	–	–	8·4	–	–	8·9	–
	28	–	–	–	–	–	–	–	–	–	8·0	–	–	–	–	7·7	7·7	–	–	7·7	–	7·9	–	–	–
	30	–	–	–	–	–	–	7·4	7·5	–	–	7·6	–	–	–	–	–	–	7·6	–	–	–	–	7·9	–
	35	7·1	–	–	–	7·2	–	–	–	7·1	–	–	7·1	–	7·1	–	–	7·1	–	7·1	–	7·2	–	–	–
	40	–	–	7·0	–	–	–	7·1	–	–	7·0	7·1	–	6·9	–	7·0	–	–	7·0	–	7·0	–	–	–	–
	50	–	–	–	–	–	–	–	–	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–
	78	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	17·1	–	17·1	–	17·1	–	16·7	16·8	16·6	16·9	17·0	17·1	17·4	17·8	17·9	18·1	18·2	18·2	17·1	17·1	17·0	–	16·7	–	*AUGUST* 20, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	16·9	–	16·9	–	–	–	–	–	–	–	–	–	
10	17·0	–	17·1	–	17·1	–	16·7	16·8	16·7	16·7	16·8	16·8	16·8	16·5	16·8	16·8	16·6	16·6	16·8	16·5	16·5	–	16·5	–	
13	17·0	–	16·9	–	16·9	–	14·9	14·4	14·2	14·2	14·8	14·1	14·0	14·2	14·1	14·0	14·2	14·2	14·3	14·2	14·4	–	14·2	–	
15	14·3	–	13·8	–	13·3	–	12·7	12·7	12·8	12·8	12·9	13·4	13·5	13·7	13·7	13·7	13·7	13·7	13·8	13·8	14·0	–	13·8	–	
18	11·5	–	11·5	–	11·9	–	11·3	11·6	11·8	–	11·6	12·1	–	12·7	12·8	12·7	12·7	12·6	12·6	–	12·7	–	12·9	–	
20	–	–	–	–	–	–	10·4	10·5	10·8	–	11·3	11·7	11·8	11·8	11·5	11·5	11·7	11·9	11·1	11·2	–	–	11·6	–	
22	10·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
23	–	–	10·4	–	9·8	–	9·6	–	–	9·6	9·7	–	–	10·9	–	9·8	9·9	9·9	9·9	9·8	9·9	–	9·5	–	
25	–	–	–	–	–	–	–	8·3	8·4	8·5	–	9·3	9·6	–	–	9·2	–	–	–	–	–	–	–	–	
28	8·7	–	8·7	–	8·3	–	7·6	–	–	8·2	8·2	8·4	–	8·7	–	–	8·3	8·2	8·2	8·2	8·2	–	7·7	–	
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·1	–	–	–	–	–	–	–	–	–	
35	7·7	–	7·7	–	7·6	–	7·1	–	7·3	–	–	–	7·6	7·6	–	7·4	7·4	7·3	7·2	7·7	7·7	–	7·1	–	
40	–	–	–	–	–	–	–	7·1	–	7·0	–	7·2	–	–	7·1	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·6	–	16·6	16·7	16·9	–	16·9	16·9	16·9	17·1	17·1	17·6	17·6	17·6	17·6	17·6	17·2	17·2	17·2	17·2	17·1	–	17·1	–	*AUGUST* 21, 1911.
1	–	–	–	16·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
2	–	–	–	16·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3	–	–	–	16·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
4	–	–	–	16·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
5	–	–	16·8	16·9	–	–	–	16·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	16·9	–	16·8	16·9	16·9	–	16·9	16·9	16·8	16·9	16·8	16·8	16·8	16·9	16·8	16·9	16·9	16·8	17·2	16·8	16·6	–	16·5	–	
13	14·5	–	–	–	–	–	14·6	14·7	14·6	14·6	14·6	14·6	14·8	14·8	14·8	14·8	–	14·9	15·2	14·9	–	–	14·7	–	
15	14·2	–	14·3	–	14·3	–	14·3	–	14·2	13·9	14·2	14·3	14·3	14·3	14·4	14·4	14·7	14·7	14·6	14·6	14·3	–	14·2	–	
18	13·3	–	13·4	–	13·1	–	11·8	12·7	12·6	12·5	12·3	12·4	12·7	13·3	13·3	13·5	–	13·9	13·8	–	–	–	11·8	–	
20	12·1	–	12·2	12·2	11·3	–	10·9	10·6	10·6	10·3	10·4	10·5	10·9	11·1	11·7	12·0	12·2	12·6	12·4	12·4	11·8	–	10·8	–	
23	–	–	9·3	–	9·6	–	8·4	8·3	8·4	8·4	–	8·3	8·6	8·2	9·2	9·5	–	–	10·2	10·1	9·9	–	9·3	–	
25	8·7	–	8·4	–	7·9	–	7·7	–	7·6	7·7	7·9	–	–	–	–	–	8·2	–	8·4	8·3	8·2	–	8·8	–	
28	–	–	–	–	–	–	–	7·3	–	–	–	7·5	7·6	7·5	7·6	7·6	–	–	–	–	–	–	–	–	
30	7·4	–	7·3	7·4	7·3	–	–	–	–	–	–	–	–	–	–	–	7·4	–	7·6	7·6	7·5	–	–	–	
35	–	–	–	–	–	–	6·9	–	7·0	–	–	7·1	7·1	7·1	7·1	7·1	–	–	–	–	–	–	7·1	–	
40	7·1	–	–	–	6·9	–	–	6·9	–	6·9	6·9	–	–	–	–	–	7·0	–	–	7·1	7·1	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	
77	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	17·0	–	16·9	–	16·9	–	17·1	17·1	17·1	17·1	17·1	17·2	17·2	17·1	17·2	17·3	17·5	17·7	17·4	17·4	17·1	–	17·2	–	*AUGUST* 22, 1911.
10	16·1	–	16·9	–	16·8	–	17·0	17·1	17·0	17·0	16·9	16·7	16·9	17·0	17·1	17·1	17·1	16·9	17·0	16·9	–	–	17·1	–	
13	14·6	–	14·1	–	14·3	–	–	14·9	14·9	14·8	14·8	14·8	–	–	14·8	14·6	14·7	–	14·6	–	14·9	–	15·5	–	
15	14·1	–	13·8	–	13·9	–	14·3	14·3	14·3	14·5	14·3	14·2	14·3	14·4	14·2	14·1	13·9	13·9	14·2	13·8	14·1	–	14·4	–	
16	–	–	13·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	13·3	12·6	12·6	–	–	–	
17	–	–	–	–	12·6	–	–	–	–	–	–	–	–	–	–	–	–	12·1	–	11·8	–	–	–	–	
18	11·2	–	11·6	–	11·5	–	12·5	12·2	12·6	12·6	12·3	13·2	12·0	11·7	11·7	11·5	11·3	11·3	11·1	11·1	11·2	–	12·5	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	11·4	–	–	–	–	–	–	–	–	–	–	–	
20	10·4	–	10·5	–	10·4	–	10·9	11·3	10·9	10·9	10·8	10·7	10·7	10·6	10·8	10·8	10·6	10·4	–	10·7	–	–	–	–	
23	8·8	–	–	–	9·3	–	9·8	9·8	9·6	10·1	10·3	–	–	–	–	–	9·6	–	9·3	–	9·3	–	9·8	–	
25	–	–	8·6	–	–	–	–	–	–	–	–	8·9	8·9	8·9	8·9	8·9	–	8·7	–	8·5	–	–	–	–	
28	7·8	–	–	–	–	–	8·3	8·7	8·2	8·2	8·4	–	–	–	–	–	8·3	–	8·1	–	–	–	8·1	–	
30	–	–	–	–	–	–	–	–	–	–	–	8·0	7·8	7·9	–	–	–	–	–	–	–	–	–	–	
35	7·1	–	–	–	7·1	–	7·5	7·2	7·5	7·4	7·5	–	–	–	7·4	7·4	7·4	–	7·2	–	7·1	–	7·4	–	
40	–	–	7·0	–	–	–	–	–	–	–	–	7·1	7·1	–	–	–	–	7·1	–	7·1	–	–	–	–	
0	17·0	–	17·0	–	17·0	–	16·8	17·0	17·0	17·0	16·9	16·9	16·9	17·0	17·1	17·1	17·3	17·2	17·2	17·1	17·1	–	16·9	–	*AUGUST* 23, 1911.
5	17·0	–	–	–	17·1	–	–	17·1	–	–	–	–	–	–	–	–	17·0	–	–	–	–	–	16·9	–	
10 {	17·0	–	17·0	–	17·0	–	17·0	17·0	17·0	17·0	16·9	16·9	16·9	16·9	16·9	16·9	16·9	16·8	15·7 16·3	15·4	15·4	–	15·4	–	
13	15·2	–	15·4	–	15·4	–	15·1	15·3	–	–	–	15·9	15·9	15·4	15·4	15·4	15·2	15·1	14·8	14·8	14·6	–	14·3	–	
15	14·3	–	14·6	–	14·8	–	14·3	14·6	14·4	14·3	14·5	14·7	14·8	14·8	14·6	14·5	14·6	14·2	–	13·4	13·6	–	13·6	–	
16	–	–	–	–	–	–	–	–	–	–	13·2	–	–	–	–	13·9	–	–	–	–	–	–	–	–	
17	–	–	–	–	–	–	–	–	–	–	12·3	–	–	–	–	12·1	–	–	–	–	–	–	–	–	
18	12·3	–	12·3	–	12·3	–	11·4	11·7	11·4	11·4	11·5	14·6	14·8	14·8	12·1	12·0	12·1	12·1	11·5	11·5	11·2	–	11·6	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	14·2	11·4	11·2	11·5	–	–	–	–	–	–	–	–	
20	11·0	–	10·9	–	10·7	–	10·6	10·6	10·6	10·4	10·3	10·9	10·9	11·2	10·9	11·0	11·0	10·9	10·9	10·8	10·4	–	10·8	–	
23	–	–	9·2	–	9·3	–	–	–	–	–	8·9	9·4	–	9·8	–	–	–	9·4	–	8·7	8·7	–	–	–	
25	8·8	–	8·7	–	–	–	8·4	8·3	8·4	8·3	8·5	–	8·7	–	–	–	8·7	8·7	8·3	8·2	8·0	–	8·4	–	
28	–	–	–	–	–	–	–	–	–	–	–	7·7	–	–	8·1	–	–	–	–	–	–	–	–	–	
30	–	–	–	–	–	–	7·5	–	7·6	7·6	7·6	–	–	7·6	–	–	–	–	7·4	–	–	–	7·6	–	
35	7·1	–	7·1	–	7·2	–	–	7·2	–	7·1	–	7·2	–	–	–	7·2	7·1	–	–	7·0	7·0	–	–	–	
40	–	–	–	–	–	–	–	–	7·1	–	–	–	7·1	–	7·0	–	–	7·1	7·0	–	–	–	7·1	–	
60	–	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
77	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION II.—*continued.*

	Depth. Metres.	Hour of Observation.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 24, 1911.	0	16·9	–	–	16·8	16·7	–	16·6	16·6	16·7	16·6	16·6	16·7	16·6	16·6	16·6	16·5	16·6	16·6	16·5	16·6	16·6	–	–	–
	10	15·9	–	–	15·5	15·9	–	16·0	16·1	16·1	16·2	16·6	16·7	16·7	16·7	16·7	16·6	16·6	16·6	16·6	16·6	16·6	–	–	–
	13	14·6	–	–	14·8	15·2	–	14·8	14·8	14·9	–	14·8	15·0	15·8	16·5	16·7	16·7	16·6	16·6	16·6	–	16·6	–	–	–
	15	14·2	–	–	–	14·3	–	14·4	14·3	14·5	14·3	14·2	14·4	–	15·7	16·7	16·7	16·6	16·6	16·6	16·6	16·6	–	–	–
	16	–	–	–	14·1	–	–	–	–	–	–	–	–	–	–	–	16·5	–	16·6	16·6	15·7	–	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	15·2	14·4	14·3	12·7	–	–	–
	18	12·6	–	–	12·6	13·7	–	13·3	13·3	12·7	12·7	12·9	12·9	13·1	13·7	13·6	13·4	13·6	13·6	12·9	10·9	10·3	–	–	–
	19	–	–	–	–	–	–	–	11·7	11·7	12·2	11·9	–	–	12·4	–	–	–	–	–	–	–	–	–	–
	20	11·4	–	–	11·8	12·6	–	11·5	11·6	11·5	11·6	11·6	11·5	11·5	11·4	11·4	11·4	11·1	11·0	10·4	9·8	9·7	–	–	–
	23	–	–	–	10·7	11·0	–	10·2	–	–	9·7	–	9·9	9·2	–	8·9	–	–	–	–	–	–	–	–	–
	25	–	–	–	–	–	–	–	9·2	–	–	8·9	9·0	8·4	8·6	–	8·2	11·0	8·2	8·1	7·7	7·6	–	–	–
	28	8·4	–	–	8·2	8·5	–	8·2	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	35	7·4	–	–	7·3	7·4	–	7·2	7·2	–	7·2	–	7·5	7·1	7·1	7·1	7·1	7·6	7·1	7·1	7·1	7·1	–	–	–
	40	–	–	–	–	–	–	–	–	7·1	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 25, 1911.	0	16·3	16·4	16·3	16·3	16·3	–	16·2	16·2	16·3	16·3	16·2	16·2	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	–	–	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·9	16·4	15·9	16·1	16·3	–	16·2	15·9	14·9	15·0	15·4	15·9	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	14·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	14·6	15·9	13·4	14·1	14·3	–	16·0	15·8	14·3	–	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	13·6	12·4	13·7	13·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	11·4	12·0	11·2	13·1	13·6	–	13·6	13·7	13·7	13·6	13·4	13·4	–	–	–	–	–	–	–	–	–	–	–	–
	18	9·9	9·2	11·0	11·4	12·2	–	12·6	12·3	12·6	12·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	8·8	9·0	9·8	10·1	11·1	–	–	11·8	11·5	12·3	12·1	11·0	–	–	–	–	–	–	–	–	–	–	–	–
	23	8·2	–	7·8	9·5	9·9	–	–	10·3	–	11·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	–	7·6	–	–	9·3	–	–	9·9	9·9	10·2	10·1	9·8	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	–	–	–	–	–	–	7·9	7·7	7·9	8·3	8·6	–	–	–	–	–	–	–	–	–	–	–	–
	35	7·1	7·1	7·1	7·2	7·1	–	–	–	–	–	–	7·4	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	–	–	–	–	–	–	–	7·3	7·5	7·6	7·1	–	–	–	–	–	–	–	–	–	–	–	–
	79	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.

Depth. Metres.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	15·7	15·7	15·8	15·7	–	15·6	–	*AUGUST* 5, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·4	15·5	15·5	15·4	–	15·4	–	
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	14·8	14·8	15·0	14·8	–	14·5	–	
15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·0	13·0	12·4	12·5	12·8	–	13·0	–	
20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·6	11·0	11·4	11·2	11·3	–	11·7	–	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	8·0	8·0	8·5	8·6	–	9·0	–	
30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	7·3	7·3	7·3	7·3	–	7·4	–	
40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	6·6	6·8	6·7	6·6	–	6·6	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	
80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	15·6	–	15·5	–	15·4	–	15·2	15·4	15·3	15·4	15·3	15·5	15·5	15·6	15·6	15·5	15·4	15·3	15·4	15·4	15·4	–	15·4	–	*AUGUST* 6, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	15·3	15·3	15·5	15·4	–	–	–	
10	14·4	–	14·7	–	15·0	–	14·9	15·0	14·9	15·0	–	14·9	14·8	–	–	–	15·1	15·2	15·1	15·3	15·4	–	15·2	–	
12	–	–	–	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	–	15·1	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	13·9	–	–	–	–	–	–	–	14·5	–	–	–	
14	–	–	–	–	–	–	–	–	14·0	–	–	–	–	13·7	13·7	14·0	13·7	–	13·5	–	13·5	–	–	–	
15	12·8	–	13·2	–	13·6	–	13·9	14·0	–	13·0	13·2	13·5	–	–	–	–	13·5	13·2	12·6	12·0	12·8	–	13·5	–	
16	–	–	–	–	–	–	–	13·0	–	–	–	–	13·0	–	–	–	–	–	–	–	–	–	12·7	–	
17	–	–	–	–	–	–	12·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	–	–	–	–	12·5	–	–	12·5	–	–	–	12·3	–	12·5	12·5	12·3	–	–	–	–	–	–	–	–	
19	–	–	–	–	11·0	–	–	11·2	–	–	–	–	11·5	–	–	–	–	–	–	–	–	–	–	–	
20	12·0	–	11·5	–	9·6	–	10·6	9·7	10·1	10·5	10·5	–	–	–	–	–	10·5	10·0	10·2	9·8	10·3	–	11·0	–	
21	–	–	–	–	–	–	–	–	–	–	–	10·2	10·4	10·3	10·2	10·2	9·8	–	–	–	–	–	–	–	
22	–	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	–	–	–	9·2	–	–	–	–	–	
23	–	–	8·6	–	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	–	–	–	–	–	–	–	–	–	8·5	8·4	8·7	9·6	9·5	9·3	8·6	8·6	–	–	–	–	–	–	–	
25	8·5	–	7·8	–	7·6	–	7·6	7·8	–	–	–	–	–	–	–	–	8·7	8·0	8·3	8·1	8·1	–	9·7	–	
26	–	–	–	–	–	–	–	–	–	13·0	7·7	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	–	–	–	–	7·6	8·7	8·4	8·5	8·0	–	–	–	–	–	–	–	–	
30	7·4	–	7·4	–	7·1	–	7·0	7·2	7·4	7·2	7·2	7·3	7·9	7·8	7·9	7·5	7·3	7·2	7·4	7·5	7·6	–	8·0	–	
35	–	–	–	–	–	–	–	–	–	6·8	–	–	7·5	–	–	–	–	–	–	–	–	–	–	–	
40	6·8	–	–	–	6·5	–	–	6·8	–	–	6·6	6·8	–	7·0	6·7	6·7	6·6	6·7	6·6	6·6	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	
80	–	–	–	–	–	–	6·0	–	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	
0	15·3	–	15·2	–	15·2	–	15·3	–	15·5	15·4	15·5	15·5	15·4	15·4	15·4	15·3	15·2	15·1	15·0	15·0	15·2	–	15·3	–	*AUGUST* 7, 1911.
5	15·2	–	15·0	–	15·2	–	15·3	–	15·3	–	–	–	–	–	–	–	15·1	15·1	15·0	15·0	15·1	–	15·2	–	
10	15·2	–	14·7	–	15·2	–	15·3	–	15·2	15·2	15·2	15·2	15·3	15·3	15·2	15·2	15·0	15·0	14·8	14·9	15·0	–	15·0	–	
12		–	–	–	–	–	–	–	–	–	14·5	14·5	15·0	–	–	–	–	–	–	–	–	–	–	–	
15	15·0	–	12·6	–	13·5	–	14·1	–	13·6	13·5	12·3	12·8	13·8	13·0	12·8	12·7	12·6	12·7	13·1	14·0	14·2	–	14·2	–	
18	–	–	–	–	–	–	–	–	–	11·3	11·5	11·5	11·4	11·9	–	–	–	–	–	–	–	–	–	–	
20	11·0	–	11·0	–	11·5	–	11·7	–	10·7	10·8	9·8	10·5	10·6	10·8	11·3	–	11·3	10·8	11·2	11·5	11·7	–	10·2	–	
22	–	–	–	–	–	–	–	–	–	8·5	–	9·5	–	–	–	–	–	–	–	–	–	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	9·6	10·1	–	–	–	–	–	–	–	–	–	–	
25	9·0		8·2	–	8·7	–	8·2	–	7·8	7·8	7·9	7·5	7·7	9·7	9·0	–	9·0	9·2	9·3	9·0	8·6	–	8·4	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	7·8	–	–	–	–	–	–	–	–	–	–	
30	7·8	–	7·2	–	7·2	–	7·1	–	6·9	7·1	7·2	7·0	7·0	7·3	7·5	–	7·7	7·8	7·9	7·8	7·9	–	7·6	–	
40	7·0	–	7·0	–	7·0	–	6·9	–	6·5	–	6·5	–	6·5	–	6·9	–	–	6·7	6·7	6·7	6·7	–	–	–	
50	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	15·3	–	15·3	–	15·2	–	15·1	–	15·3	15·4	15·4	15·6	16·2	16·1	15·6	15·8	16·6	16·9	16·6	16·0	15·9	–	15·5	–	*AUGUST* 8, 1911.
5	15·3	–	15·2	–	15·1	–	15·1	–	15·2	–	–	–	–	–	–	–	15·5	–	–	15·5	–	–	–	–	
10	15·3	–	15·2	–	15·0	–	15·0	–	–	15·0	15·0	15·1	15·2	15·2	15·2	15·6	15·2	15·2	15·2	15·3	15·1	–	15·1	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·3	14·8	–	–	–	–	–	–	
13	–	–	–	–	–	–	–	–	14·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	–	–	–	–	–	–	–	–	
15	13·6	–	15·2	–	15·0	–	14·0	–	12·6	13·4	14·8	14·4	15·0	14·9	13·0	12·8	12·9	14·3	14·5	15·0	15·0	–	13·5	–	
16	–	–	–	–	–	–	–	–	–	–	–	–	–	12·5	12·6	–	–	–	–	–	–	–	–	–	
17	–	–	–	–	12·0	–	–	–	12·4	–	–	14·2	13·7	–	12·3	–	–	–	–	–	–	–	–	–	
18	–	–	–	–	–	–	–	–	–	–	–	–	12·6	11·9	–	11·0	10·8	11·6	14·4	13·6	12·5	–	–	–	
19	–	–	–	–	–	–	–	–	–	–	–	12·2	–	–	10·9	–	–	–	12·5	–	–	–	–	–	
20	10·0	–	10·3	–	10·8	–	10·5	–	11·2	10·5	11·8	11·3	11·1	10·9	10·5	9·8	9·5	10·0	11·0	11·9	11·6	–	10·7	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·4	9·0	–	–	–	
25	8·0	–	8·3	–	7·7	–	8·8	–	8·4	9·0	11·6	8·9	9·0	8·3	7·8	7·8	8·0	8·0	8·5	8·5	8·0	–	8·0	–	
27	–	–	–	–	–	–	–	–	–	–	8·7	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·3	–	7·4	–	7·4	–	7·2	–	7·5	8·6	7·5	7·6	7·5	7·5	7·3	7·0	7·0	7·3	7·4	7·5	7·0	–	7·2	–	
40	6·7	–	6·8	–	6·7	–	6·6	–	6·6	6·8	6·8	6·6	6·7	7·0	6·7	6·7	6·5	6·8	6·7	6·5	6·5	–	6·7	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	
80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.—*continued.*

	Depth Metres.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 9, 1911.	0	15·6	–	15·9	–	15·7	–	–	15·7	15·8	15·8	16·0	16·0	16·0	16·0	16·1	16·5	–	–	–	–	16·0	–	16·0	–
	5	15·5	–	15·5	–	15·7	–	–	15 2	15·7	15·7	15·7	15·7	15·7	16·0	16·0	15·9	–	–	–	–	16·0	–	16·0	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	15·6	–	–	–	–	–	–	–	–	–	–
	10	15·3	–	15·4	–	15·3	–	–	15·2	15·0	15·3	15·5	15·5	15·3	15·1	15·0	14·8	–	–	–	–	15·2	–	15·0	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·3	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	14·3	–	–	–	–	–	13·3	–	–	–	–	–	–	–	–
	15	13·3	–	13·8	–	14·0	–	–	13·4	13·0	13·6	13·3	13·5	13·5	13·2	12·8	12·8	–	–	–	–	13·5	–	14·0	–
	16	–	–	–	–	–	–	–	–	–	13·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·0	–	–	–
	18	–	–	–	–	–	–	–	–	–	–	12·3	–	–	–	–	11·5	–	–	–	–	–	–	13·5	–
	20	10·1	–	11·2	–	10·6	–	–	10·2	10·9	11·5	11·7	11·7	10·5	10·6	10·1	10·7	–	–	–	–	11·5	–	10·5	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–	–
	25	8·0	–	8·0	–	8·5	–	–	8·0	7·7	8·4	9·2	8·8	8·5	8·5	8·5	8·1	–	–	–	–	9·5	–	–	–
	30	7·1	–	7·2	–	7·5	–	–	7·4	7·5	7·4	7·5	7·5	7·6	7·6	7·6	7·2	–	–	–	–	8·6	–	8·0	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·4	–	6·9	–
	40	6·7	–	6·7	–	6·7	–	–	6·7	7·0	–	6·8	6·8	6·7	6·6	6·8	–	–	–	–	–	8·0	–	6·5	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 10, 1911.	0	16·0	–	15·7	–	15·5	–	15·5	–	15·7	15·7	15·8	15·9	16·2	16·7	16·5	16·6	16·5	16·7	16·5	16·5	16·3	–	16·2	–
	5	15·9	–	15·5	–	–	–	15·5	–	15·5	15·5	15·5	15·6	15·5	15·5	15·5	15·5	15·8	15·8	15·8	15·8	15·7	–	15·7	–
	10	15·1	–	15·4	–	15·4	–	15·0	–	14·9	15·3	15·3	15·5	15·4	15·4	15·2	15·4	15·5	15·5	15·5	15·6	15·5	–	15·3	–
	15	14·6	–	15·0	–	14·5	–	13·6	–	13·5	14·1	14·2	14·2	13·6	13·1	13·6	12·6	13·0	13·7	14·2	14·1	14·0	–	13·5	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·9	–	–	–	–	–
	18	11·6	–	13·5	–	12·2	–	11·8	–	–	–	–	–	–	11·4	11·1	–	11·4	11·7	12·4	12·2	11·9	–	11·2	–
	20	9·5	–	11·3	–	11·0	–	10·5	–	11·9	11·8	11·6	11·0	10·9	10·0	9·5	9·8	10·2	11·3	11·5	11·5	10·7	–	10·3	–
	25	8·3	–	9·2	–	8·5	–	8·2	–	10·0	8·8	8·6	8·5	8·3	8·0	8·0	8·2	8·4	8·3	8·5	8·8	8·6	–	8·0	–
	30	7·2	–	7·4	–	7·3	–	7·3	–	7·5	7·8	8·0	7·8	7·5	7·6	7·5	7·6	7·7	7·7	7·7	7·5	7·5	–	7·2	–
	40	6·5	–	–	–	6·7	–	–	–	6·7	6·7	6·8	6·9	7·2	6·7	6·7	6·7	6·8	6·8	6·7	6·7	6·7	–	6·7	–
	60	–	–	6·5	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 11, 1911.	0	16·2	–	16·2	–	16·5	–	16·4	–	16·5	16·5	16·5	16·7	16·4	16·5	16·5	16·4	16·8	16·6	16·5	16·4	16·2	–	16·5	–
	5	16·0	–	16·0	–	16·3	–	16·3	–	15·8	15·7	15·8	15·8	16·2	16·4	16·4	16·4	16·6	16·6	16·4	16·2	16·2	–	16·0	–
	10	15·5	–	15·7	–	15·3	–	15·3	–	15·0	14·7	15·0	15·0	15·2	15·4	15·3	15·5	15·6	15·5	15·8	15·9	15·7	–	15·5	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·0	–	–	–	–	–	–	–	–	–
	15	14·3	–	14·1	–	13·6	–	13·8	–	13·8	13·5	14·0	13·9	13·3	13·5	13·0	13·5	13·7	14·0	14·0	14·0	13·6	–	13·5	–
	17	–	–	–	–	–	–	–	–	–	–	13·4	–	–	12·7	–	–	–	–	–	–	–	–	–	–
	18	10·5	–	12·3	–	12·5	–	12·3	–	–	–	11·9	–	11·7	–	–	–	–	–	11·9	–	–	–		–
	20	10·5	–	11·5	–	10·5	–	10·4	–	11·2	11·5	11·0	11·3	10·5	10·3	10·6	10·3	11·0	11·0	10·7	11·0	10·9	–	10·6	–
	25	7·9	–	9·0	–	8·8	–	8·0	–	8·5	8·7	8·7	9·4	9·7	8·5	8·5	8·2	8·3	8·1	8·9	8·6	8·7	–	8·5	–
	30	7·5	–	7·2	–	7·3	–	7·3	–	7·3	7·3	7·4	7·6	7·8	7·5	7·5	7 5	–	7·5	7·5	–	7·4	–	7·3	–
	40	6·8	–	6·8	–	6·7	–	6·6	–	6·5	6·5	6·7	6·7	–	–	6·6	6·6	6·7	6·8	6·7	6·7	6·7	–	6·7	–
	50	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 12, 1911.	0	16·2	–	16·0	–	16·2	–	16·0	–	16·2	16·0	16·2	16·2	16·2	16·2	16·3	16·2	16·2	16·2	16·3	16·3	16·3	–	16·2	–
	5	16·1	–	16·0	–	16·0	–	16·0	–	15·8	16·0	16·1	16·0	16·0	16·0	16·1	16·1	16·1	16·1	16·0	16·0	16·0	–	16·2	–
	10	15·7	–	16·0	–	16·0	–	15·8	–	15·6	15·7	15·7	15·6	15·6	15·6	15·8	15·9	15·7	15·7	15·5	14·9	15·5	–	15·6	–
	12	–	–	–	–	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	13·5	–	13·2	–	13·5	–	13·7	–	13·6	13·6	13·6	13·7	13·7	13·7	13·9	13·6	13·2	13·5	13·6	13·6	13·7	–	13·9	–
	18	11·8	–	–	–	12·5	–	12·5	–	12·7	12·6	12·6	12·6	13·0	12·6	12·4	12·8	12·1	12·0	–	12·3	12·4	–	12·5	–
	20	10·5	–	11·2	–	11·7	–	11·7	–	11·2	10·2	10·7	10·6	10·5	10·8	10·8	11·2	10·5	11·0	10·9	11·0	10·9	–	10·5	–
	25	8·2	–	8·0	–	8·3	–	8·2	–	8·0	8·0	8·2	8·0	8·6	8·4	8·3	8·2	8·2	8·0	8·5	8·5	8·4	–	8·6	–
	30	7·5	–	7·5	–	7·5	–	7·5	–	7·2	7·3	7·3	7·4	7·4	7·4	7·5	7·3	7·6	7·3	7·5	7·5	7·5	–	7·5	–
	40	6·9	–	6·7	–	6·8	–	6·7	–	6·7	6·7	6·7	6·8	6·8	6·7	6·7	6·7	6·7	6·8	6·8	6·8	6·6	–	6·6	–
AUGUST 13, 1911.	0	16·1	–	16·0	–	16·1	–	16·1	–	16·0	16·0	16·2	16·3	16·3	16·3	16·3	16·3	16·4	16·4	16·4	16·4	16·3	–	16·4	–
	5	16·0	–	16·0	–	16·0	–	16·0	–	16·0	16·0	16·0	16·0	16·2	16·2	16·3	16·2	16·3	16·3	16·4	16·4	16·3	–	16·4	–
	10	15·5	–	16·0	–	16·0	–	15·8	–	16·0	15·9	15·9	16·0	16·0	16·0	16·0	15·0	15·3	15·4	15·2	15·6	16·1	–	16·3	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	–	–	–	–	–	–	–	–
	15	13·6	–	14·0	–	14·2	–	14·0	–	13·7	13·7	13·7	14·0	14·1	14·2	14·2	13·9	13·7	13·6	13·8	13·6	13·8	–	13·6	–
	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·7	–	11·5	11·4	11·6	11·8	11·6	–	11·6	–
	20	10·2	–	10·0	–	10·8	–	10·7	–	10·5	10·3	10·3	10·7	11·3	11·4	11·2	11·3	10·2	10·5	10·8	10·9	10·6	–	10·5	–
	25	8·3	–	8·0	–	8·2	–	8·5	–	8·0	7·9	7·8	7·9	8·0	8·2	8·0	8·3	8·6	8·3	8·5	8·7	8·8	–	8·5	–
	30	7·4	–	7·2	–	10·3	–	10·1	–	7·2	7·2	7·2	7·3	7·3	7·2	7·2	7·2	7·5	7·5	7·4	7·3	7·4	–	7·5	–
	40	6·7	–	6·6	–	8·0	–	6·7	–	6·7	6·7	6·7	6·7	6·7	6·7	6·7	6·6	6·8	6·8	6·7	6·7	6·7	–	6·8	–
	60	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·5	–	16·4	–	16·4	–	16·2	–	16·2	16·2	16·3	16·4	16·4	16·5	16·5	16·5	16·5	16·5	16·5	16·5	16·4	–	16·3	–	*AUGUST* 14, 1911.
5	16·5	–	16·5	–	16·5	–	16·2	–	16·1	16·2	16·2	16·4	16·4	16·3	16·3	16·4	16·5	16·5	16·5	16·5	16·5	–	16·3	–	
10	16·5	–	16·5	–	16·4	–	16·2	–	16·1	16·1	16·2	16·2	16·2	16·1	16·1	16·2	15·5	15·6	15·2	15·2	16·0	–	16·2	–	
12	15·0	–	–	–	15·0	–	15·0	–	–	–	–	–	–	–	–	–	14·6	–	–	–	14·5	–	–	–	
15	13·5	–	13·6	–	14·1	–	14·0	–	13·7	13·8	14·0	14·0	14·0	14·0	14·0	13·9	14·0	14·0	13·8	13·7	14·0	–	14·0	–	
18	12·0	–	–	–	12·0	–	12·0	–	–	–	–	–	–	–	–	–	12·2	–	–	–	–	–	–	–	
20	10·5	–	10·5	–	11·5	–	11·1	–	10·8	10·5	10·5	11·0	10·6	10·8	10·8	10·9	10·7	10·7	10·6	10·7	11·1	–	11·0	–	
25	8·5	–	8·5	–	8·8	–	8·5	–	8·2	8·2	8·1	8·0	8·1	8·1	8·0	8·1	8·5	8·0	8·5	8·7	8·2	–	8·7	–	
30	7·6	–	7·5	–	7·5	–	7·5	–	7·5	7·3	7·2	7·3	7·1	7·2	7·2	7·2	–	7·2	7·4	7·5	7·6	–	7·5	–	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	
40	6·8	–	6·7	–	6·8	–	6·8	–	7·8	7·6	6·7	6·6	6·7	6·7	6·7	6·7	–	–	6·7	–	–	–	6·7	–	
0	16·4	–	16·3	–	16·3	–	16·3	–	16·4	16·5	16·9	17·3	17·5	18·1	18·5	18·5	18·1	17·8	17·0	16·7	16·9	–	17·4	–	*AUGUST* 15, 1911.
5	16·4	–	16·3	–	16·3	–	16·3	–	16·4	16·4	16·8	16·4	16·4	16·5	–	16·4	16·4	16·5	16·5	16·7	16·8	–	16·6	–	
10	15·8	–	16·0	–	16·3	–	16·3	–	16·0	16·3	16·2	16·3	16·3	16·1	16·0	16·0	15·5	15·7	15·5	16·0	16·0	–	15·7	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	–	–	–	–	–	–	–	–	
15	13·8	–	14·0	–	14·2	–	14·2	–	14·0	14·2	14·0	14·2	14·4	13·5	13·6	13·5	13·4	13·4	13·6	13·9	13·7	–	13·8	–	
17	–	–	–	–	–	–	–	–	–	–	13·0	–	–	13·0	–	–	–	–	–	–	–	–	–	–	
18	12·0	–	12·8	–	12·3	–	11·7	–	11·3	11·0	–	11·6	11·0	–	–	–	–	–	–	–	–	–	–	–	
20	10·6	–	10·7	–	11·2	–	10·4	–	10·2	10·2	10·4	10·3	10·4	10·6	10·5	10·7	10·6	11·2	11·4	11·1	10·8	–	10·7	–	
25	8·3	–	8·1	–	8·2	–	8·3	–	8·0	8·0	8·1	8·4	8·3	8·5	8·5	8·6	8·9	9·1	9·0	8·6	9·1	–	–	–	
30	7·4	–	7·5	–	7·6	–	7·6	–	7·5	7·5	7·9	7·5	7·4	7·5	7·5	7·5	–	7·8	7·6	7·6	7·6	–	7·5	–	
40	6·8	–	6·8	–	6·8	–	6·7	–	6·7	6·7	–	6·8	6·7	6·8	6·8	6·7	–	6·7	6·7	6·7	6·7	–	6·7	–	
60	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	
80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	
0	17·0	–	17·0	–	16·7	–	16·7	–	16·9	17·1	17·1	17·2	17·2	17·4	17·7	17·9	17·6	17·6	17·5	17·4	17·2	–	17·0	–	*AUGUST* 16, 1911.
5	16·7	–	16·5	–	16·5	–	16·7	–	16·7	16·7	16·7	16·5	16·7	16·6	16·7	16·7	16·7	16·7	16·7	17·0	17·0	–	17·0	–	
10	15·9	–	15·3	–	16·0	–	15·5	–	15·7	15·4	15·9	16·2	15·4	15·5	15·7	15·7	15·8	15·8	15·6	15·8	15·6	–	16·2	–	
12	14·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	13·7	–	14·0	–	13·7	–	14·1	–	14·3	14·2	14·4	14·8	13·6	14·0	13·8	13·6	14·0	14·0	13·5	14·0	14·0	–	14·0	–	
18	–	–	–	–	–	–	–	–	11·7	11·6	11·6	11·9	12·5	12·4	11·9	11·4	11·9	12·0	11·6	11·6	11·6	–	11·5	–	
20	10·5	–	10·5	–	11·5	–	10·8	–	9·8	10·3	10·7	10·9	11·8	11·0	11·0	10·6	10·4	10·4	10·7	10·8	11·0	–	11·0	–	
25	8·2	–	8·3		8·0	–	8·0	–	8·5	8·2	8·4	8·9	8·4	8·4	8·8	8·3	8·2	8·2	8·2	8·5	8·9	–	8·0	–	
30	7·5	–	7·4	–	7·2	–	7·0	–	7·2	7·3	7·4	7·3	7·3	7·5	7·5	7·5	7·3	7·5	7·5	7·5	7·4	–	7·6	–	
40	–	–	6·7	–	6·6	–	6·5	–	6·7	6·7	6·7	6·7	6·7	6·7	6·7	6·7	6·7	6·7	–	6·8	6·9	–	6·7	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	
80	–	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	
0	17·2	–	17·0	–	17·0	–	–	–	–	17·3	17·3	17·6	18·6	13·5	18·2	18·0	18·0	17·6	17·5	17·5	17·2	–	17·1	–	*AUGUST* 17, 1911.
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	18·0	–	–	–	–	–	–	–	–	–	
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·2	–	–	–	–	–	–	–	–	–	
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·0	–	–	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	16·9	–	17·0	–	–	–	–	–	16·9	–	–	–	–	–	–	–	–	–	
5	16·8	–	16·8	–	16·9	–	16·9	–	16·7	16·7	16·2	16·8	16·8	16·8	16·8	16·7	16·7	16·5	16·5	16·6	16·6	–	16·6	–	
10	16·0	–	16·3	–	16·0	–	16·0	–	16·0	15·8	15·9	16·0	15·9	16·0	15·8	16·0	16·0	15·9	15·8	15·8	15·7	–	15·6	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·2	–	–	–	–	–	–	–	–	
15	13·8	–	13·9	–	13·7	–	14·0	–	13·2	13·5	13·9	13·6	14·0	13·5	13·7	13·8	13·8	14·8	14·0	14·2	14·3	–	14·4	–	
18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·9	–	12·3	12·2	12·5	12·2	–	–	–	
20	10·2	–	10·0	–	10·5	–	10·4	–	11·0	10·7	10·7	11·0	10·7	10·5	10·2	10·3	10·5	10·4	11·0	10·7	10·5	–	10·5	–	
25	8·0	–	8·5	–	8·5	–	8·8	–	8·2	8·7	8·6	8·5	8·7	8·4	8·3	8·4	8·2	8·0	8·0	8·0	8·3	–	8·0	–	
30	7·5	–	7·5	–	7·8	–	7·4	–	7·6	7·7	7·6	7·6	7·5	7·4	7·2	7·2	7·0	7·0	7·3	7·2	7·2	–	–	–	
40	6·8	–	6·7	–	6·8	–	6·7	–	6·7	6·7	6·7	6·7	–	–	–	–	–	–	–	–	–	–	–	–	
0	17·4	–	17·7	–	17·6	–	17·0	–	16·7	16·8	16·7	16·7	16·8	–	16·8	16·8	16·8	16·8	16·7	16·7	16·7	–	17·5	–	*AUGUST* 18, 1911.
5	16·8	–	16·7	–	16·7	–	16·8	–	–	16·7	16·7	–	–	–	–	–	16·7	16·7	16·7	16·8	16·7	–	16·7	–	
10	15·9	–	15·6	–	15·6	–	15·8	–	15·6	15·6	15·8	16·3	16·0	–	16·5	16·5	16·5	16·5	16·5	16·6	16·6	–	16·3	–	
12	15·3	–	–	–	15·2	–	–	–	–	–	–	–	–	–	–	–	15·7	15·8	15·6	15·5	15·8	–	15·1	–	
15	14·1	–	14·0	–	13·8	–	14·2	–	13·9	13·8	13·7	14·0	14·1	–	14·4	14·3	14·0	13·6	13·7	13·8	13·7	–	13·6	–	
18	11·7	–	12·0	–	12·3	–	12·0	–	11·5	11·4	–	12·2	–	–	11·6	–	11·6	11·6	11·6	11·5	12·0	–	12·0	–	
20	11·5	–	10·8	–	11·0	–	11·0	–	11·0	10·7	11·0	11·5	10·8	–	10·7	10·8	10·4	10·1	10·1	10·4	11·2	–	11·0	–	
25	9·5	–	8·5	–	9·0	–	8·5	–	8·5	8·0	8·3	8·1	8·4	–	8·0	8·1	8·0	7·8	7·8	8·0	8·5	–	8·7	–	
30	7·6	–	7·6	–	7·8	–	7·6	–	–	7·5	7·5	7·5	7·5	–	–	7·3	7·2	7·2	7·2	7·4	7·4	–	7·3	–	
40	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	6·7	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 19, 1911.	0	17·4	–	17·3	–	17·2	–	17·2	–	17·2	17·2	17·2	17·2	17·2	17·0	17·1	17·0	17·1	17·1	17·0	17·0	17·0	–	17·1	–
	5	16·8	–	16·8	–	16·8	–	16·8	–	17·0	17·0	17·0	–	–	–	–	–	–	17·1	–	17·0	–	–	–	–
	10	16·4	–	15·7	–	16·5	–	16·5	–	16·2	16·2	16·2	16·3	16·7	16·3	16·2	15·6	15·9	16·0	16·1	16·3	16·3	–	16·5	–
	12	–	–	–	–	–	–	–	–	–	15·3	15·4	15·0	–	–	–	–	–	–	–	–	14·9	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	14·5	14·7	14·9	14·5	–	–	–	–	–	–	–	–
	15	13·4	–	13·5	–	13·6	–	13·8	–	13·5	13·7	13·6	13·8	13·7	14·0	13·8	13·9	13·9	13·6	13·6	13·5	13·0	–	13·0	–
	18	12·4	–	11·6	–	12·2	–	12·0	–	12·0	11·7	11·7	12·0	11·5	11·4	11·6	11·5	11·6	11·1	11·2	11·5	11·4	–	11·7	–
	20	11·0	–	11·0	–	11·2	–	10·6	–	10·5	10·6	10·5	10·9	10·0	10·5	10·4	10·5	10·3	10·5	10·7	11·0	10·9	–	11·1	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	8·5	–	8·7	–	8·6	–	8·3	–	8·5	8·5	8·5	8·0	8·1	8·2	8·0	8·0	8·4	8·7	9·0	8·9	8·7	–	8·7	–
	30	7·4	–	7·6	–	7·3	–	7·5	–	7·3	7·4	7·3	7·2	7·3	7·3	7·3	7·3	7·5	7·6	7·6	7·6	7·3	–	7·6	–
	40	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 20, 1911.	0	17·0	–	–	17·0	17·0	17·0	17·0	–	17·2	17·2	17·3	17·2	17·5	18·3	18·3	18·3	18·5	–	17·5	17·4	17·3	–	17·2	–
	5	17·0	–	–	17·0	16·9	16·8	16·8	–	16·9	16·9	16·8	16·8	16·9	17·1	16·9	16·8	16·8	–	–	–	–	–	17·1	–
	10	16·6	–	–	16·3	16·3	16·3	16·3	–	16·5	16·5	16·6	16·3	16·1	16·0	16·2	16·1	15·8	–	16·0	16·0	15·7	–	15·5	–
	12	15·0	–	–	–	15·0	–	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	13·5	–	–	13·2	13·4	13·3	13·4	–	13·8	13·8	14·0	14·0	14·2	14·3	14·2	14·2	14·0	–	14·0	14·0	13·9	–	14·0	–
	18	12·0	–	–	12·4	12·5	–	12·4	–	12·7	13·0	13·0	13·1	12·6	12·2	11·8	11·8	12·4	–	–	12·5	12·3	–	12·0	–
	20	11·5	–	–	11·3	11·1	11·0	11·0	–	10·9	11·3	11·1	10·7	10·3	10·7	10·9	11·1	11·4	–	10·5	10·8	10·3	–	10·5	–
	25	8·6	–	–	8·5	8·5	8·5	8·5	–	8·2	8·2	8·0	8·0	8·0	7·9	8·0	8·0	8·5	–	8·5	8·5	8·3	–	8·5	–
	30	7·6	–	–	7·5	7·3	7·1	7·0	–	7·3	7·5	7·4	7·2	7·2	7·2	7·3	7·3	7·5	–	7·5	7·5	7·5	–	7·5	–
	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·9	–	–	–	–
AUGUST 21, 1911.	0	17·0	–	16·5	–	–	–	17·1	–	17·2	17·2	17·4	–	18·0	18·0	18·1	17·7	17·4	17·3	17·2	17·2	17·6	–	17·4	–
	1	–	–	–	–	–	–	–	–	–	–	–	–	17·4	–	–	–	–	–	–	–	–	–	–	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	17·2	–	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–	–	–	16·9	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	16·8	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	16·8	16·8	16·9	–	–	16·7	16·8	16·8	17·1	17·2	17·2	17·2	17·1	–	17·4	–
	10	15·9	–	16·0	–	–	–	16·0	–	16·5	16·4	16·0	–	16·0	16·0	16·0	16·0	16·1	16·0	15·7	16·0	16·0	–	15·9	–
	12	–	–	–	–	–	–	–	–	15·2	15·5	15·2	–	–	15·0	15·2	15·3	–	–	–	–	–	–	–	–
	15	14·0	–	14·3	–	–	–	14·1	–	14·3	14·5	14·4	–	14·4	14·3	14·2	14·2	13·8	13·7	13·6	13·6	13·7	–	13·6	–
	18	12·1	–	12·0	–	–	–	12·3	–	12·3	11·9	12·0	–	11·8	12·2	12·5	12·0	12·1	12·7	11·2	11·6	11·6	–	11·5	–
	20	10·8	–	10·5	–	–	–	10·7	–	11·0	11·0	10·8	–	10·4	10·6	10·5	10·7	11·0	10·7	10·5	10·7	10·7	–	10·5	–
	25	8·6	–	8·3	–	–	–	8·2	–	8·2	8·2	8·0	–	8·1	8·0	8·3	8·7	9·1	9·1	8·9	8·5	9·0	–	8·5	–
	30	7·5	–	7·7	–	–	–	7·3	–	7·2	7·3	7·3	–	7·2	7·2	7·3	7·7	7·6	7·6	7·4	7·4	7·5	–	7·6	–
AUGUST 22, 1911.	0	17·0	–	17·0	–	17·0	–	17·0	–	17·1	17·1	17·1	17·3	17·2	–	17·0	17·1	17·6	17·8	17·5	17·3	17·2	–	17·0	–
	5	17·0	–	17·0	–	17·0	–	17·0	–	–	–	–	–	–	–	–	–	17·0	17·0	17·0	17·0	17·2	–	17·0	–
	10	16·2	–	16·5	–	16·6	–	16·6	–	16·5	16·5	16·5	16·5	16·5	–	16·0	16·0	15·8	16·0	16·0	16·0	16·0	–	16·0	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·2	15·4	15·3	15·1	–	–	–	–
	13	–	–	15·0	–	15·5	–	15·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	13·8	–	13·7	–	13·7	–	14·0	–	14·0	14·0	14·0	14·0	14·1	–	14·0	14·0	15·0	15·1	14·1	14·0	14·0	–	13·8	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·5	13·6	13·3	13·5	–	–	–	–
	18	12·5	–	12·4	–	12·2	–	12·0	–	11·6	11·5	11·7	11·7	12·0	–	12·1	11·6	12·1	12·6	12·1	12·4	12·1	–	11·5	–
	20	10·7	–	11·0	–	11·2	–	10·4	–	10·5	10·5	10·5	10·9	11·1	–	10·9	10·9	11·0	11·0	11·0	11·2	11·2	–	10·5	–
	25	8·5	–	8·4	–	8·3	–	8·0	–	8·2	8·2	8·2	8·2	8·1	–	8·3	8·2	8·3	8·6	8·6	8·6	8·5	–	8·2	–
	30	7·3	–	7·5	–	7·5	–	7·3	–	7·3	7·3	7·2	7·2	7·2	–	7·4	7·4	7·4	7·4	7·3	7·5	7·5	–	7·5	–
	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–
AUGUST 23, 1911.	0	17·0	–	16·9	–	16·9	–	16·9	–	16·8	16·8	16·8	16·8	17·0	17·0	17·2	17·3	17·3	17·3	17·0	17·0	17·0	–	16·9	–
	5	17·0	–	16·9	–	17·0	–	16·8	–	16·6	–	16·8	–	–	–	–	16·8	–	–	–	–	16·9	–	16·8	–
	10	16·0	–	16·5	–	16·5	–	16·6	–	16·6	16·5	16·4	16·4	16·0	16·7	16·7	16·7	16·7	16·7	16·6	16·0	15·8	–	16·0	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·7	14·9	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	14·6	15·2	14·8	14·5	–	–	14·4	–	14·5	14·5	14·4	14·4	–	–	–	–
	15	13·5	–	14·0	–	14·3	–	13·6	–	14·0	14·0	14·0	14·0	13·5	13·5	13·6	13·9	13·9	14·0	13·8	13·6	13·9	–	14·0	–
	18	11·9	–	11·0	–	11·6	–	11·6	–	11·9	11·9	12·3	12·2	11·9	12·0	12·1	11·9	12·0	12·3	12·0	12·0	–	–	12·5	–
	20	10·4	–	10·6	–	10·5	–	10·3	–	10·6	10·7	11·0	10·6	11·0	11·0	11·0	11·3	11·0	11·0	10·5	11·0	10·9	–	11·0	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	9·5	9·4	9·5	9·5	–	–	–	–
	24	–	–	–	–	–	–	–	–	–	–	–	–	9·2	–	–	–	–	–	–	–	–	–	–	–
	25	8·5	–	8·5	–	8·3	–	8·3	–	8·7	8·8	8·5	8·5	8·5	–	8·5	8·5	8·5	8·7	8·5	8·7	8·5	–	8·6	–
	30	7·5	–	7·5	–	7·5	–	7·3	–	7·4	7·4	7·2	7·3	7·3	–	7·5	7·5	–	7·3	7·5	7·5	7·4	–	7·2	–
	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–
	80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·2	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·7	–	16·7	–	16·7	–	16·5	–	17·2	16·6	16·6	16·6	16·6	16·6	16·5	16·5	16·5	16·5	16·4	16·4	16·3	16·5	16·4	–	*AUGUST* 24, 1911.
5	16·8	–	16·7	–	16·7	–	16·7	–	16·6	16·6	16·6	16·6	16·6	16·5	16·5	–	–	–	–	16·4	–	–	–	–	
10	16·3	–	16·3	–	16·5	–	16·4	–	16·3	16·5	16·0	16·0	16·1	16·4	16·5	16·5	16·2	16·2	16·2	16·4	16·2	16·4	16·5	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·4	14·9	15·0	15·6	15·7	15·7	–	–	
15	14·5	–	14·5	–	14·5	–	14·1	–	13·9	13·7	13·5	12·8	13·1	14·0	13·6	13·2	14·0	13·5	13·9	13·9	14·1	14·0	14·0	–	
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·0	13·0	–	–	–	13·0	–	–	
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·5	–	
18	12·1	–	11·6	–	11·5	–	12·0	–	12·0	11·7	11·6	11·5	11·6	11·6	12·0	12·3	11·5	11·5	12·0	11·6	11·6	11·5	–	–	
20	10·5	–	10·5	–	10·8	–	10·5	–	10·6	10·6	10·8	10·5	10·9	10·6	10·8	10·5	10·5	10·5	10·8	10·7	–	10·5	10·5	–	
22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·8	10·0	10·0	9·0	9·1	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·6	–	8·5	8·5	–	
25	8·3	–	8·0	–	8·2	–	8·5	–	8·6	8·6	8·4	8·6	8·6	8·6	8·6	8·5	8·4	8·3	8·5	8·3	8·5	8·2	8·2	–	
30	7·1	–	7·0	–	7·3	–	7·4	–	7·5	7·3	7·5	7·6	7·5	7·5	7·5	7·6	7·4	7·4	7·5	7·4	7·5	–	7·5	–	
0	–	16·5	–	16·4	–	16·1	–	16·1	16·2	16·2	16·2	16·2	16·2	16·2	16·3	16·2	16·2	16·2	16·0	16·0	–	–	16·0	–	*AUGUST* 25, 1911.
5	–	16·5	–	16·4	–	16·1	–	16·1	16·2	–	–	–	16·2	–	–	–	16·2	–	–	–	–	–	–	–	
10	–	16·5	–	16·1	–	15·9	–	16·0	16·0	16·0	16·1	16·0	16·0	16·1	16·1	16·0	16·0	16·0	16·0	16·0	–	–	16·0	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	–	–	–	–	
13	–	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	15·9	–	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	–	–	–	–	
15	–	13·0	–	13·7	–	13·9	–	13·8	14·0	14·5	13·8	14·5	15·7	15·8	15·6	15·7	15·8	–	–	14·9	–	–	–	–	
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	14·8	14·7	–	–	–	14·6	–	
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·9	13·3	13·0	13·0	–	–	13·6	–	
18	–	12·4	–	–	–	12·1	–	–	12·9	12·6	12·8	12·9	12·7	13·1	12·8	12·8	12·2	11·9	11·6	11·9	–	–	11·5	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·5	–	–	–	–	–	–	
20	–	10·7	–	12·0	–	12·0	–	12·0	10·2	10·4	10·3	10·2	10·2	10·2	10·2	9·8	9·6	10·2	10·5	10·2	–	–	10·6	–	
21	–	–	–	–	–	–	–	9·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
22	–	–	–	10·9	–	–	–	8·8	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–	
25	–	–	–	8·9	–	8·8	–	7·9	8·9	7·6	8·0	7·5	7·5	7·5	7·6	7·7	8·8	8·9	8·7	8·6	–	–	8·8	–	
30	–	7·7	–	–	–	7·5	–	–	7·2	7·0	7·2	7·1	7·0	7·1	7·2	7·0	7·5	7·5	7·6	7·5	–	–	7·7	–	
40	–	–	–	–	–	–	–	–	–	–	–	6·5	6·6	6·6	6·6	–	–	7·0	6·7	7·2	–	–	–	–	
0	16·0	–	16·0	–	15·9	15·8	15·9	–	15·8	15·8	15·8	15·9	15·9	16·0	16·0	15·9	15·8	15·9	15·9	–	–	–	15·6	15·8	*AUGUST* 26, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·9	15·9	–	–	–	–	
10	16·0	–	16·0	–	16·0	–	15·8	–	15·8	15·7	15·8	15·8	15·8	15·8	15·9	–	15·8	15·9	–	–	–	–	15·6	–	
13	15·8	–	–	–	–	–	15·7	–	–	–	–	–	–	–	15·7	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	–	–	–	
15	15·8	–	15·8	–	15·0	13·8	13·6	–	14·0	14·0	14·0	14·5	14·3	14·5	14·5	15·1	14·8	14·7	–	–	–	13·7	14·6	15·5	
16	14·0	–	–	–	13·6	12·3	–	–	–	–	12·6	13·4	13·5	13·7	13·7	14·3	14·4	14·3	14·0	13·7	–	13·3	–	–	
17	–	–	12·8	–	–	12·3	–	–	–	12·3	–	13·0	12·6	12·8	13·0	13·7	13·6	13·2	12·7	13·1	–	12·6	13·8	13·2	
18	11·6	–	11·7	–	12·1	12·0	12·0	–	12·1	12·0	12·1	–	12·0	11·8	12·4	12·7	12·7	12·6	12·2	12·1	–	12·1	12·3	12·5	
19	–	–	–	–	–	11·8	–	–	–	–	–	–	–	–	11·4	–	–	–	–	–	–	11·7	11·5	12 5	
20	11·0	–	10·6	–	10·3	–	11·0	–	10·8	11·0	11·0	11·4	11·1	11·0	11·3	11·3	11·2	11·5	10·8	10·9	–	10·8	11·4	10·5	
21	–	–	–	–	–	–	–	–	–	–	10·5	–	10·9	–	–	–	–	11·1	10·2	10·4	–	10·0	10·2	10·5	
22	10·0	–	10·3	–	9·5	–	9·9	–	10·0	10·0	–	10·1	10·4	10·8	10·6	10·2	10·0	10·5	10·0	10·2	–	9·8	10·0	10·0	
23	–	–	–	–	–	–	–	–	–	–	10·0	–	9·8	9·9	9·9	9·0	9·7	9·7	9·7	9·6	–	9·6	9·3	9·5	
24	–	–	–	–	–	–	–	–	–	–	–	–	9·1	9·1	9·1	8·5	8·7	8·6	–	–	–	–	–	–	
25	8·6	–	8·6	–	8·5	–	8·5	–	8·4	8·3	8·4	8·4	8·2	8·5	8·1	–	8·1	8·5	8·6	–	–	–	8·6	9·0	
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·6	–	7·4	–	7·5	–	7·5	–	7·2	7·2	7·2	7·2	7·2	7·2	7·0	–	7·2	7·0	7·2	–	–	7·6	–	7·7	
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
40	–	–	–	–	–	–	6·7	–	6·7	–	–	6·7	6·7	–	6·7	6·7	–	6·7	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION III.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 27, 1911.	0	15·7	15·6	15·6	–	15·7	15·5	15·6	–	15·6	–	15·9	15·9	16·0	–	–	–	15·9	15·8	15·8	15·8	–	15·7	15·7	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	–	–	–	–	–	–	–	–	–	–
	10	15·7	–	15·6	15·7	15·7	–	–	15·7	–	15·6	15·6	–	–	–	–	15·8	–	–	15·7	15·6	–	15·6	15·7	–
	12	–	–	–	–	–	–	–	–	–	–	–	15·6	–	–	–	–	–	–	–	15·6	–	15·6	15·6	–
	13	–	–	–	–	–	–	–	–	–	–	15·6	–	–	–	–	–	15·7	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	15·7	–	–	–	–	–	–	–	–
	15	–	–	–	15·4	14·5	14·7	–	15·1	15·2	15·4	15·0	14·8	15·3	15·0	15·2	15·2	15·4	15·4	13·6	13·5	–	14·4	15·3	–
	16	13·3	–	–	13·7	–	14·2	–	14·6	14·5	14·9	14·2	14·3	14·4	13·7	14·3	13·4	15·3	14·7	–	–	–	–	–	–
	17	13·4	–	13·0	12·4	13·0	13·3	13·5	13·8	13·7	13·3	12·9	12·2	13·2	13·1	13·6	13·2	13·6	13·3	–	–	–	–	–	–
	18	12·6	13·3	12·0	12·2	12·3	–	12·0	12·6	12·9	12·5	12·0	11·5	12·9	12·0	12·0	12·7	12·5	12·5	11·7	11·7	–	11·8	12·6	–
	19	12·3	12·0	11·0	–	11·1	11·7	11·4	–	12·3	–	–	–	–	11·0	11·3	–	–	–	–	–	–	–	–	–
	20		10·7	10·7	9·8	–	10·7	11·3	11·5	11·9	10·3	10·2	10·1	10·0	10·4	10·6	11·7	11·6	11·4	11·0	10·7	–	11·2	11·6	–
	21	10·7	10·5	9·5	9·7	–	–	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	10·9	10·5	9·2	9·2	9·2	10·0	9·8	9·8	9·7	9·3	9·0	9·0	8·8	9·8	10·0	10·1	10·1	10·0	–	–	–	–	–	–
	23	9·5	–	–	8·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	9·1	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	–	–	8·5	–	–	8·7	8·5	8·7	8·7	8·3	8·0	8·4	8·2	–	9·0	9·0	9·0	9·0	8·7	8·7	–	8·8	8·6	–
	26	–	–	–	–	8·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	29	7·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	7·5	–	7·5	–	7·5	–	–	7·8	–	7·5	7·6	7·7	7·5	7·5	7·5	7·5	7·5	7·5	7·3	–	7·3	7·5	–
	35	–	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	–	–	–	–	–	–	–	–
	39	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	–	–	–	6·8	6·8	–	6·8	–	6·8	–	–	–	6·6	–	–	–	–	–	6·6	–	6·6	6·6	–
	60	–	–	–	–	–	–	–	6·8	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–	–
AUGUST 28, 1911.	0	16·0	–	16·0	–	15·9	–	15·7	–	15·7	–	15·8	–	16·0	–	17·3	–	16·1	16·0	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·8	–	15·8	–	15·8	–	15·7	–	15·7	–	15·6	–	15·7	–	16·8	–	16·0	16·0	–	–	–	–	–	–
	13	–	–	15·6	–	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	15·5	–	–	–	15·0	–	15·4	–	15·4	–	15·1	–	14·4	–	15·3	–	–	–	–	–	–	–	–	–
	16	–	–	13·7	–	–	–	–	–	14·0	–	–	–	–	–	–	–	13·7	13·6	–	–	–	–	–	–
	17	–	–	–	–	–	–	13·4	–	13·0	–	13·0	–	–	–	14·1	–	13·3	–	–	–	–	–	–	–
	18	12·4	–	12·3	–	12·0	–	12·7	–	12·6	–	–	–	12·2	–	12·5	–	12·6	–	–	–	–	–	–	–
	19	–	–	11·5	–	–	–	–	–	–	–	–	–	–	–	11·8	–	12·2	–	–	–	–	–	–	–
	20	10·5	–	–	–	10·1	–	11·1	–	11·0	–	10·5	–	10·7	–	11·3	–	12·0	11·3	–	–	–	–	–	–
	21	–	–	10·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	10·3	–	10·2	–	9·2	–	9·7	–	–	–	10·4	10·0	–	–	–	–	–	–
	23	–	–	9·2	–	9·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	–	–	–	–	–	–	8·6	–	9·5	–	9·7	9·5	–	–	–	–	–	–
	25	9·0	–	–	–	–		9·0	–	8 6	–	8·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	7·7	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	7·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	7·6	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	–	–	–	–	–	7·6	–	7·3	–	7·2	–	–	–	7·6	–	7·7	7·8	–	–	–	–	–	–
	32		–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–
	35	7·0	–	7·0	–	7·0	–	7·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	–	–	–	–	–	6·8	–	6·7	–	6·6	–	6·8	–	–	–	6·9	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	75	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–
	81·5		–	–		–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·1	–	16·0	15·7	16·0	15·8	15·8	15·8	16·0	16·1	16·1	16·1	16·1	15·9	15·9	16·0	16·1	16·1	16·0	16·1	15·6	16·0	16·0	16·1	*AUGUST* 4, 1911.
5	–	–	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·6	–	15·6	15·7	15·7	15·7	16·1	15·4	15·6	15·7	15·7	15·7	15·8	15·8	15·8	15·8	15·7	15·6	15·6	15·6	14·6	15·0	–	14·7	
12	–	–	–	–	–	–	–	–	–	–	15·2	15·0	–	–	–	–	–	–	–	14·9	–	–	14·1	13·7	
13	–	–	–	–	15·0	–	13·0	–	14·3	14·4	15·0	–	–	–	–	–	15·0	–	14·4	14·2	–	–	–	–	
14	–	–	–	–	–	14·7	–	12·8	12·8	12·8	13·6	14·2	15·0	15·3	–	–	–	14·1	–	13·9	–	–	–	–	
15	14·2	–	14·3	14·6	13·5	12·6	11·1	11·2	11·7	12·1	12·7	13·8	15·3	15·0	15·0	14·7	14·7	13·6	13·3	13·2	12·2	12·2	12·2	12·1	
16	–	–	13·4	12·9	11·2	11·1	14·4	11·1	11·1	–	12·1	12·8	14·4	14·7	14·7	13·6	13·3	12·7	12·5	12·2	–	–	–	–	
17	–	–	11·3	11·7	10·6	10·6	11·0	10·6	10·5	10·7	11·3	12·3	–	–	–	12·7	12·5	12·2	11·8	11·8	–	–	–	–	
18	11·6	–	–	–	–	–	–	10·1	10·0	10·1	10·4	11·7	14·2	–	12·0	12·2	12·3	11·8	11·7	11·7	–	–	11·1	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·7	–	–	–	11·7	–	–	–	–	
20	10·1	–	–	9·2	9·3	9·4	9·4	9·2	8·9	9·4	10·0	10·6	–	–	11·4	11·4	11·2	11·1	11·1	10·0	10·4	10·1	10·4	10·4	
22	–	–	8·3	–	–	8·4	–	–	–	–	–	–	10·0	–	–	–	–	–	–	–	–	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	–	–	–	–	–	–	
25	7·7	–	7·7	–	–	7·6	–	7·7	–	7·8	7·8	8·0	–	–	–	9·4	9·1	7·5	–	–	–	–	8·5	–	
30	7·2	–	–	7·2	7·2	7·3	7·2	7·2	7·2	–	7·2	7·2	–	–	7·5	7·9	–	7·5	7·2	–	–	7·3	7·4	7·2	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–	
40	6·7	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	7·6	–	–	–	–	6·9	6·7	–	
45	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	6·7	
55	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
65	–	–	–	6·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·1	16·0	16·0	16·1	15·8	15·9	15·8	15·9	15·9	15·9	16·0	16·1	16·1	15·9	16·0	15·8	15·7	–	–	–	15·8	15·7	15·7	–	*AUGUST* 5, 1911.
5	–	–	–	–	–	–	–	–	–	–	15·8	–	–	15·6	15·6	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	16·0	–	14·6	14·4	–	–	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	15·8	–	–	–	14·1	13·9	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	14·4	14·1	–	–	–	13·9	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	13·8	–	13·4	13·6	–	–	–	–	–	–	–	–	–	
10	14·8	14·7	15·0	14·9	15·2	15·0	14·4	15·0	14·6	13·4	13·2	–	13·9	13·2	13·6	14·6	–	–	–	–	14·6	–	15·1	–	
11	–	14·4	–	–	–	–	–	–	–	13·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	13·7	12·9	13·7	14·0	–	–	–	–	–	–	13·1	12·8	13·3	13·1	–	–	–	–	–	–	–	–	–	–	
13	–	–	–	–	13·2	–	–	–	12·9	12·8	–	–	–	–	13·1	–	–	–	–	–	–	–	13·9	–	
14	–	–	–	12·7	12·8	12·8	13·1	13·3	–	–	–	–	12·5	–	–	–	–	–	–	–	–	–	–	–	
15	11·8	11·7	11·9	12·1	12·4	–	12·8	–	–	–	–	12·2	12·5	12·5	12·5	14·6	13·6	–	–	–	14·6	13·6	13·4	–	
16	–	–	–	–	12·2	12·3	–	12·4	12·1	–	12·8	–	12·2	–	–	–	–	–	–	–	–	–	–	–	
17	11·1	–	–	–	–	–	11·9	–	–	11·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	–	10·8	–	–	–	11·7	11·7	11·7	–	–	11·1	11·3	–	11·9	11·9	–	13·3	–	–	–	–	13·3	13·3	–	
19	–	–	–	–	11·3	–	–	–	11·7	–	–	–	–	11·7	–	–	–	–	–	–	–	–	–	–	
20	10·1	10·1	10·1	10·7	–	11·2	11·1	11·3	–	10·6	9·4	–	–	10·8	11·8	12·8	–	–	–	–	12·8	12·9	12·6	–	
21	–	–	–	–	–	–	–	–	–	–	–	10·3	–	–	–	–	–	–	–	–	–	–	11·4	–	
22	–	–	–	–	–	10·3	10·7	10·6	10·1	–	–	–	–	–	–	12·8	–	–	–	–	12·8	12·8	–	–	
23	–	–	–	–	–	–	–	10·3	–	–	–	–	–	–	10·3	–	–	–	–	–	–	12·0	10·2	–	
24	–	–	–	–	9·4	9·4	9·7	8·3	8·9	9·0	8·9	–	–	–	–	–	–	–	–	–	–	10·2	–	–	
25	–	7·6	7·9	8·1	–	–	–	8·5	–	–	–	8·6	–	–	8·9	–	–	–	–	–	–	10·1	8·8	–	
26	–	–	–	–	–	8·9	–	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	7·9	–	–	–	–	–	–	–	–	–	–	–	–	–	8·9	–	–	
28	–	–	–	–	7·8	–	8·1	–	7·9	7·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	8·3	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·2	7·2	–	7·2	–	–	–	–	–	–	–	7·8	–	7·5	–	–	–	–	–	–	–	7·9	7·2	–	
32	–	–	–	–	–	–	–	7·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
35	–	–	–	–	–	–	–	–	7·3	6·9	7·8	–	–	–	–	–	–	–	–	–	–	–	–	–	
40	6·7	–	–	–	6·7	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

	Depth. Metres.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
August 6, 1911.	0	15·8	15·6	15·7	–	15·6	–	15·6	–	15·3	–	15·5	–	15·6	–	16·1	–	16·1	–	15·7	–	–	–	–	–
	5	–	–	–	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	15·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	7	–	–	–	–	15·6	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	15·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	14·8	–	14·4	–	14·4	–	14·9	–	15·2	–	15·4	–	15·4	–	15·5	–	15·4	–	15·3	–	–	–	–	–
	11	–	–	–	–	–	–	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	14·0	–	14·1	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–	–	–
	13	14·1	–	13·7	–	13·3	–	13·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·6	–	–	–	–	–
	15	13·7	13·3	13·4	–	13·0	–	13·6	–	14·6	–	15·2	–	15·3	–	15·0	–	14·4	–	12·9	–	–	–	–	–
	16	13·3	–	–	–	12·8	–	–	–	–	–	–	–	–	–	–	–	14·1	–	11·5	–	–	–	–	–
	17	12·9	–	11·7	–	–	–	12·8	–	–	–	–	–	–	–	14·2	–	13·2	–	9·9	–	–	–	–	–
	18	12·8	12·2	–	–	9·6	–	12·4	–	13·7	–	14·2		14·4	–	13·9	–	11·7	–	–	–	–	–	–	–
	19	11·4	10·7	–	–	–	–	11·9	–	13·4	–	13·9	–	–	–	13·7	–	9·8	–	9·4	–	–	–	–	–
	20	9·1	9·4	8·9	–	8·9	–	10·0	–	13·3	–	13·8	–	13·9	–	13·3	–	9·0	–	–	–	–	–	–	–
	21	8·9	8·5	–	–	8·3	–	–	–	10·8	–	–	–	13·1	–	13·3	–	–	–	8·5	–	–	–	–	–
	22	–	–	–	–	–	–	–	–	10·6	–	12·8	–	12·2	–	9·2	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	11·0	–	11·6	–	8·7	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	–	–	–	–	9·5	–	9·4	–	8·3	–	–	–	–	–	–	–	–	–
	25	–	7·8	–	–	7·5	–	–	–	8·9	–	–	–	8·3	–	8·4	–	7·6	–	7·8	–	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·3	–	6·7	–	7·0	–	7·2	–	7·3	–	7·3	–	7·1	–	7·2	–	–	–	7·3	–	–	–	–	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	–	–
	40	–	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	55	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
August 7, 1911.	0	15·6	–	15·7	–	15·6	–	15·6	–	15·7	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·4		15·2	–	15·3	–	15·5	–	15·5	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–
	11	–	–	–	–	–	–	–	–	–	–	15·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	15·0	–	13·7	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	15·0	–	13·3	–	12·9	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	12·7	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	14·6	–	–	–	14·7	–	14·4	–	12·6	–	10·9	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	–	–	–	–	13·4	–	12·8	–	11·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	17	–	–	–	–	13·3	–	–	–	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	–	–	–	–	13·1	–	12·2	–	–	–	10·2	–	–	–	–	–	–	–	–	–	–	–	–	–
	19	–	–	–	–	12·2	–	11·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	12·8	–	13·2	–	11·7	–	10·2	–	9·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	21	12·2	–	12·6	–	11·4	–	9·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	10·0	–	–	–	–	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	10·0	–	10·8	–	10·0	–	9·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	9·2	–	10·6	–	9·3	–	8·9	–	7·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	9·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·9	–	7·9	–	8·3	–	–	–	–	–	7·5	–	–	–	–	–	–	–	–	–	–	–	–	–
	35	–	–	–	–	–	–	–	–	7·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
August 8, 1911.	0	–	–	–	–	–	–	–	–	15·5	–	15·6	–	16·0	–	16·0	–	16·6	–	16·6	–	16·1	–	16·0	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	15·6	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	15·4	–	–	–	15·6	–	15·6	–	16·4	–	15·4	–	–	–	15·6	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·3	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	14·8	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·3	–	12·2	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	15·4	–	15·3	–	–	–	14·7	–	12·2	–	11·1	–	14·3	–	15·0	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·5	–	11·1	–	11·1	–	–	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	13·9	–	10·7	–	10·3	–	10·4	–	12·4	–	12·8	–
	18	–	–	–	–	–	–	–	–	15·3	–	–	–	–	–	–	–	10·0	–	–	–	–	–	–	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	11·7	–	–	–	–	–	–	–	–	–	12·3	–
	20	–	–	–	–	–	–	–	–	15·2	–	15·2	–	11·1	–	9·3	–	9·0	–	9·0	–	10·6	–	–	–
	21	–	–	–	–	–	–	–	–	13·7	–	11·2	–	–	–	–	–	–	–	–	–	–	–	11·1	–
	22	–	–	–	–	–	–	–	–	12·6	–	10·7	–	9·3	–	8·3	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	11·3	–	10·3	–	–	–	–	–	–	–	–	–	–	–	10·2	–
	24	–	–	–	–	–	–	–	–	10·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	–	–	–	–	–	–	–	–	9·8	–	9·4	–	7·7	–	7·3	–	7·2	–	7·4	–	9·0	–	9·2	–
	28	–	–	–	–	–	–	–	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	–	–	–	–	–	–	–	–	–	7·3	–	6·9	–	7·1	–	–	–	–	–	7·3	–	7·8	–
	35	–	–	–	–	–	–	–	–	7·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	40	–	–	–	–	–	–	–	–	–	–	6·7	–	–	–	–	–	6·6	–	–	–	6·7	–	–	–
	50	–	–	–	–	–	–	–	–	6·6	–	6·6	–	–	–	–	–	–	–	6·6	–	–	–	6·3	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–
	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	15·8	–	15·9	–	16·0	–	16·1	–	15·9	–	16·6	–	16·7	–	16·7	–	16·7	–	16·9	–	16·3	–	16·2	–	*AUGUST* 9, 1911.
5	–	–	–	–	15·6	–	15·6	–	–	–	–	–	16·0	–	–	–	–	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	16·6	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	14·4	–	16·4	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	–	–	15·6	–	15·1	–	14·7	–	13·9	–	13·8	–	14·8	–	15·0	–	16·6	–	15·8	–	15·0	–	15·0	–	
11	–	–	–	–	–	–	–	–	12·7	–	13·2	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	13·9	–	12·9	–	12·7	–	13·0	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	12·9	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	11·9	–	–	–	11·8	–	12·7	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	14·6	–	14·2	–	11·8	–	11·7	–	11·7	–	–	–	12·9	–	13·9	–	15·8	–	14·4	–	14·2	–	–	–	
16	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·8	–	
17	–	–	–	–	–	–	–	–	11·0	–	–	–	–	–	–	–	–	–	13·8	–	13·3	–	–	–	
18	–	–	12·2	–	11·1	–	–	–	–	–	11·3	–	–	–	–	–	15·6	–	–	–	–	–	11·8	–	
19	12·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	–	–	–	–	–	
20	11·4	–	11·3	–	10·6	–	11·0	–	9·8	–	10·4	–	11·8	–	12·9	–	14·9	–	–	–	11·8	–	9·7	–	
21	11·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	–	12·3	–	9·1	–	–	–	
22	–	–	10·0	–	10·0	–	9·6	–	–	–	–	–	–	–	–	–	12·2	–	–	–	8·8	–	8·6	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·9	–	12·1	–	–	–	–	–	
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·2	–	–	–	–	–	
25	10·4	–	9·1	–	8·8	–	8·3	–	7·8	–	8·3	–	10·7	–	11·3	–	11·7	–	10·7	–	7·9	–	7·9	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·4	–	–	–	–	–	
27	–	–	–	–	–	–	–	–	–	–	–	–	10·0	–	–	–	–	–	9·4	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·8	–	7·8	–	7·5	–	7·3	–	–	–	–	–	8·3	–	9·9	–	9·7	–	7·8	–	7·4	–	–	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	–	–	–	–	–	–	
35	–	–	–	–	–	–	–	–	6·8	–	–	–	7·8	–	–	–	–	–	–	–	–	–	–	–	
40	7·1	–	–	–	6·8	–	6·7	–	–	–	–	–	6·9	–	7·3	–	–	–	6·7	–	6·9	–	6·9	–	
45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	6·7	–	6·8	–	–	–	–	–	–	–	–	–	
55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
64	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	
65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·1	–	16·1	–	16·0	–	16·0	–	16·6	–	16·6	–	16·6	–	17·2	–	17·2	–	17·2	–	16·9	–	16·7	–	*AUGUST* 10, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·1	–	14·8	–	15·8	–	15·8	–	16·1	–	16·1	–	15·8	–	15·8	–	15·8	–	15·9	–	16·0	–	15·8	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	–	14·9	–	–	–	–	–	
13	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·5	–	14·4	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·8	–	13·7	–	–	–	–	–	
15	12·9	–	12·9	–	14·6	–	15·6	–	15·6	–	16·1	–	14·6	–	13·6	–	13·3	–	13·1	–	14·6	–	14·4	–	
16	–	–	–	–	–	–	–	–	–	–	14·6	–	–	–	–	–	12·4	–	12·4	–	–	–	–	–	
17	10·9	–	11·7	–	13·8	–	–	–	–	–	–	–	12·9	–	12·5	–	12·2	–	11·1	–	13·6	–	13·3	–	
18	9·9	–	11·1	–	–	–	–	–	14·4	–	13·8	–	–	–	–	–	10·1	–	10·3	–	12·8	–	–	–	
19	–	–	8·7	–	13·1	–	–	–	14·1	–	12·3	–	11·7	–	10·0	–	9·8	–	–	–	11·8	–	12·0	–	
20	8·5	–	8·1	–	11·4	–	13·1	–	13·2	–	11·7	–	9·0	–	9·2	–	8·9	–	8·9	–	10·7	–	–	–	
21	–	–	–	–	–	–	–	–	12·3	–	–	–	–	–	–	–	–	–	–	–	–	–	10·1	–	
22	–	–	–	–	10·1	–	11·7	–	11·7	–	10·8	–	7·8	–	–	–	–	–	–	–	9·4	–	–	–	
23	–	–	–	–	–	–	–	–	11·1	–	7·8	–	–	–	–	–	–	–	–	–	–	–	8·9	–	
24	–	–	–	–	–	–	–	–	10·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	8·2	–	–	–	8·1	–	9·4	–	9·4	–	7·7	–	7·7	–	7·5	–	7·7	–	–	–	7·8	–	8·4	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	8·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	–	–	7·2	–	7·2	–	7·2	–	7·3	–	7·2	–	6·9	–	7·2	–	7·1	–	–	–	7·3	–	7·4	–	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·9	–	–	–	–	–	
40	6·8	–	–	–	6·7	–	6·7	–	–	–	–	–	6·7	–	6·7	–	–	–	–	–	6·7	–	6·8	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	
64	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 11, 1911.	0	16·8	–	16·8	–	16·7	–	16·7	–	16·8	–	16·8	–	16·6	–	16·6	–	16·7	–	16·7	–	16·7	–	16·2	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·1	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·6	–	15·3	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	15·7	–	15·8	–	15·7	–	15·4	–	–	–	–	–	–	–	15·2	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	–	–	–
	9	–	–	–	–	–	–	–	–	14·7	–	15·1	–	–	–	–	–	14·4	–	–	–	–	–	–	–
	10	15·6	–	14·9	–	14·7	–	15·0	–	14·2	–	–	–	14·6	–	14·1	–	14·4	–	14·1	–	14·0	–	14·3	–
	11	–	–	–	–	–	–	–	–	–	–	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	13·8	–	–	–	13·8	–	–	–	–	–	–	–	14·2	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	13·4	–	13·8	–	–	–	13·8	–	–	–	–	–	13·3	–	–	–
	14	–	–	13·2	–	–	–	–	–	12·9	–	–	–	–	–	–	–	–	–	–	–	–	–	13·8	–
	15	13·9	–	12·2	–	12·3	–	12·3	–	12·7	–	13·1	–	13·0	–	12·8	–	12·8	–	12·8	–	–	–	–	–
	16	13·3	–	–	–	–	–	–	–	–	–	12·8	–	–	–	–	–	–	–	–	–	12·2	–	–	–
	17	–	–	11·5	–	–	–	–	–	12·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	11·6	–	–	–	–	–	–	–	–	–	12·2	–	–	–	11·9	–	–	–	11·7	–	–	–	12·3	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·2	–	–	–
	20	11·1	–	10·6	–	11·1	–	11·2	–	11·3	–	11·7	–	11·3	–	11·1	–	11·1	–	10·3	–	11·0	–	11·8	–
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	11·5	–
	22	–	–	–	–	10·0	–	–	–	–	–	10·6	–	–	–	10·2	–	–	–	–	–	8·9	–	10·2	–
	23	9·1	–	–	–	–	–	–	–	10·6	–	–	–	–	–	–	–	–	–	8·8	–	8·7	–	9·8	–
	24	–	–	–	–	–	–	–	–	10·0	–	–	–	–	–	–	–	–	–	–	–	–	–	9·2	–
	25	8·7	–	9·2	–	8·9	–	9·4	–	–	–	9·8	–	9·7	–	9·3	–	8·4	–	7·9	–	7·9	–	8·9	–
	26	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·6	–	7·8	–	7·9	–	7·9	–	7·9	–	7·9	–	8·0	–	7·8	–	7·8	–	–	–	7·3	–	7·4	–
	40	–	–	–	–	6·9	–	7·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	45	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	50	–	–	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	6·5	–	6·6	–	–	–	–	–	6·2	–	–	–	–	–	–	–
	65	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 12, 1911.	0	16·4	–	15·8	–	15·8	–	15·8	–	15·7	–	16·0	–	16·0	–	16·1	–	16·3	–	16·2	–	16·1	–	16·0	–
	5	–	–	–	–	–	–	–	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	15·6	–	15·3	–	14·9	–	14·8	–	15·0	–	14·8	–	14·6	–	15·1	–	15·2	–	15·3	–	15·7	–	15·1	–
	15	13·9	–	14·2	–	13·9	–	13·9	–	14·0	–	14·0	–	14·0	–	14·3	–	14·4	–	14·4	–	14·4	–	14·4	–
	16	–	–	–	–	–	–	–	–	–	–	13·7	–	–	–	–	–	–	–	–	–	–	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	13·6	–	13·9	–	–	–	–	–	14·0		14·2	–
	18	–	–	–	–	–	–	13·3	–	12·8	–	11·6	–	12·1	–	–	–	–	–	–	–	13·9	–	13·3	–
	19	–	–	–	–	–	–	–	–	11·7	–	10·2	–	10·4	–	12·4	–	–	–	–	–	12·8	–	13·1	–
	20	12·8	–	13·2	–	13·0	–	12·3	–	9·5	–	8·4	–	9·1	–	8·9	–	13·3	–	13·5	–	11·0	–	11·1	–
	20·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·4	–	–	–	–	–	–	–
	21	–	–	–	–	–	–	11·8	–	–	–	–	–	8·4	–	8·4	–	9·3	–	13·3	–	–	–	9·4	–
	22	12·2	–	12·8	–	12·3	–	9·9	–	–	–	7·8	–	–	–	–	–	8·3	–	9·3	–	9·7	–	–	–
	23	–	–	–	–	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·6	–
	24	11·1	–	11·7	–	9·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	–	–
	25	10·0	–	10·0	–	8·9	–	8·1	–	7·4	–	–	–	7·2	–	7·3	–	–	–	7·9	–	8·1	–	8·3	–
	27	–	–	8·3	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·2	–	7·5	–	7·5	–	7·3	–	7·2	–	–	–	6·8	–	–	–	7·2	–	7·4	–	7·5	–	7·2	–
	40	6·9	–	6·9	–	6·8	–	–	–	6·8	–	–	–	–	–	6·6	–	–	–	–	–	–	–	–	–
	50	–	–	–	–	–	–	6·2	–	–	–	6·3	–	6·3	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–		–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 13, 1911.	0	15·9	–	15·8	–	15·7	–	15·8	–	15·8	–	15·9	–	16·1	–	16·1	–	16·2	–	16·2	–	16·2	–	16·2	–
	10	15·1	–	14·8	–	14·8	–	14·9	–	15·1	–	15·1	–	15·0	–	15·0	–	14·9	–	14·9	–	14·9	–	15·3	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·5	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	–	14·5	–	14·4	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·3	–	14·0	–	–	–	14·4	–	14·5	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·8	–	12·2	–	13·4	–	–	–
	15	14·0	–	14·2	–	14·0	–	14·1	–	14·3	–	14·2	–	14·0	–	12·8	–	12·1	–	12·1	–	12·3	–	13·8	–
	16	–	–	12·8	–	–	–	–	–	–	–	–	–	–	–	–	–	11·7	–	–	–	12·1	–	13·7	–
	17	13·1	–	11·9	–	12·4	–	12·4	–	–	–	–	–	12·7	–	12·1	–	11·7	–	–	–	–	–	12·8	–
	18	12·2	–	10·8	–	–	–	–	–	12·2	–	12·7	–	–	–	–	–	–	–	10·7	–	11·2	–	11·7	–
	19	10·8	–	10·3	–	11·0	–	11·4	–	–	–	–	–	10·7	–	10·7	–	–	–	–	–	–	–	11·3	–
	20	9·6	–	–	–	9·9	–	–	–	11·4	–	11·2	–	–	–	–	–	9·9	–	10·0	–	10·7	–	–	–
	21	–	–	9·4	–	–	–	10·7	–	–	–	–	–	10·1	–	9·6	–	–	–	–	–	–	–	10·7	–
	22	9·1	–	–	–	8·4	–	–	–	10·2	–	10·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	8·9	–	–	–	–	–	9·4	–	–	–	–	–	–	–	–	–	–	–
	25	7·7	–	7·8	–	8·1	–	8·5	–	9·1	–	9·3	–	8·9	–	8·4	–	8·3	–	8·5	–	9·9	–	9·9	–
	30	7·6	–	7·3	–	7·4	–	7·7	–	8·5	–	8·2	–	7·9	–	–	–	7·3	–	7·7	–	8·4	–	8·4	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–
	40	–	–	–	–	–	–	6·8	–	7·2	–	–	–	7·1	–	–	–	–	–	6·9	–	–	–	7·1	–
	50	6·5	–	6·5	–	6·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	6·3	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·1	–	16·0	–	16·1	–	16·0	–	16·0	–	16·1	–	16·1	–	16·2	–	16·2	–	16·3	–	16·2	–	16·1	–	*AUGUST* 14, 1911.
5	–	–	–	–	–	–	–	–	16·0	–	–	–	–	–	–	–	16·2	–	16·2	–	16·1	–	16·0	–	
10	15·8	–	15·3	–	14·4	–	15·0	–	15·0	–	15·0	–	15·2	–	15·6	–	15·6	–	15·3	–	15·3	–	15·1	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	–	–	–	–	–	–	–	
15	14·0	–	14·2	–	14·2	–	14·1	–	13·9	–	13·3	–	14·4	–	14·7	–	14·6	–	14·5	–	13·9	–	–	–	
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·1	–	–	–	
17	13·6	–	13·8	–	13·3	–	–	–	12·2	–	12·0	–	13·0	–	13·5	–	13·7	–	13·1	–	11·7	–	12·8	–	
18		–	–	–	–	–	11·8	–	–	–	–	–	–	–	–	–	–	–	–	–	11·4	–	–	–	
19	11·9	–	12·5	–	12·4	–	–	–	–	–	11·2	–	–	–	12·1	–	–	–	11·3	–	11·0	–	11·2	–	
20	11·6	–	11·9	–	11·6	–	10·0	–	10·0	–	–	–	11·2	–	11·0	–	11·1	–	–	–	9·6	–	10·1	–	
21	–	–	–	–	10·2	–	–	–	–	–	9·4	–	–	–	–	–	–	–	9·8	–	–	–	–	–	
22	–	–	–	–	9·9	–	8·9	–	8·8	–	–	–	9·4	–	10·4	–	9·9	–	–	–	–	–	8·6	–	
23	–	–	–	–	9·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	10·1	–	10·1	–	8·6	–	8·2	–	7·8	–	7·9	–	8·2	–	8·4	–	8·2	–	8·2	–	7·9	–	8·1	–	
30	8·6	–	8·2	–	7·8	–	7·6	–	7·1	–	7·1	–	7·1	–	7·1	–	7·1	–	7·2	–	6·9	–	7·1	–	
40	7·1	–	7·1	–	–	–	6·7	–	–	–	6·7	–	6·7	–	6·7	–	–	–	–	–	6·6	–	6·8	–	
50	6·7	–	–	–	6·5	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	6·2	–	–	–	6·2	–	–	–		–	–	–	–	–	–	–	
0	16·1	–	16·2	–	16·2		16·1	–	16·1	–	16·7	–	17·3	–	17·8	–	17·9	–	17·3	–	17·1	–	17·2	–	*AUGUST* 15, 1911.
5	16·1	–	16·1	–	16·1	–	–	–	–	–	16·0	–	16·1	–	16·1	–	16·1	–	16·2	–	–	–	–	–	
7	–	–	–	–	–	–	15·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·1	–	15·1	–	15·3	–	–	–	15·2	–	15·0	–	15·1	–	15·3	–	15·8	–	15·8	–	16·7	–	15·7	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·6	–	–	–	–	–	15·0	–	–	–	
15	14·3	–	14·6	–	14·7	–	15·2	–	13·8	–	13·9	–	13·2	–	13·6	–	14·3	–	14·7	–	14·4	–	14·4	–	
16	14·2	–	–	–	–	–	–	–	–	–	12·6	–	–	–	–	–	–	–	–	–	–	–	13·2	–	
17	13·3	–	13·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·3	–	12·2	–	
18	12·2	–	13·2	–	13·4	–	12·8	–	11·9	–	11·7	–	11·6	–	11·8	–	12·6	–	12·7	–	12·3	–	11·7	–	
19	11·2	–	12·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20	11·0	–	11·6	–	11·8	–	11·1	–	11·3	–	10·5	–	10·9	–	10·7	–	11·8	–	11·5	–	11·2	–	10·7	–	
22	9·9	–	10·7	–	10·8	–	10·6	–	10·6	–	9·3	–	9·7	–	9·9	–	10·7	–	10·7	–	10·0	–	–	–	
25	8·6	–	9·2	–	9·8	–	8·9	–	9·0	–	8·3	–	8·2	–	8·5	–	8·7	–	8·4	–	8·4	–	8·2	–	
30	7·1	–	7·2	–	7·6	–	7·8	–	7·5	–	7·1	–	6·8	–	6·8	–	7·5	–	7·6	–	7·3	–	7·3	–	
40	–	–	6·7	–	–	–	–	–	6·8	–	–	–	–	–	–	–	–	–		–	–	–	–	–	
50	6·3	–	–	–	6·6	–	6·3	–	–	–	–	–	6·6	–	–	–	6·3	–	–	–	6·5	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	6·3	–	–	–	–	–	–	–	–	–	–	–	6·3	–	
0	17·2	–	17·1	–	16·7	–	16·8	–	16·8	–	16·8	–	17·0	–	17·5	–	17·3	–	17·3	–	16·8	–	16·8	–	*AUGUST* 16, 1911.
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·2	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·7	–	–	–	–	–	–	–	
5	–	–	16·2	–	–	–	–	–	–	–	16·3	–	–	–	16·4	–	–	–	–	–	–	–	16·2	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·4	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·1	–	16·1	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·6	–	15·6	–	15·8	–	16·0	–	16·0	–	16·1	–	16·0	–	15·8	–	15·9	–	–	–	15·6	–	15·6	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	–	–	–	–	15·6	–	–	–	15·6	–	15·4	–	–	–	14·8	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	15·6	–	15·5	–	15·4	–	–	–	13·9	–	–	–	14·9	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·6	–	13·4	–	–	–	–	–	–	–	
15	13·8	–	14·2	–	14·3	–	14·6	–	14·6	–	13·9	–	13·7	–	13·6	–	–	–	–	–	13·3	–	13·4	–	
16	–	–	12·8	–	12·9	–	–	–	–	–	–	–	–	–	–	–	12·4	–	12·5	–	–	–	–	–	
17	12·1	–	12·1	–	11·6	–	12·4	–	13·0	–	–	–	11·8	–	11·7	–	–	–	–	–	–	–	11·9	–	
18	–	–	–	–	11·0	–	–	–	–	–	11·9	–	–	–	–	–	10·9	–	11·8	–	–	–	–	–	
19	–	–	10·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20	10·6	–	10·0	–	10·1	–	10·7	–	10·7	–	10·2	–	10·2	–	9·9	–	10·4	–	10·6	–	11·4	–	11·2	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
22	9·3	–	9·2	–	9·4	–	9·3	–	9·9	–	–	–	–	–	–	–	9·6	–	–	–	10·0	–	10·1	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·3	–	–	–	–	–	
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·4	–	–	–	–	–	–	–	
25	8·1	–	7·9	–	8·2	–	8·8	–	8·9	–	9·0	–	8·3	–	7·9	–	–	–	–	–	9·0	–	8·9	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·3	–	–	–	7·3	–	7·4	–	7·5	–	7·3	–	7·3	–	7·3	–	7·8	–	7·8	–	7·9	–	–	–	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
40	6·8	–	–	–	–	–	6·8	–	6·8	–	–	–	–	–	6·9	–	–	–	–	–	–	–	–	–	
50	–	–	6·6	–	6·6	–	–	–	–	–	–	–	6·6	–	6·7	–	–	–	–	–	–	–	–	–	
55	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

	Depth. Metres.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 17, 1911.	0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·3	17·2	–	16·9	–	17·0	–	17·4	–
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·1	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·0	16·2	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	17·2	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·6	–	15·7	–
	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·8	15·3	–	–	–	15·4	–	–	–
	16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·1	–	14·4	–	14·3	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·5	–	–	–
	18	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·2	14·0	–	13·3	–	–	–	13·0	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·4	–	11·9	–
	20	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·1	12·5	–	11·7	–	11·0	–	10·4	–
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·2	11·5	–	–	–	10·0	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·9	9·5	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·6	–	9·0	–
	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·2	–	9·8	–	–	–	8·1	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·0	–	–	–
	30	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·6	–	–	7·9	–	–	–	7·2	–
	40	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	7·7	–	7·0	–	–	–	–	–
	50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·9	7·0	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	6·5	–	–	–	6·7	–
	70	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	–	–
AUGUST 18, 1911.	0	17·4	–	17·3	–	17·0	–	16·8	–	16·7	–	16·6	–	17·0	–	17·5	–	17·6	–	17·1	–	17·5	–	17·4	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	16·6	–	16·6	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·0	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·0	–	–	–
	10	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	11	–	–	–	–	–	–	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	16·0	–	16·0	–	–	–	–	–	–	–	–	–	16·2	–	15·9	–	15·5	–	15·4	–	16·3	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·7	–
	14	15·5	–	15·5	–	14·6	–	–	–	15·0	–	–	–	–	–	15·0	–	14·0	–	14·5	–	13·6	–	13·9	–
	15	–	–	14·5	–	–	–	15·0	–	–	–	15·4	–	15·5	–	–	–	–	–	–	–	–	–	–	–
	16	13·9	–	13·2	–	13·2	–	13·6	–	13·8	–	–	–	–	–	13·5	–	12·9	–	12·5	–	12·0	–	12·6	–
	17	–	–	11·7	–	–	–	12·1	–	–	–	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–
	18	11·6	–	11·0	–	11·4	–	–	–	12·7	–	13·4	–	13·5	–	12·6	–	12·0	–	–	–	–	–	–	–
	20	10·2	–	10·1	–	10·2	–	10·5	–	11·2	–	13·0	–	11·7	–	11·3	–	10·7	–	11·5	–	11·0	–	11·2	–
	21	–	–	–	–	–	–	–	–	–	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	8·6	–	9·0	–	–	–	10·2	–	10·8	–	–	–	10·5	–	–	–	–	–	–	–	9·7	–
	23	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	8·7	–	8·1	–	8·2	–	–	–	–	–	–	–	10·2	–	–	–	9·5	–	10·2	–	9·6	–	–	–
	25	–	–	–	–	–	–	–	–	9·2	–	9·5	–	–	–	9·1	–	–	–	–	–	–	–	8·8	–
	26	7·7	–	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·4	–	7·4	–	7·2	–	7·4	–	7·8	–	9·4	–	8·5	–	8·0	–	8·0	–	8·5	–	8·2	–	7·8	–
	34	–	–	–	–	–	–	–	–	–	–	8·0	–	7·8	–	–	–	7·5	–	–	–	–	–	–	–
	40	6·9	–	–	–	6·8	–	6·7	–	–	–	7·1	–	7·4	–	–	–	–	–	7·6	–	7·6	–	–	–
	50	–	–	6·9	–	–	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	7·0	–	6·8	–
	60	6·3	–	–	–	6·4	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–	–	–	–	–
AUGUST 19, 1911.	0	17·2	–	17·3	–	17·3	–	17·3	–	17·3	–	17·4	–	17·4	–	17·5	–	17·5	–	17·3	–	17·4	–	17·4	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	17·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·5	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	16·6	–	16·5	–	15·9	–	15·6	–	16·0	–	15·1	–
	10	–	–	–	–	–	–	–	–	16·5	–	16·4	–	14·9	–	14·9	–	14·5	–	14·7	–	–	–	14·2	–
	12	16·3	–	16·5	–	16·4	–	15·9	–	15·0	–	15·0	–	14·0	–	13·8	–	–	–	14·4	–	14·4	–	–	–
	13	15·0	–	16·0	–	15·0	–	14·1	–	13·8	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	13·2	–	14·1	–	13·7	–	13·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·5	–
	16	12·8	–	13·2	–	12·5	–	12·7	–	12·3	–	12·5	–	12·4	–	13·4	–	14·0	–	13·2	–	13·5	–	12·8	–
	18	–	–	12·0	–	11·4	–	11·8	–	11·4	–	11·4	–	–	–	–	–	–	–	12·4	–	12·5	–	11·6	–
	20	11·1	–	11·0	–	11·0	–	10·9	–	10·4	–	10·6	–	10·8	–	12·0	–	12·0	–	11·8	–	11·7	–	10·0	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·5	–	–	–	10·7	–	9·2	–
	24	9·4	–	9·2	–	9·2	–	9·3	–	9·1	–	9·2	–	10·5	–	10·4	–	9·5	–	9·9	–	9·6	–	–	–
	26	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	9·2	–	–	–	–	–	–	–	–	–	7·6	–
	30	7·9	–	8·1	–	8·0	–	8·0	–	7·9	–	8·8	–	–	–	8·4	–	7·9	–	7·9	–	7·5	–	–	–
	34	–	–	–	–	–	–	–	–	–	–	8·4	–	7·9	–	7·6	–	–	–	7·2	–	6·4	–	–	–
	40	–	–	–	–	–	–	7·0	–	–	–	–	–	7·8	–	7·2	–	7·6	–	–	–	–	–	7·1	–
	50	6·6	–	6·5	–	6·5	–	–	–	6·6	–	7·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	6·4	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	17·4	–	17·4	–	17·2	–	17·4	–	17·2	–	17·4	–	17·9	–	17·4	–	18·1	–	17·6	–	17·5	–	17·5	–	*AUGUST* 20, 1911.
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	–	–	–	–	–	–	17·2	–	17·2	–	17·5	–	17·0	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·6	–	–	–	
8	16·0	–	16·0	–	15·8	–	16·4	–	16·4	–	15·8	–	16·0	–	16·1	–	16·0	–	16·2	–	–	–	15·7	–	
10	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	14·0	–	14·2	–	14·6	–	15·0	–	15·3	–	14·8	–	14·9	–	15·2	–	15·1	–	15·2	–	15·2	–	15·2	–	
14	–	–	–	–	–	–	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	
16	13·2	–	13·4	–	13·7	–	14·2	–	14·5	–	14·2	–	14·5	–	14·5	–	–	–	14·6	–	14·7	–	14·1	–	
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·3	–	–	–	13·6	–	–	–	13·1	–	
18	–	–	–	–	–	–	–	–	–	–	13·6	–	13·1	–	12·1	–	14·5	–	12·6	–	13·0	–	12·0	–	
19	–	–	–	–	–	–	–	–	–	–	12·5	–	11·8	–	–	–	14·0	–	11·2	–	10·8	–	–	–	
20	12·0	–	12·2	–	12·6	–	12·9	–	13·0	–	11·2	–	10·4	–	10·2	–	12·6	–	10·2	–	10·3	–	10·5	–	
21	10·5	–	10·5	–	–	–	–	–	–	–	–	–	–	–	–	–	11·5	–	–	–	–	–	–	–	
22	10·0	–	9·5	–	10·8	–	11·0	–	11·0	–	9·5	–	9·4	–	–	–	9·9	–	–	–	9·1	–	9·5	–	
24	8·7	–	8·7	–	9·5	–	9·5	–	9·4	–	8·5	–	8·4	–	9·5	–	9·0	–	8·4	–	8·3	–	–	–	
26	–	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·2	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·6	–	7·7	–	7·5	–	8·0	–	7·7	–	–	–	7·4	–	7·7		7·8	–	–	–	–	–	7·6	–	
34	7·1	–	7·1	–	7·2	–	7·5	–	7·4	–	7·5	–	–	–	–	–	7·6	–	7·0	–	–	–	–	–	
40	–	–	–	–	–	–	–	–	–	–	–	–	6·9	–	7·0	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·5	–	6·6	–	
60	–	–	6·8	–	–	–	–	–	–	–	–	–	–	–	6·5	–	–	–	–	–	–	–	–	–	
0	17·3	–	17·0	–	17·0	–	16·8	–	17·2	–	17·4	–	17·6	–	17·6	–	17·5	–	17·3	–	16·9	–	16·9	–	*AUGUST* 21, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·6	–	–	–	–	–	–	–	
6	16·6	–	–	–	–	–	16·4	–	16·8	–	16·8	–	16·7	–	16·1	–	16·5	–	16·7	–	16·6	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	15·5	–	15·4	–	15·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	15·1	–	15·5	–	15·5	–	15·4	–	15·0	–	15·1	–	15·0	–	15·5	–	15·9	–	
14	14·7	–	14·7	–	14·4	–	–	–	–	–	–	–	15·2	–	–	–	13·2	–	13·2	–	13·7	–	15·0	–	
15	–	–	14·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·0	–	
16	12·8	–	12·7	–	13·2	–	13·5	–	13·8	–	13·5	–	13·5	–	12·7	–	12·3	–	12·3	–	12·6	–	13·2	–	
17	–	–	–	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	11·0	–	11·6	–	11·0	–	12·0	–	12·0	–	–	–	12·1	–	11·6	–	11·6	–	–	–	–	–	12·0	–	
20	–	–	–	–	10·4	–	10·9	–	11·0	–	11·7	–	11·1	–	10·5	–	10·5	–	10·4	–	11·0	–	11·0	–	
22	9·8	–	9·8	–	–	–	10·2	–	–	–	–	–	–	–	10·0	–	–	–	–	–	–	–	10·2	–	
24	–	–	–	–	–	–	9·7	–	10·0	–	10·1	–	10·2	–	–	–	8·8	–	9·0	–	9·3	–	–	–	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·8	–	–	–	–	–	–	–	–	–	
26	8·7	–	8·3	–	9·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·8	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·8	–	7·8	–	–	–	8·5	–	8·6	–	8·9	–	8·5	–	8·7	–	7·8	–	–	–	8·0	–	7·8	–	
34	–	–	–	–	7·3	–	–	–	–	–	8·1	–	–	–	–	–	–	–	7·4	–	7·5	–	–	–	
40	7·0	–	7·0	–	–	–	7·1	–	7·4	–	7·5	–	7·5	–	–	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	6·8	–	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–	6·8	–	
60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	
0	16·8	–	16·8	–	16·7	–	16·6	–	16·6	–	16·8	–	16·9	–	16·8	–	17·0	–	16·6	–	16·9	–	16·7	–	*AUGUST* 22, 1911.
2	–	–	–	–	–	–	16·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	16·5	–	–	–	16·5	–	–	–	16·6	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	16·5	–	–	–	16·7	–	–	–	–	–	16·6	–	–	–	–	–	
8	–	–	–	–	–	–	16·3	–	–	–	16·3	–	–	–	16·3	–	–	–	–	–	–	–	–	–	
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	15·8	–	15·8	–	15·5	–	15·5	–	15·5	–	15·7	–	15·4	–	15·5	–	15·7	–	16·0	–	15·6	–	15·0	–	
14	14·8	–	15·1	–	15·1	–	14·4	–	14·8	–	14·4	–	–	–	14·5	–	–	–	14·6	–	–	–	14·5	–	
16	13·3	–	13·5	–	13·5	–	13·4	–	13·1	–	13·6	–	13·5	–	13·4	–	14·0	–	13·6	–	14·0	–	13·0	–	
18	12·5	–	12·5	–	12·2	–	12·2	–	12·1	–	12·3	–	12·1	–	12·5	–	13·1	–	12·5	–	13·5	–	–	–	
20	11·3	–	11·6	–	11·5	–	11·0	–	10·7	–	10·7	–	10·7	–	11·2	–	11·6	–	12·0	–	11·6	–	11·4	–	
22	–	–	10·5	–	10·8	–	9·8	–	–	–	–	–	–	–	10·0	–	10·5	–	–	–	–	–	10·5	–	
24	10·0	–	9·8	–	9·5	–	9·0	–	8·6	–	8·9	–	9·1	–	9·0	–	9·0	–	10·6	–	10·2	–	9·0	–	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·9	–	–	–	–	–	
26	9·0	–	9·0	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·7	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·8	–	8·0	–	7·8	–	–	–	–	–	7·6	–	7·5	–	7·7	–	–	–	7·9	–	8·1	–	7·4	–	
34	–	–	7·8	–	7·2	–	7·5	–	7·2	–	7·3	–	–	–	–	–	7·0	–	–	–	–	–	7·0	–	
40	7·0	–	–	–	–	–	–	–	–	–	6·9	–	6·9	–	–	–	–	–	–	–	–	–	–	–	
50	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	7·0	–	–	–	
60	–	–	–	–	–	–	6·4	–	–	–	–	–	–	–	6·9	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION IV.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 23, 1911.	0	16·6	–	16·5	–	16·5	–	16·5	–	16·5	–	16·4	–	16·6	–	16·9	–	16·7	–	16·7	–	16·8	–	16·6	–
	4	–	–	–	–	–	–	16·4	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	16·0	–	16·0	–	–	–	–	–	–	–	16·0	–	16·4	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	15·1	–	14·8	–	14·5	–	15·1	–	15·5	–	15·6	–	15·2	–	14·8	–	15·1	–	15·3	–	15·7	–	16·1	–
	14	14·1	–	14·0	–	–	–	–	–	–	–	14·5	–	14·4	–	13·6	–	14·4	–	14·5	–	–	–	–	–
	16	13·6	–	12·9	–	13·2	–	13·3	–	13·5	–	13·4	–	12·9	–	13·1	–	13·3	–	13·7	–	14·7	–	15·0	–
	18	12·0	–	12·0	–	12·4	–	12·4	–	–	–	–	–	–	–	12·5	–	12·4	–	12·8	–	13·6	–	13·5	–
	20	10·9	–	11·0	–	11·5	–	11·8	–	12·2	–	11·5	–	12·4	–	10·8	–	11·5	–	12·0	–	12·5	–	12·0	–
	22	9·6	–	10·0	–	10·4	–	11·4	–	11·3	–	–	–	–	–	–	–	10·2	–	11·0	–	11·6	–	10·0	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	11·1	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	8·7	–	9·1	–	9·9	–	10·1	–	10·3	–	9·5	–	9·5	–	9·0	–	–	–	10·1	–	9·4	–
	26	8·0	–	–	–	–	–	9·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	7·6	–	8·0	–	–	–	–	–
	30	7·3	–	7·4	–	7·7	–	8·9	–	8·8	–	7·9	–	8·5	–	7·5	–	7·2	–	–	–	8·5	–	7·8	–
	34	–	–	–	–	7·3	–	–	–	–	–	–	–	7·7	–	–	–	7·0	–	7·3	–	–	–	–	–
	40	6·9	–	–	–	–	–	–	–	7·4	–	6·9	–	7·5	–	–	–	–	–	6·8	–	7·5	–	7·3	–
	50	–	–	6·6	–	–	–	7·6	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 24, 1911.	0	16·6	–	16·6	–	16·3	–	16·5	–	16·5	–	16·5	–	16·5	–	16·5	–	16·5	–	16·7	–	16·2	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·0	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	16·2	–	16·0	–	16·0	–	16·0	–	16·0	–	16·1	–	14·9	–	14·1	–	14·5	–	15·3	–	15·0	–	–	–
	13	–	–	–	–	–	–	15·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	15·0	–	14·0	–	13·6	–	14·4	–	14·5	–	–	–	–	–	13·0	–	14·5	–	13·9	–	–	–
	15	–	–	–	–	–	–	–	–	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	14·2	–	13·0	–	12·2	–	12·4	–	12·6	–	12·9	–	13·1	–	11·9	–	12·0	–	13·7	–	13·1	–	–	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	11·8	–	–	–	–	–	–	–	–	–	–	–
	18	12·4	–	11·1	–	10·4	–	11·0	–	11·3	–	11·5	–	10·4	–	–	–	–	–	12·8	–	–	–	–	–
	20	10·8	–	10·0	–	9·1	–	9·8	–	10·0	–	10·0	–	10·3	–	10·1	–	10·3	–	12·0	–	12·3	–	–	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·0	–	–	–	–	–
	24	9·1	–	8·9	–	8·2	–	8·4	–	8·5	–	8·7	–	–	–	–	–	–	–	9·1	–	10·6	–	–	–
	25	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	9·0	–	9·1	–	–	–	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	8·0	–	–	–	–	–
	30	–	–	7·9	–	–	–	7·3	–	7·5	–	–	–	–	–	–	–	8·1	–	–	–	9·3	–	–	–
	34	7·4	–	–	–	7·3	–	–	–	–	–	7·4	–	7·4	–	7·5	–	–	–	7·3	–	–	–	–	–
	40	–	–	7·3	–	–	–	7·0	–	6·8	–	7·1	–	–	–	–	–	7·0	–	6·8	–	7·6	–	–	–
	50	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	60	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·2	16·3	16·3	16·3	16·3	16·2	16·4	16·5	16·5	16·5	16·5	16·5	16·5	16·3	16·4	16·2	*AUGUST* 4, 1911.
6	16·0	16·0	16·0	16·0	–	–	–	–	–	–	–	–	16·2	–	–	–	–	–	–	–	–	16·0	–	16·0	
8	15·8	16·0	16·0	16·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·5	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	–	
10	–	16·0	16·0	16·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·1	14·4	13·8	13·5	
12	–	16·0	16·0	–	16·0	15·8	–	15·5	16·0	14·9	15·7	16·2	17·0	17·2	16·1	16·1	16·1	15·2	14·0	14·3	14·0	13·5	13·2	13·0	
12·75	–	–	–	–	–	–	15·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	–	15·9	15·9	–	15·8	15·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13·25	–	–	–	–	–	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13·5	–	–	–	–	–	–	–	14·4	13·2	13·2	14·5	15·8	–	–	–	–	14·9	13·4	–	–	–	–	–	–	
14	–	15·8	15·8	–	–	13·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	–	15·7	15·2	15·7	14·2	12·5	13·2	11·6	11·9	12·5	14·6	14·4	–	16·2	–	15·8	13·8	13·0	12·9	13·1	13·1	12·7	12·5	12·5	
16	–	15·7	12·0	12·2	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
16·5	–	–	–	–	–	–	12·1	10·9	10·3	11·5	12·4	13·4	–	15·2	–	14·3	–	–	–	–	–	–	–	–	
17	–	15·7	12·0	11·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	–	15·7	12·0	11·5	11·2	10·7	10·2	9·8	11·2	11·5	11·5	12·1	–	13·0	15·5	13·7	12·5	12·2	12·5	12·3	12·5	12·0	12·0	11·7	
19	–	15·7	11·3	10·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·7	–	10·5	
19·5	–	–	–	–	–	–	9·0	–	8·7	–	11·4	12·0	–	–	13·5	12·5	–	–	12·0	–	–	–	–	–	
20	–	15·7	10·8	9·9	–	9·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
20·25	–	–	–	–	–	–	–	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
21	–	15·7	10·4	9·5	–	8·8	8·5	8·0	8·0	–	10·3	11·7	–	12·5	13·0	12·0	11·9	11·8	–	11·5	11·2	10·0	9·8	8·8	
22	–	15·3	10·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
22·5	–	9·6	–	–	–	–	–	–	–	–	9·8	11·4	–	–	12·0	–	–	–	11·3	10·8	–	–	–	–	
24	–	8·9	9·5	–	–	7·7	7·9	–	–	8·0	8·6	9·8	18·1	11·5	11·5	11·5	11·5	10·6	10·5	9·7	9·5	–	8·1	7·8	
24·5	–	–	–	–	–	–	–	7·2	7·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	7·0	–	–	–	8·0	–	–	–	–	–	–	–	–	–	7·5	7·8	–	
30	–	–	7·5	–	–	–	7·5	–	7·2	7·4	7·5	–	8·0	8·8	8·0	8·5	8·3	9·2	–	–	–	–	–	7·1	
33	–	–	–	–	–	–	7·0	–	7·0	7·0	7·0	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·4	–	–	–	
0	16·1	16·0	15·6	16·2	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·0	16·2	16·2	16·2	16·2	16·2	16·2	16·2	16·2	16·0	–	15·9	–	*AUGUST* 5, 1911.
5	–	–	–	–	–	–	–	–	–	–	–	14·0	14·1	15·1	14·2	15·0	14·2	14·5	16·0	16·0	–	–	–	–	
6	16·0	16·0	15·5	15·7	–	–	–	–	–	15·0	15·3	13·0	14·0	13·8	13·4	–	–	–	–	–	16·0	–	15·8	–	
7	–	15·0	–	14·2	14·8	–	–	16·0	15·5	13·8	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–	
7·5	15·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	13·7	13·8	13·6	–	16·0	16·0	14·6	14·8	13·5	13·8	13·2	13·5	–	–	–	–	–	15·6	–	–	–	–	–	
8·5	–	–	–	–	–	–	14·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	13·5	13·5	13·4	13·5	13·6	14·5	–	13·8	13·5	–	–	–	–	–	–	–	–	–	–	–	16·0	–	–	–	
10	–	–	–	–	13·5	–	–	–	–	–	–	–	13·2	13·2	–	14·0	13·6	13·9	14·5	15·8	15·6	–	15·7	–	
10·5	–	13·2	13·2	13·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	12·8	12·8	12·9	13·0	13·2	13·5	–	–	–	13·0	12·7	11·5	13·0	–	–	–	–	–	–	–	15·1	–	14·9	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	12·7	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	12·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·1	–	
15	12·4	12·4	12·5	12·5	12·8	–	–	–	–	–	–	–	–	12·7	12·8	13·0	13·2	13·6	14·0	14·8	14·0	–	–	–	
16	–	12·0	–	–	–	–	–	–	–	12·5	12·0	10·9	12·0	–	–	–	–	–	–	–	–	–	13·8	–	
17	–	11·4	11·0	11·7	12·5	12·8	12·8	12·8	12·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
18	11·1	10·2	10·2	10·6	–	–	–		–	10·0	11·0	–	–	11·7	–	–	–	–	–	–	13·5	–	13·5	–	
19	9·5	–	–	9·7	11·7	12·6	–	–	11·6	–	10·0	–	10·6	–	–	–	–	–	–	–	–	–	–	–	
20	9·2	8·9	8·9	9·2	–	–	–	–	–	12·5	–	9·9	–	11·0	12·0	12·2	12·6	13·0	13·6	13·6	–	–	13·0	–	
21	–	–	–	–	10·5	12·4	–	–	–	10·0	9·0	–	–	–	–	–	–	–	–	–	13·4	–	12·0	–	
22	8·2	–	–	–	9·2	–	–	11·4	10·0	–	–	–	–	–	–	11·3	–	–	–	–	–	–	10·7	–	
23	–	–	–	–	9·2	11·5	11·5	10·1	–	–	–	9·3	–	10·3	10·8	–	12·0	–	–	–	–	–	9·5	–	
24	–	7·8	7·8	8·0	–	–	–	–	9·0	–	–	–	9·5	–	–	–	–	–	–	–	12·5	–	9·2		
25	–	–	–	–	–	9·0	9·0	8·6	–	9·0	8·7	8·7	–	9·4	10·0	10·3	11·0	11·8	13·0	13·1	11·5	–	–	–	
26	–	–	–	–	–	–	–	–	–	8·5	8·5	–	–	–	–	–	–	–	–	–	9·6	–	–	–	
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·3	9·6	–	11·4	–	11·9	9·0	–	8·4	–	
28	–	–	–	–	–	8·0	8·5	8·5	8·6	–	–	8·0	–	–	–	–	9·8	11·1	12·2	11·6	–	–	–	–	
30	7·0	–	7·1	7·2	–	–	–	8·0	8·0	7·5	7·7	–	7·9	8·2	8·2	8·2	8·4	9·8	10·6	11·1	7·7	–	7·4	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	–	–	
33	–	–	–	–	–	7·2	7·2	–	–	–	7·2	7·1	–	–	–	–	–	–	–	–	7·3	–	–	–	
34	–	–	6·8	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
36	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 6, 1911.	0	16·0	–	15·9	–	15·8	–	15·8	–	15·8	–	16·0	–	16·1	–	16·0	–	16·2	–	16·2	–	16·0	–	16·0	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	15·9	–	15·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	–	–	–
	10	–	–	14·1	–	15·0	–	15·2	–	15·8	–	15·8	–	15·7	–	15·7	–	15·8	–	16·2	–	15·6	–	15·6	–
	11	–	–	–	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	14·0	–	13·6	–	13·6	–	15·0	–	–	–	–	–	–	–	–	–	15·6	–	15·4	–	15·5	–	14·7	–
	13	–	–	–	–	–	–	13·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	13·7	–	13·4	–	–	–	13·6	–	–	–	–	–	–	–	–	–	15·6	–	13·7	–	13·8	–	13·4	–
	15	–	–	–	–	–	–	–	–	15·6	–	15·8	–	15·7	–	14·4	–	14·0	–	13·5	–	12·7	–	12·7	
	15·5	–	–	–	–	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	13·5	–	12·0	–	8·6	–	13·0		–	–	–	–	–	–	–	–	13·6	–	10·8	–	9·2	–	10·4	–
	17	13·0	–	10·5	–	–	–	12·2	–	15·6	–	–	–	15·7	–	–	–	13·2	–	9·4	–	–	–	–	–
	18	11·8	–	9·8	–	–	–	9·8	–	13·8	–	15·2	–	–	–	13·5	–	12·2	–	8·6	–	7·6	–	10·2	–
	19	11·2	–	–	–	–	–	–	–	–	–	14·0	–	14·0	–	–	–	9·9	–	–	–	–	–	–	–
	20	9·8	–	8·7	–	–	–	8·6	–	13·5	–	13·8	–	13·8	–	12·6	–	8·9	–	7·4	–	–	–	8·6	–
	21	9·5	–	–	–	–	–	–	–	–	–	–	–	–	–	11·6	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	–	–	–	–	13·6	–	13·4	–	10·0	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	11·4	–	–	–	–	–	9·0	–	–	–	–	–	–	–	–	–
	24	8·6	–	7·8	–	–	–	–	–	9·5	–	13·0	–	–	–	8·0	–	–	–	–	–	7·0		7·4	–
	25	–	–	–	–	–	–	–	–	8·4	–	11·5	–	14·0	–	7·7	–	8·2	–	7·0	–	–	–	–	–
	26	–	–	–	–	7·2	–	–	–	–	–	9·5	–	8·4	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·4	–	7·2	–	7·0	–	7·0	–	7·2	–	7·2	–	–	–	7·0	–	6·9	–	6·7	–	6·8	–	6·7	–
	31	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	–	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	–	–	6·8	–	–	–	–	–	6·8	–	6·8	–	–	–	–	–	–	–	–	–
	34	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·6	–	6·5	–
	36	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 7, 1911.	0	15·8	–	15·9	–	16·0	–	15·8	–	15·8	–	15·8	–	15·8	–	16·0	–	16·0	–	16·0	–	–	15·9	16·0	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·9	–	–
	10	15·7	–	15·7	–	15·7	–	–	–	15·2	–	15·6	–	15·6	–	–	–	15·8	–	15·8	–	–	–	16·0	–
	11	–	–	–	–	–	–	–	–	14·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	13·1	–	15·6	–	–	–	–	–	–	–	–	–	–	15·7	–	–
	13	–	–	–	–	–	–	–	–	12·0	–	12·3	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	15·6	–	15·7	–	–	–	–	–	–	–	11·5	–	14·6	–	–	–	–	–	–	–	–	–	–	–
	15	–	–	–	–	15·5	–	–	–	11·0	–	11·1	–	11·5	–	15·5	–	15·7	–	15·7	–	–	–	–	–
	16	15·2	–	15·7	–	–	–	–	–	–	–	–	–	10·8	–	–	–	–	–	–	–	–	15·7	15·7	–
	16·5	–	–	–	–	–	–	–	–	–	–	–	–	–		14·2	–	–	–	–	–	–	–	–	–
	17	–	–	–	–	–	15·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	15·0	–
	18	13·5	–	15·7	–	15·0	10·8	–	–	–	–	11·1	–	–	–	12·4	–	–	–	–	–	–	13·5	12·0	–
	19	12·4	–	–	–	13·5	10·2	–	–	–	–	–	–	–	–	–	11·0	–	–	–	–	–	11·5	–	–
	20	12·1	–	15·6	–	11·9	–	–	–	10·2	–	10·4	–	–	–	–	10·7	15·7	–	15·7	–	–	11·5	10·7	–
	21	10·5	–	14·2	–	10·8	–	–	–	–	–	–	–	10·1	–	–	–	–	–	–	–	–	–	–	–
	22	10·0	–	11·4		10·4	9·6	–	–	–	–	–	–	–	–	–	–	15·4	–	15·5	–	–	9·6	8·8	–
	24	9·7	–	10·3	–	–	–	–	–	–	–	–	–	–	–	–	–	11·4	–	11·9	–	–	8·4	8·0	–
	25	–	–	–	–	–	–	–	–	9·5	–	9·6	–	9·0	–	–	9·5	10·5	–	10·4	–	–	–	–	–
	26	–	–	–	–	9·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	8·7	–	–	–	–	–	–	–	–	–	–	–	–	10·0	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·3	–	9·2	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	–
	30	8·0	–	8·7	–	8·5	8·1	–	–	8·9	–	8·6	–	7·8	–	–	–	8·4	–	8·2	–	–	7·4	7·2	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	7·0	7·2	–	–	–	–	–	–	7·3	–	–	7·3	–	–	–	–	–	–	–	–
	34	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·1	7·0	–
	36	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	15·8	–	15·8	–	16·0	–	16·0	–	15·9	–	15·8	–	16·1	–	16·2	–	16·7	–	17·2	–	17·0	–	16·7	–	*AUGUST* 8, 1911.
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·2	–	–	–	–	–	
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	–	16·0	–	16·0	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·7	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·4	–	15·5	–	15·7	–	
10	15·8	–	15·8	–	–	–	–	–	15·9	–	–	–	–	–	–	–	–	–	15·4	–	15·5	–	–	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·1	–	–	–	
12	15·7	–	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·0	–	14·0	–	15·5	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·4	–	–	–	
14	15·4	–	11·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·6	–	–	–	15·4	–	
15	12·4	–	11·2	–	15·6	–	15·6	–	15·7	–	15·7	–	15·2	–	15·4	–	16·6	–	11·4	–	11·7	–	15·3	–	
16	11·2	–	10·9	–	12·0	–	–	–	–	–	–	–	12·8	–	14·8	–	–	–	–	–	–	–	–	–	
17	10·5	–	8·6	–	10·8	–	15·6	–	–	–	–	–	11·7	–	12·0	–	10·6	–	–	–	–	–	15·1	–	
18	9·0	–	8·1	–	9·6	–	15·4	–	–	–	–	–	–	–	–	–	8·8	–	–	–	–	–	13·1	–	
19	–	–	–	–	–	–	15·2	–	–	–	–	–	–	–	10·5	–	–	–	–	–	–	–	–	–	
20	7·8	–	7·4	–	–	–	–	–	15·6	–	15·5	–	10·4	–	–	–	8·7	–	10·2	–	10·6	–	11·8	–	
21	–	–	–	–	–	–	11·5	–	–	–	11·4	–	–	–	9·3	–	–	–	10·0	–	–	–	–	–	
22	–	–	–	–	7·7	–	10·0	–	15·5	–	10·8	–	–	–	–	–	–	–	–	–	–	–	–	–	
23	–	–	–	–	–	–	9·0	–	–	–	–	–	9·0	–	8·6	–	–	–	8·4	–	–	–	–	–	
24	7·4	–	7·2	–	–	–	–	–	12·9	–	10·6	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	–	–	–	–	–	–	8·0	–	10·6	–	9·8	–	–	–	–	–	7·2	–	7·8	–	8·7	–	10·8	–	
26	–	–	–	–	–	–	–	–	9·8	–	8·2	–	8·2	–	7·4	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	–	8·6	–	7·7	–	–	–	–	–	–	–	–	–	–	–	10·2	–	
28	–	–	–	–	–	–	–	–	–	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	6·8	–	6·9	–	7·0	–	7·1	–	7·2	–	7·3	–	7·2	–	7·0	–	6·8	–	7·0	–	7·2	–	8·5	–	
33	–	–	–	–	6·8	–	6·8	–	–	–	–	–	7·0	–	6·8	–	–	–	–	–	–	–	–	–	
34	6·7	–	6·8	–	–	–	–	–	–	–	–	–		–	–	–	–	–	–	–	6·8	–	7·0	–	
0	16·5	–	16·4	–	16·0	–	16·2	–	15·5	–	16·2	–	16·5	–	16·6	–	17·2	–	16·8	–	16·7	–	16·7	–	*AUGUST* 9, 1911.
4	–	–	–	–	–	–	14·8	–	–	–	–	–	15·4	–	15·5	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	15·3	–	–	–	–	–	16·4	–	–	–	–	–	
8	15·7	–	–	–	–	–	–	–	14·2	–	–	–	–	–	–	–	–	–	–	–	16·4	–	16·3	–	
10	–	–	15·1	–	15·8	–	13·8	–	13·7	–	16·2	–	13·9	–	–	–	15·5	–	15·0	–	14·8	–	15·0	–	
11	–	–	–	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	13·0	–	12·6	–	15·0	–	–	–	–	–	–	–	–	–	14·7	–	14·0	–	
13	–	–	–	–	12·5	–	–	–	–	–	12·2	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	14·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	15·4	–	–	–	–	–	11·9	–	11·7	–	11·7	–	13·1	–	14·8	–	14·9	–	14·2	–	13·6	–	–	–	
16	–	–	12·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·6	–	
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·6	–	–	–	
18	13·7	–	12·1	–	11·5	–	10·7	–	–	–	–	–	12·0	–	–	–	–	–	–	–	–	–	10·7	–	
20	12·5	–	11·7	–	–	–	9·0	–	10·2	–	10·5	–	11·5	–	14·5	–	14·4	–	13·2	–	11·4	–	10·1	–	
22	12·4	–	11·5	–	9·8	–	8·8	–	–	–	–	–	10·6	–	13·5	–	–	–	11·7	–	9·3	–	8·1	–	
23	–	–	–	–	–	–	–	–	8·5	–	9·2	–	–	–	–	–	–	–	11·5	–	–	–	–	–	
24	11·9	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·5	–	7·9	–	
25	–	–	–	–	–	–	–	–	8·2	–	8·6	–	10·5	–	12·0	–	13·6	–	10·7	–	–	–	–	–	
26	–	–	10·5	–	7·9	–	8·0	–	–	–	–	–	9·9	–	–	–	12·0	–	–	–	–	–	–	–	
27	10·5	–	8·4	–	–	–	–	–	–	–	–	–	–	–	11·6	–	–	–	9·3	–	–	–	–	–	
28	–	–	8·0	–	7·5	–	–	–	–	–	–	–	–	–	11·4	–	11·6	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·6	–	–	–	–	–	–	–	–	–	
30	9·3	–	7·8	–	–	–	7·0	–	7·2	–	7·5	–	8·5	–	9·9	–	11·0	–	8·4	–	7·4	–	–	–	
32	7·2	–	–	–	–	–	–	–	–	–	–	–	7·7	–	8·5	–	–	–	–	–	–	–	–	–	
34	6·9	–	7·0	–	7·0	–	6·8	–	–	–	–	–	7·0	–	8·0	–	–	–	–	–	7·0	–	6·7	–	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·6	–	–	–	–	–	–	–	
0	16·6	–	16·6	–	16·4	–	16·5	–	16·6	–	16·6	–	16·7	–	17·0	–	17·0	–	17·2	–	17·1	–	17·2	–	*AUGUST* 10, 1911.
10	15·3	–	14·9	–	16·4	–	–	–	–	–	–	–	16·4	–	–	–	16·2	–	16·2	–	15·7	–	16·0	–	
12	14·1	–	13·9	–	–	–	16·3	–	–	–	–	–	–	–	16·1	–	–	–	15·0	–	14·1	–	16·0	–	
13	–	–	–	–	14·5	–	–	–	–	–	–	–	–	–	–	–	15·9	–	13·8	–	–	–	–	–	
14	13·0	–	12·9	–	–	–	–	–	–	–	–	–	16·1	–	–	–	13·8	–	13·2	–	14·0	–	15·1	–	
15	–	–	12·1	–	14·0	–	16·3	–	16·1	–	15·9	–	–	–	14·2	–	13·0	–	12·2	–	12·3	–	–	–	
16	11·5	–	10·4	–	–	–	–	–	–	–	15·4	–	14·1	–	13·5	–	11·6	–	10·3	–	11·6	–	13·7	–	
17	–	–	–	–	12·2	–	–	–	–	–	–	–	12·6	–	11·6	–	10·3	–	10·2	–	–	–	–	–	
18	9·6	–	9·0	–	–	–	15·5	–	16·1	–	13·8	–	12·0	–	10·0	–	9·8	–	–	–	11·1	–	12·5	–	
19	–	–	–	–	11·0	–	–	–	13·9	–	–	–	10·3	–	–	–	8·2	–	8·0	–	–	–	–	–	
20	8·2	–	7·8	–	9·0	–	14·7	–	13·5	–	13·0	–	8·9	–	8·1	–	8·0	–	7·9	–	10·5	–	11·5	–	
21	–	–	–	–	–	–	–	–	–	–	9·8	–	–	–	–	–	–	–	–	–	–	–	–	–	
22	7·9	–	–	–	–	–	–	–	12·3	–	9·4	–	–	–	–	–	–	–	–	–	–	–	11·0	–	
23	–	–	–	–	7·9	–	–	–	11·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	7·6	–	–	–	–	–	–	–	9·2	–	7·8	–	7·5	–	7·3	–	–	–	–	–	8·8	–	10·4	–	
25	–	–	–	–	7·5	–	13·3	–	8·2	–	7·5	–	–	–	–	–	7·1	–	7·2	–	–	–	–	–	
26	–	–	–	–	–	–	11·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·7	–	
27	–	–	–	–	–	–	10·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	8·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·1	–	
30	–	–	–	–	7·0	–	7·3	–	7·0	–	7·0	–	7·0	–	7·0	–	6·8	–	6·8	–	7·0	–	7·4	–	
34	7·1	–	6·8	–	6·8	–	7·0	–	–	–	–	–	–	–	6·9	–	–	–	–	–	6·8	–	6·9	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 11, 1911.	0	17·1	–	17·0	–	17·0	–	17·0	–	17·0	–	16·8	–	16·6	–	16·5	–	16·0	–	15·3	–	14·7	–	15·0	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	16·1	–	16·0	–	15·6	–	15·4	–	15·0	–	14·2	–	14·1	–	–	–	–	–
	8	–	–	15·5	–	15·4	–	14·9	–	15·7	–	14·5	–	14·5	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	14·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	16·0	–	14·0	–	14·0	–	14·1	–	–	–	–	–	14·1	–	14·0	–	13·9	–	13·7	–	13·7	–	14·0	–
	12	14·7	–	12·9	–	13·3	–	–	–	14·0	–	13·6	–	–	–	–	–	–	–	13·5	–	–	–	–	–
	14	–	–	–	–	12·5	–	13·0	–	–	–	–	–	13·4	–	13·5	–	–	–	12·6	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	13·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	16	13·1	–	11·6	–	11·0	–	12·0	–	–	–	12·8	–	12·8	–	–	–	12·7	–	11·0	–	12·4	–	13·5	–
	18	11·8	–	–	–	10·2	–	10·7	–	11·8	–	11·8	–	–	–	–	–	11·9	–	10·4	–	11·4	–	–	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·7	–	–	–	–	–
	20	11·3	–	10·2	–	10·0	–	–	–	10·8	–	10·8	–	11·9	–	12·0	–	11·2	–	8·3	–	10·1	–	11·8	–
	22	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	8·8	–	11·2	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·5	–
	24	10·1	–	9·6	–	9·1	–	9·8	–	–	–	–	–	10·5	–	10·5	–	8·4	–	–	–	–	–	8·6	–
	25	–	–	–	–	–	–	–	–	9·7	–	9·8	–	–	–	–	–	–	–	7·7	–	7·5	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·5	–	–	–
	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–	–	–
	28	9·3	–	8·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–
	30	8·3	–	7·5	–	8·4	–	8·7	–	9·5	–	9·0	–	8·9	–	8·4	–	7·3	–	7·1	–	–	–	7·2	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	6·9	–	7·0	–	7·2	–	7·1	–	7·1	–	7·2	–	7·5	–	7·2	–	–	–	–	–	7·0	–	6·9	–
AUGUST 12, 1911.	0	14·7	–	14·7	–	15·0	–	15·4	–	15·4	–	15·5	–	15·6	–	15·7	–	15·7	–	15·7	–	15·6	–	15·6	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·1	–	–	–	–	–	–	–	–	–
	10	14·2	–	14·5	–	–	–	–	–	15·0	–	15·0	–	15·1	–	–	–	–	–	–	–	15·0	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	15·0	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	14·5	–	15·0	–	15·0	–	–	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	13·9	–	14·7	–	12·6	–	–	–	–	–	14·9	–	14·9	–	15·0	–
	16	14·0	–	14·2	–	14·5	–	14·6	–	12·5	–	11·1	–	11·6	–	14·5	–	14·7	–	–	–	–	–	–	–
	17	–	–	–	–	–	–	–	–	12·4	–	–	–	10·7	–	13·5	–	–	–	14·5	–	–	–	–	–
	18	–	–	–	–	–	–	14·5	–	10·4	–	10·3	–	9·7	–	12·1	–	14·4	–	–	–	13·5	–	13·2	–
	19	–	–	–	–	–	–	13·0	–	–	–	9·6	–	–	–	–	–	13·6	–	13·2	–	13·4	–	12·0	–
	20	13·6	–	14·0	–	14·4	–	12·4	–	–	–	8·5	–	8·4	–	10·5	–	12·7	–	12·7	–	11·5	–	10·5	–
	21	–	–	–	–	–	–	10·4	–	–	–	–	–	–	–	9·8	–	11·8	–	10·6	–	10·8	–	–	–
	22	12·9	–	–	–	13·0	–	9·5	–	–	–	–	–	–	–	8·6	–	11·0	–	9·9	–	8·8	–	9·1	–
	23	–	–	–	–	12·0	–	–	–	8·0	–	–	–	–	–	–	–	9·4	–	–	–	–	–	–	–
	24	11·5	–	13·8	–	11·0	–	8·3	–	–	–	–	–	–	–	7·7	–	8·3	–	8·6	–	–	–	–	–
	25	10·3	–	12·0	–	9·4	–	–	–	7·8	–	7·3	–	–	–	–	–	–	–	8·2	–	–	–	–	–
	26	9·1	–	11·0	–	8·3	–	7·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·5	–
	27	–	–	10·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·4	–	–	–	7·5	–	–	–	7·0	–	6·9	–	7·0	–	7·0	–	7·0	–	7·1	–	7·0	–	7·0	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	7·0	–	7·0	–	7·1	–	7·0	–	–	–	–	–	6·9	–	–	–	–	–	–	–	6·8	–	6·8	–
AUGUST 13, 1911.	0	15·5	–	15·5	–	15·4	–	15·4	–	15·5	–	15·5	–	15·7	–	15·8	–	15·9	–	15·7	–	15·7	–	15·9	–
	10	–	–	15·4	–	14·8	–	15·2	–	–	–	–	–	15·1	–	–	–	14·6	–	14·6	–	14·7	–	15·0	–
	12	–	–	–	–	13·8	–	14·1	–	–	–	–	–	14·7	–	14·9	–	13·6	–	14·0	–	–	–	–	–
	13	–	–	14·4	–	–	–	–	–	–	–	–	–	–	–	12·8	–	12·5	–	–	–	–	–	–	–
	14	–	–	–	–	12·5	–	12·5	–	–	–	–	–	13·7	–	11·8	–	11·4	–	12·7	–	–	–	–	–
	15	14·5	–	–	–	–	–	–	–	14·6	–	14·3	–	–	–	–	–	–	–	–	–	13·5	–	15·0	–
	16	13·7	–	–	–	11·7	–	12·3	–	–	–	–	–	12·0	–	10·9	–	10·5	–	11·2	–	12·6	–	–	–
	17	12·5	–	11·2	–	–	–	–	–	–	–	13·0	–	–	–	–	–	–	–	–	–	11·4	–	14·0	–
	18	11·2	–	–	–	11·0	–	10·8	–	13·6	–	11·9	–	11·0	–	10·4	–	–	–	10·5	–	10·8	–	12·2	–
	19	10·0	–	11·0	–	–	–	–	–	12·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	9·0	–	10·5	–	10·0	–	10·2	–	11·3	–	11·1	–	10·3	–	9·9	–	9·8	–	9·7	–	10·1	–	11·0	–
	22	–	–	9·9	–	–	–	–	–	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	10·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	8·4	–	9·0	–	9·1	–	–	–	–	–	9·7	–	8·9	–	–	–	–	–	–	–	9·6	–
	25	7·3	–	–	–	–	–	–	–	9·7	–	9·7	–	–	–	–	–	8·8	–	8·6	–	8·8	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·0	–	–	–	7·5	–	7·9	–	8·7	–	8·6	–	8·4	–	8·1	–	7·9	–	8·0	–	8·0	–	8·1	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·8	–	–	–
	34	6·7	–	6·8	–	6·9	–	6·9	–	–	–	–	–	7·0	–	7·2	–	7·5	–	7·2	–	7·5	–	7·6	–
	35	–	–	–	–	–	–	–	–	7·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Table II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

Depth. Metres.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	15·5	–	15·5	–	15·5	–	15·5	–	15·5	–	15·6	–	16·9	–	16·1	–	16·1	–	16·0	–	16·0	–	16·0	–	*August* 14, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	–	–	–	–	–	–	15·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	14·7	–	14·7	–	15·0	–	15·1	–	15·3	–	15·3	–	–	–	15·4	–	15·5	–	
14	–	–	–	–	–	–	–	–	13·8	–	14·4	–	14·7	–	–	–	15·1	–	14·5	–	14·3	–	14·3	–	
15	14·5	–	15·0	–	14·1	–	13·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
16	–	–	–	–	12·3	–	11·7	–	12·1	–	12·5	–	14·0	–	14·5	–	14·6	–	13·5	–	12·8	–	12·5	–	
18	14·3	–	–	–	11·6	–	10·8	–	10·5	–	11·0	–	12·4	–	–	–	13·5	–	12·1	–	11·0	–	11·0	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	
20	13·6	–	13·7	–	11·0	–	10·0	–	9·6	–	9·9	–	10·5	–	12·6	–	11·7	–	10·5	–	10·5	–	9·0	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·8	–	–	–	
22	12·6	–	12·5	–	–	–	–	–	–	–	–	–	9·5	–	10·5	–	10·0	–	8·9	–	8·1	–	–	–	
23	–	–	–	–	3·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	11·2	–	11·0	–	–	–	–	–	8·2	–	8·0	–	8·4	–	8·8	–	9·0	–	8·1	–	7·4	–	7·5	–	
25	–	–	–	–	8·9	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
26	10·0	–	10·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·3	–	–	–	–	–	–	–	–	–	
30	8·5	–	8·5	–	7·9	–	7·2	–	7·3	–	7·1	–	7·1	–	7·1	–	7·1	–	7·1	–	7·0	–	7·0	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	7·5	–	7·3	–	7·1	–	6·9	–	6·8	–	6·8	–	6·8	–	6·8	–	6·8		6·8	–	6·8	–	6·8	–	
0	16·0	–	16·0	–	16·0	–	15·9	–	15·9	–	16·5	–	17·0	–	17·6	–	17·3	–	17·0	–	16·9	–	17·2	–	*August* 15, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	16·0	–	16·1	–	16·1	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	15·4	–	15·4	–	15·3	–	15·6	–	–	–	15·9	–	–	–	–	–	
10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·9	–	16·0	–	
12	15·4	–	15·2	–	14·5	–	14·6	–	14·4	–	14·1	–	14·2	–	15·1	–	15·5	–	15·8	–	–	–	–	–	
14	14·5	–	14·3	–	–	–	–	–	–	–	13·5	–	13·1	–	–	–	–	–	–	–	15·4	–	15·5	–	
15	–	–	–	–	–	–	13·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·2	–	
16	13·5	–	13·0	–	13·3	–	–	–	13·1	–	13·0	–	12·8	–	13·5	–	14·5	–	14·6	–	13·8	–	12·2	–	
18	12·0	–	–	–	12·8	–	12·5	–	12·5	–	12·2	–	12·0	–	13·0	–	13·4	–	13·1	–	12·5	–	11·5	–	
20	11·0	–	12·0	–	12·1	–	12·2	–	12·0	–	10·9	–	10·0	–	11·5	–	12·3	–	11·6	–	11·0	–	10·0	–	
22	10·2	–	–	–	11·7	–	–	–	10·8	–	9·3	–	–	–	10·0	–	10·7	–	–	–	9·7	–	–	–	
24	8·3	–	11·0	–	11·1	–	11·0	–	10·0	–	8·1	–	8·0	–	8·9	–	9·5	–	9·8	–	–	–	8·5	–	
26	–	–	10·1	–	–	–	10·0	–	8·3	–	–	–	–	–	–	–	–	–	–	–	8·2	–	–	–	
27	–	–	9·1	–	10·2	–	9·0	–	–	–	–	–	–	–	–	–	8·1	–	–	–	–	–	–	–	
28	–	–	8·1	–	10·0	–	–	–	7·8	–	–	–	–	–	–	–	–	–	7·8	–	–	–	–	–	
29	–	–	–	–	8·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·0	–	7·4	–	7·5	–	7·5	–	–	–	7·0	–	7·0	–	7·4	–	7·5	–	–	–	7·0	–	7·3	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	6·8	–	7·0	–	7·0	–	7·0	–	7·0	–	6·7	–	6·7	–	7·0	–	7·0	–	6·7	–	6·8	–	6·8		
0	17·0	–	16·7	–	16·7	–	16·6	–	16·6	–	16·6	–	16·7	–	17·0	–	17·1	–	17·0	–	16·5	–	16·4	–	*August* 16, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	16·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·9	–	
10	16·0	–	16·5	–	–	–	–	–	–	–	–	–	–	–	16·1	–	16·1	–	16·1	–	15·5	–	14·4	–	
12	–	–	16·0	–	16·0	–	16·1	–	16·2	–	16·4	–	16·1	–	–	–	15·6	–	15·4	–	14·0	–	13·9	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	14·9	–	–	–	–	–	–	–	–	–	–	–	
14	15·2	–	14·2	–	14·0	–	14·5	–	–	–	15·4	–	14·0	–	–	–	13·6	–	14·0	–	13·0	–	13·2	–	
15	13·7	–	–	–	–	–	–	–	14·9	–	14·0	–	–	–	–	–	12·6	–	–	–	–	–	–	–	
16	13·0	–	12·4	–	12·9	–	13·0	–	13·7	–	13·2	–	12·0	–	15·7	–	–	–	12·5	–	12·6	–	12·6	–	
17	12·0	–	–	–	12·2	–	–	–	–	–	–	–	–	–	11·1	–	11·7	–	–	–	–	–	–	–	
18	11·0	–	10·6	–	10·8	–	11·7	–	12·5	–	11·5	–	10·7	–	10·5	–	11·1	–	11·5	–	–	–	12·3	–	
20	9·6	–	9·3	–	10·1	–	10·5	–	10·8	–	10·5	–	9·8	–	9·8	–	10·2	–	10·2	–	11·2	–	12·0	–	
22	–	–	–	–	–	–	9·6	–	10·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	8·0	–	8·2	–	8·4	–	–	–	9·4	–	9·1	–	8·4	–	–	–	8·5	–	8·6	–	9·2	–	11·0	–	
25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	–	–	–	–	–	–	–	–	
26	–	–	–	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·6	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·0	–	
30	7·4	–	7·4	–	7·6	–	7·8	–	7·9	–	7·8	–	7·9	–	7·5	–	7·5	–	7·5	–	7·5	–	7·6	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	6·8	–	6·8	–	7·1	–	7·1	–	7·4	–	7·0	–	7·1	–	7·0	–	7·2	–	7·2	–	7·2	–	7·0	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

	Depth. Metres.	Hour of Observation. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
August 17, 1911.	0	16·2	–	16·2	–	16·0	–	16·1	–	16·3	–	16·5	–	17·3	–	17·5	–	17·3	–	17·2	–	17·5	–	18·1	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·3	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·0	–	–	–	17·1	–	17·2	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	15·8	–	15·9	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·9	–	16·0	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·8	–	–	–	16·1	–	16·4	–	16·3	–
	12	15·6	–	15·8	–	14·3	–	14·6	–	14·9	–	14·9	–	15·4	–	–	–	15·9	–	–	–	–	–	–	–
	13	13·6	–	13·9	–	–	–	–	–	–	–	–	–	–	–	15·4	–	–	–	–	–	–	–	–	–
	14	13·2	–	13·6	–	14·0	–	14·2	–	–	–	14·4	–	–	–	14·5	–	–	–	–	–	–	–	–	–
	15	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·1	–	14·8	–	15·8	–	16·0	–	15·7	–
	16	13·0	–	–	–	13·6	–	13·9	–	13·9	–	13·7	–	13·8	–	–	–	14·3	–	–	–	15·7	–	14·2	–
	17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·5	–	14·0	–	14·1	–	14·2	–	–	–
	18	–	–	–	–	13·0	–	–	–	–	–	12·9	–	12·4	–	12·8	–	–	–	13·5	–	13·7	–	13·3	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·0	–	13 1	–	11·6	–	12·5	–	10·7	–
	20	12·4	–	12·4	–	12·5	–	13·0	–	12·5	–	10·8	–	9·8	–	10·2	–	12·0	–	10·9	–	12·5	–	10·3	–
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·9	–	–	–	–	–	–	–
	22	–	–	–	–	11·3	–	11·5	–	10·5	–	9·5	–	9·0	–	9·1	–	–	–	9·5	–	9·8	–	9·3	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	–	–	–	–	–	–	–
	24	10·8	–	10·8	–	10 0	–	10·0	–	9·5	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·0	–	8·5	–	8·2	–	8·7	–	8·0	–
	26	–	–	–	–	–	–	–	–	–	–	8·0	–	7·6	–	–	–	–	–	–	–	–	–	–	–
	27	–	–		–	–	–	8·5	–	8·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	9·4	–	9·0	–	8·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	8·0	–	8·0	–	–	–	7·8	–	7·5	–	7·2	–	7·2	–	7·2	–	7·2	–	7·2	–	7·3	–	7·3	–
	34	7·2	–	7·2	–	7·2	–	7·3	–	7·2	–	6·9	–	6·8	–	–	–	–	–	–	–	–	–	6·9	–
August 18, 1911.	0	18·1	–	17·7	–	17·5	–	17·4	–	17·4	–	17·4	–	17·5	–	17·7	–	17·7	–	17·7	–	17·6	–	17·7	–
	5	17·4	–	–	–	–	–	17·4	–	17·3	–	17·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	16·5	–	16·5	–	16·4	–	16·4	–	17·3	–	17·4	–	17·4	–	17·5	–	17·6	–	17·6	–	17·5	–	17·5	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17·5	–	17·5	–	17·4	–
	12	15·3	–		–	–	–	16·1	–	–	–	–	–	–	–	–	–	17·5	–	14·5	–	15·0	–	14·0	–
	13	–	–	15·0	–	16·0	–	–	–	16·4	–	17·3	–	16·8	–	17·4	–	15·0	–	13·4	–	13·5	–	13·2	–
	14	–	–	–	–	15·2	–	15·7	–	–	–	16·6	–	14·6	–	13·9	–	13·2	–	–	–	12·6	–	12·7	–
	15	14·2	–	13·9	–	13·8	–	14·1	–	16·0	–	15·7	–	13·8	–	13·4	–	12·9	–	12·2	–	10·8	–	12·4	–
	16	13·3	–	12·4	–	13·2	–	13·7	–	14·1	–	14·0	–	13·1	–	–	–	–	–	10·9	–	–	–	–	–
	17	11·7	–	10·5	–	11·5	–	13·2	–	13·7	–	13·6	–	–	–	12·7	–	11·6	–	10·4	–	–	–	10·8	–
	18	–	–	9·7	–	10·2	–	12·4	–	–	–	13·1	–	12·7	–	–	–	–	–	–	–	–	–	–	–
	19	9·8	–	–	–	–	–	11·4	–	12·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	9·3	–	8·5	–	8·7	–	10·6	–	–	–	11·8	–	12·2	–	11·9	–	10·6	–	10·0	–	9·8	–	9·7	–
	21	–	–	–	–	–	–	–	–	11·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	22	–	–	–	–	–	–	8·6	–	–	–	11·4	–	–	–	11·2	–	–	–	–	–	–	–	–	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	11·5	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	–	–	8·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	25	7·6	–	7·5	–	7·5	–	7·0	–	–	–	10·0	–	–	–	10·2	–	9·6	–	9·3	–	9·0	–	8·6	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	10·8	–	–	–	–	–	–	–	–	–	–	–
	30	7·0	–	6·9	–	6·8	–	6·9	–	7·1	–	8·1	–	8·9	–	8·5	–	8·8	–	7·6	–	8·0	–	7·6	–
	34	6·8	–	6·8	–	–	–	–	–	–	–	–	–	–	–	7·0	–	7·0	–	7·0	–	7·0	–	7·1	–
August 19, 1911.	0	17·7	–	17·7	–	17·5	–	17·5	–	17·5	–	17·5	–	17·5	–	17·5	–	17·5	–	17·0	–	16·8	–	16·7	–
	5	–	–	–	–	–	–	17·4	–	17·3	–	17·1	–	16·7	–	16·6	–	16·2	–	15·8	–	15·6	–	–	–
	8	–	–	–	–	–	–	17·0	–	16·7	–	15·8	–	15·3	–	15·4	–	15·0	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	16·2	–	15·3	–	14·2	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	17·5	–	–	–	16·4	–	14·8	–	14·3	–	14·0	–	14·5	–	14·5	–	14·7	–	14·8	–	15·0	–
	11	17·5	–	17·2	–	–	–	–	–	14·1	–	13·8	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	17·4	–	17·0	–	16·0	–	16·0	–	–	–	–	–	13·6	–	–	–	–	–	–	–	–	–	14·7	–
	13	17·4	–	14·7	–	15·3	–	14·1	–	13·5	–	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	14·8	–	–	–	15·0	–	13·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	13·7	–	13·5	–	13·3	–	13·2	–	13·4	–	13·0	–	13·2	–	13·6	–	13·8	–	14·1	–	14·2	–	14·5	–
	16	13·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	17	13·0	–	–	–	12·0	–	12·4	–	12·7	–	12·2	–	–	–	13·3	–	–	–	–	–	–	–	–	–
	18	12·3	–	12·0	–	–	–	–	–	–	–	11·5	–	11·5	–	–	–	–	–	–	–	–	–	13·3	–
	19	11·0	–	10·3	–	–	–	–	–	–	–	–	–	–	–	12·4	–	–	–	–	–	–	–	–	–
	20	10·3	–	–	–	10·6	–	10·7	–	11·6	–	10·7	–	10·8	–	11·2	–	13·2	–	12·8	–	13·1	–	13·3	–
	21	10·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	12·6	–	10·7	–	11·5	–	11·5	–
	22	–	–	9·7	–	9·7	–	9·9	–	–	–	–	–	–	–	10·2	–	10·8	–	10·0	–	10·0	–	9·7	–
	23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·0	–	9·5	–	9·7	–	9·0	–
	25	8·8	–	8·5	–	–	–	8·5	–	9·6	–	9·5	–	9·5	–	8·8	–	8·9	–	8·4	–	8·6	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·7	–	7·6	–	7·7	–	7·7	–	7·6	–	7·7	–	7·8	–	7·9	–	7·8	–	7·5	–	7·5	–	7·3	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	7·0	–	7·0	–	–	–	–	–	–	–	–	–	–	–	7·1	–	7·2	–	7·0	–	7·1	–	7·0	–
	35	–	–	–	–	–	–	6·9	–	–	–	6·9	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·8	–	16·4	–	16·4	–	16·3	–	16·4	–	16·6	–	16·8	–	17·4	–	17·8	–	17·0	–	16·7	–	16·7	–	*AUGUST* 20, 1911.
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·7	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
5	16·4	–	–	–	–	–	15·8	–	–	–	–	–	–	–	16·3	–	16·3	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	–	–	15·0	–	15·0	–	15·3	–	15·4	–	15·5	–	15·8	–	16·0	–	16·1	–	16·1	–	16·1	–	16·1	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·5	–	–	–	–	–	–	–	
13	14·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	–	–	14·6	–	14·7	–	14·9	–	14·9	–	15·0	–	14·9	–	14·9	–	14·6	–	14·9	–	15·0	–	15·0	–	
16	14·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	14·1	–	14·4	–	–	–	–	–	
17	–	–	–	–	–	–	–	–	14·6	–	14·3	–	13·9	–	13·7	–	12·6	–	13·4	–	14·4	–	14·0	–	
18	11·3	–	13·8	–	14·2	–	–	–	–	–	–	–	11·8	–	11·9	–	11·7	–	12·3	–	12·9	–	12·5	–	
19	–	–	12·5	–	–	–	–	–	13·6	–	11·7	–	11·2	–	11·2	–	–	–	11·4	–	12·0	–	11·3	–	
20	11·4	–	11·2	–	13·0	–	14·3	–	12·5	–	11·1	–	10·5	–	10·5	–	10·4	–	10·8	–	11·2	–	10·1	–	
21	10·3	–	10·6	–	11·6	–	13·4	–	11·1	–	–	–	–	–	–	–	–	–	10·0	–	10·0	–	–	–	
22	9·0	–	9·7	–	10·8	–	11·9	–	10·5	–	10·0	–	9·3	–	8·8	–	8·9	–	8·7	–	9·5	–	9·1	–	
23	–	–	–	–	–	–	11·0	–	9·9	–	9·4	–	–	–	–	–	–	–	–	–	9·0	–	–	–	
24	–	–	–	–	–	–	10·0	–	8·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	8·0	–	8·0	–	8·2	–	9·0	–	8·2	–	8·0	–	7·8	–	7·8	–	7·6	–	7·7	–	7·8	–	7·9	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·3	–	7·2	–	7·2	–	7·1	–	6·9	–	7·0	–	7·0	–	7·0	–	7·0	–	7·0	–	7·1	–	7·1	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	7·0	–	7·0	–	–	–	–	–	–	–	–	–	–	–	6·8	–	–	–	–	–	–	–	6·9	–	
35	–	–	–	–	–	–	6·8	–	–	–	6·8	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·5	–	16·6	–	16·5	–	16·5	–	16·6	–	17·0	–	17·1	–	16·8	–	16·7	–	16·6	–	–	–	16·5	–	*AUGUST* 21, 1911.
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·5	–	–	–	
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
5	–	–	16·3	–	–	–	16·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	16·2	–	16·2	–	–	–	15·7	–	16·0	–	16·2	–	16·2	–	16·1	–	16·0	–	16·1	–	16·1	–	16·2	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·0	–	15·2	–	–	–	–	–	–	–	
12	–	–	–	–	16·2	–	15·0	–	–	–	–	–	–	–	15·1	–	14·7	–	14·8	–	–	–	–	–	
13	15·3	–	15·0	–	–	–	14·6	–	15·0	–	15·3	–	15·5	–	14·7	–	13·4	–	14·4	–	14·9	–	15·0	–	
14	14·8	–	14·6	–	14·2	–	14·1	–	–	–	–	–	–	–	13·6	–	12·0	–	13·8	–	–	–	–	–	
15	12·5	–	13·2	–	–	–	13·4	–	13·5	–	14·7	–	14·2	–	12·3	–	–	–	12·6	–	13·9	–	14·2	–	
16	11·8	–	11·8	–	12·6	–	–	–	–	–	13·1	–	13·0	–	11·5	–	11·2	–	–	–	13·0	–	–	–	
17	–	–	11·3	–	–	–	12·0	–	11·7	–	12·3	–	12·1	–	–	–	–	–	11·2	–	11·8	–	13·2	–	
18	–	–	10·8	–	11·2	–	–	–	–	–	–	–	–	–	10·7	–	10·2	–	–	–	–	–	–	–	
19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·4	–	11·0	–	
20	9·7	–	9·3	–	11·0	–	11·2	–	10·8	–	11·1	–	11·0	–	10·3	–	9·9	–	9·8	–	10·0	–	9·8	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
22	–	–	8·7	–	10·8	–	10·5	–	–	–	–	–	10·2	–	–	–	–	–		–	9·2	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	–	–	–	–	10·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	7·7	–	7·6	–	–	–	9·4	–	9·5	–	9·9	–	9·7	–	9·4	–	9·0	–	8·7	–	8·2	–	8·2	–	
26	–	–	–	–	8·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	8·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	7·0	–	7·0	–	7·8	–	7·5	–	8·2	–	9·0	–	9·0	–	8·7	–	8·0	–	8·0	–	7·8	–	7·6	–	
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
32	–	–	–	–	–	–	–	–	–	–	8·2	–	8·3	–	–	–	–	–	–	–	–	–	–	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	–	–	6·8	–	6·8	–	–	–	–	–	7·2	–	7·1	–	–	–	–	–	–	–	7·2	–	7·2	–	
35	–	–	–	–	–	–	6·8	–	6·9	–	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

	DEPTH. METRES.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 22, 1911.	0	16·4	–	16·4	–	16·4	–	16·2	–	16·2	–	16·4	–	16·5	–	16·6	–	16·7	–	16·6	–	16·5	–	16·4	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	16·3	–	–	–	16·2	–	–	–	16·2	–	–	–	16·5	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	16·2	–	16·2	–	16·2	–	15·9	–	15·9	–	15·8	–	16·0	–	16·1	–	16·2	–	16·2	–	16·0	–	16·1	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	15·3	–	–	–	–	–	–	–	15·3	–	15·8	–	–	–	–	–	15·4	–
	13	–	–	–	–	–	–	15·0	–	14·8	–	14·8	–	14·8	–	–	–	–	–	–	–	15·0	–	–	–
	14	–	–	14·7	–	–	–	14·5	–	–	–	14·0	–	14·0	–	–	–	15·0	–	–	–	–	–	–	–
	15	15·0	–	–	–	14·6	–	13·9	–	14·0	–	13·4	–	13·5	–	13·7	–	12·8	–	14·9	–	14·2	–	14·3	–
	16	–	–	–	–	13·6	–	13·6	–	13·3	–	–	–	12·7	–	–	–	–	–	–	–	–	–	–	–
	17	–	–	–	–	–	–	12·4	–	12·7	–	12·1	–	12·1	–	–	–	–	–	13·5	–	13·0	–	–	–
	18	14·2	–	13·7	–	11·7	–	11·8	–	11·9	–	–	–	–	–	12·4	–	–	–	–	–	–	–	12·6	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	20	12·7	–	12·3	–	11·3	–	11·0	–	11·2	–	10·8	–	10·8	–	11·0	–	11·8	–	12·0	–	11·6	–	11·8	–
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	11·2	–	11·1	–	–	–	–	–
	22	10·8	–	10·4	–	–	–	10·3	–	–	–	9·8	–	9·8	–	–	–	10·3	–	10·3	–	10·3	–	10·3	–
	23	–	–	–	–	–	–	10·0	–	–	–	9·1	–	9·0	–	9·4	–	9·4	–	–	–	9·2	–	–	–
	24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·6	–	–	–	–	–
	25	8·8	–	8·6	–	8·6	–	8·7	–	8·9	–	8·0	–	8·1	–	8·0	–	8·0	–	8.0	–	8·2	–	8·0	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·7	–	7·5	–	7·6	–	7·5	–	7·3	–	7·2	–	7·1	–	7·2	–	7·2	–	7·2	–	7·1	–	7·1	–
	31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	7·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	35	–	–	–	–	–	–	6·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 23, 1911.	0	16·4	–	16·3	–	16·3		16·1	–	16·2	–	16·1	–	16·2	–	16·7	–	16·6	–	16·7	–	16·5	–	16·5	–
	2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	16·2	–	–	–	16·1	–	–	–	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	16·0	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	16·0	–	14·7	–	15·2	–	15·7	–	15·4	–	15·4	–	15·6	–	15·8	–	16·1	–	16·2	–	16·4	–	16·5	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	15·0	–	–	–	–	–	–	–	–	–	14·5	–	–	–	–	–	–	–	–	–	–	–	16·4	–
	13	–	–	13·3	–	13·7	–	14·6	–	14·5	–	14·0	–	14·4	–	14·4	–	14·8	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	13·4	–	12·8	–	13·2	–	13·9	–	13·6	–	13·5	–	13·5	–	13·7	–	13·4	–	15·6	–	15·9	–	14·6	–
	17	–	–	–	–	–	–	13·4	–	13·2	–	13·1	–	12·8	–	13·0	–	12·7	–	14·4	–	14·6	–	–	–
	18	12·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·6	–	–	–	13·3	–
	19	–	–	–	–	–	–	–	–	–	–	–	–	11·8	–	11·6	–	10·7	–	–	–	13·6	–	–	–
	20	11·7	–	11·3	–	11·5	–	12·9	–	12·7	–	11·5	–	10·1	–	11·2	–	10·3	–	12·2	–	12·9	–	11·4	–
	21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·7	–	–	–	–	–	–	–	–	–
	22	11·0	–	9·7	–	9·8	–	12·5	–	12·0	–	10·4	–	–	–	9·2	–	9·1	–	10·6	–	11·5	–	9·9	–
	23	–	–	–	–	–	–	–	–	10·9	–	–	–	9·1	–	–	–	–	–	–	–	–	–	–	–
	24	–	–	–	–	–	–	11·2	–	10·5	–	9·0	–	–	–	–	–	–	–	–	–	10·5	–	–	–
	25	8·7	–	7·8	–	8·0	–	10·4	–	9·5	–	8·6	–	–	–	8·2	–	8·4	–	9·2	–	9·4	–	9·0	–
	26	–	–	–	–	–	–	9·2	–	8·7	–	–	–	7·8	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	8·3	–	–	–
	28	–	–	–	–	–	–	7·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	7·2	–	7·1	–	7·0	–	7·2	–	7·3	–	7·0	–	7·1	–	7·2	–	7·4	–	7·6	–	7·7	–	7·7	–
	31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	6·9	–
	35	–	–	6·8	–	–	–	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

DEPTH. METRES.	HOUR OF OBSERVATION.																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
0	16·5	–	16·4	–	16·4	–	16·5	–	16·5	–	16·4	–	16·4	–	16·3	–	16·4	–	16·2	–	16·2	–	16·2	–	*AUGUST* 24, 1911.
2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	15·0	–	16·2	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	–	–	–	–	–	–	16·5	–	16·5	–	16·2	–	16·1	–	15·4	–	16·2	–	13·9	–	14·0	–	15·0	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	16·4	–	16·2	–	15·2	–	16·0	–	15·2	–	–	–	–	–	–	–	13·8	–	13·5	–	13·7	–	–	–	
13	–	–	–	–	14·1	–	14·4	–	14·2	–	15·2	–	15·1	–	14·0	–	13·4	–	–	–	–	–	–	–	
14	15·5	–	13·5	–	–	–	–	–	–	–	14·2	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	14·2	–	–	–	12·7	–	13·0	–	13·3	–	13·7	–	14·1	–	12·6	–	12·9	–	13·1	–	13·2	–	14·2	–	
16	13·2	–	11·7	–	11·5	–	11·5	–	12·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
17	–	–	–	–	–	–	10·8	–	11·4	–	13·0	–	13·0	–	11·1	–	11·8	–	–	–	–	–	–	–	
18	11·5	–	10·3	–	10·0	–	10·3	–	10·9	–	12·8	–	11·0	–	–	–	–	–	–	–	–	–	–	–	
19	–	–	–	–	–	–	–	–	–	–	11·0	–	–	–	–	–	–	–	12·2	–	–	–	–	–	
20	10·5	–	9·2	–	8·7	–	8·8	–	9·1	–	10·4	–	10·0	–	9·7	–	10·2	–	–	–	12·2	–	13·7	–	
21	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
22	9·2	–	8·3	–	–	–	–	–	–	–	9·1	–	–	–	–	–	–	–	11·6	–	–	–	–	–	
23	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
24	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
25	8·4	–	7·8	–	7·8	–	7·8	–	8·0	–	8·3	–	8·2	–	8·0	–	8·2	–	11·0	–	11·3	–	12·3	–	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	–	10·7	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·2	–	–	–	
30	7·7	–	7·3	–	7·4	–	7·4	–	7·4	–	7·5	–	7·4	–	7·5	–	7·5	–	7·8	–	8·4	–	10·5	–	
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·6	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	7·0	–	6·9	–	–	–	7·0	–	7·0	–	–	–	–	–	7·1	–	–	–	–	–	–	–	8·0	–	
35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
0	16·2	–	16·1	–	16·0	–	16·0	16·0	16·0	–	16·2	16·2	16·2	–	16·3	16·2	16·2	16·3	16·2	16·2	16·1	16·1	16·2	16·1	*AUGUST* 25, 1911.
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
10	16·2	–	16·1	16·1	16·0	–	16·0	16·0	–	–	16·2	–	–	–	–	–	–	–	–	–	16·1	–	–	–	
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
15	14·7	–	14·9	–	16·0	–	16·0	16·0	16·0	–	16·0	–	–	–	–	–	–	–	–	–	16·0	–	–	–	
16	–	–	–	–	–	–	15·3	15·3	14·9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
17	–	–	–	–	15·6	–	–	–	14·0	–	–	15·9	16·0	–	–	–	–	–	–	–	–	–	–	–	
18	–	–	–	–	14·5	–	14·0	13·6	13·6	–	15·9	–	–	–	–	–	–	–	–	–	–	–	–	–	
19	–	–	–	–	–	–	11·8	13·7	11·0	–	15·9	15·6	16·0	–	–	–	–	–	–	–	–	–	–	–	
20	14·2	–	14·2	14·1	14·0	–	10·9	9·7	9·8	–	14·2	9·9	12·8	–	16·0	–	16·0	16·0	16·0	16·0	16·0	15·9	16·0	16·0	
21	–	–	–	–	–	–	–	–	–	–	10·7	9·7	10·0	–	16·0	–	–	14·2	15·9	13·8	12·2	11·9	15·5	13·4	
22	–	–	–	–	12·9	–	9·6	9·1	–	–	9·5	–	9·0	–	16·0	16·0	16·0	9·6	9·1	9·0	9·0	9·6	9·4	9·0	
23	–	–	13·3	13·1	11·3	–	–	–	–	–	8·7	8·4	–	–	13·2	16·0	11·5	–	–	8·3	8·1	8·3	8·6	8·1	
24	–	–	–	–	9·8	–	–	–	–	–	–	–	–	–	9·3	9·7	9·6	8·2	8·0	7·9	7·9	–	–	–	
25	13·9	–	11·8	11·1	9·3	–	8·6	8·4	8·3	–	8·2	7·9	8·1	–	8·7	8·7	8·3	–	–	–	–	–	7·5	7·2	
26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·9	–	–	–	–	–	–	–	
27	12·8	–	10·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
28	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·4	7·4	–	–	–	–	–	
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
30	11·6	–	8·4	8·0	7·9	–	7·8	7·5	7·4	–	7·4	7·3	7·2	–	7·4	7·4	–	–	–	7·0	–	6·9	7·0	6·9	
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
32	10·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–	
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
34	8·0	–	–	–	–	–	–	7·2	–	–	–	7·2	7·0	–	–	–	–	7·0	7·0	–	6·9	–	–	6·9	
35	–	–	7·4	–	7·6	–	–	–	–	–	–	–	–	–	7·0	–	–	–	–	–	–	–	–	–	

Table II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

	Depth. Metres.	HOUR OF OBSERVATION.																							
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
AUGUST 26, 1911.	0	16·0	16·1	16·1	16·1	16·1	–	15·9	16·0	16·0	–	15·9	16·0	16·2	16·2	16·0	15·9	16·1	16·2	16·2	15·9	15·9	15·9	16·0	16·1
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–	–	–	–	–	–	–	–	16·2	16·0	16·1	16·1	–	–	–	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–		–	–	15·9	–	–	–	15·9	–	16·0	16·0	15·8	16·1	15·9	16·1	–	–	–	–	15·9	16·1
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	16·2	16·0	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	15·7	15·7	15·8	–	–	–	–	–	–	–	–	15·6	–	15·8	–	–	–	–
	15	–	–	–	–	–	–	12·7	12·8	15·6	–	15·7	15·7	16·1	15·6	15·9	15·8	15·7	15·5	15·4	15·7	15·7	15·9	–	15·8
	16	–	–	–	–	–	–	12·3	12·0	11·7	–	13·8	14·4	15·4	15·5	15·7	15·7	15·5	13·5	12·6	15·6	15·7	13·5	15·7	15·8
	17	–	–	–	–	16·0	–	10·7	11·8	11·3	–	11·2	11·8	13·9	14·5	13·5	15·3	13·1	12·2	11·9	12·6	11·9	12·2	–	13·0
	18	–	–	15·9	15·8	11·6	–	10·4	11·0	–	–	10·7	10·8	11·8	12·3	12·5	13·8	12·4	11·9	11·6	11·6	11·7	–	12·2	12·0
	19	15·9	15·9	13·9	11·6	10·5	–	–	–	–	–	–	10·4	11·5	11·7	12·0	13·3	11·8	11·5	11·6	–	11·7	11·6	11·6	11·6
	20	15·4	10·0	8·9	8·7	9·4	–	9·1	10·2	10·0	–	10·2	–	10·5	10·8	11·7	12·5	11·5	–	–	–	11·6	11·2	11·5	11·4
	21	9·4	8·3	8·0	–	–	–	–	–	–	–	–	–	10·5	10·8	11·1	11·4	11·2	11·2	–	–	11·2	11·1	11·4	11·5
	22	8·2	7·7	7·5	7·7	8·7	–	–	–	–	–	–	–	10·3	10·6	10·8	11·6	11·2	11·0	–	–	11·1	–	11·0	11·2
	23	7·9	–	–	–	–	–	–	–	–	–	–	–	9·9	–	–	–	–	10·8	–	–	–	–	11·0	11·4
	24	–	–	–	–	–	–	–	–	–	–	–	–	9·6	9·8	10·3	10·5	10·7	–	10·6	10·7	–	–	–	–
	25	7·1	7·0	7·2	7·0	7·2	–	8·8	9·1	9·2	–	9·2	9·4	9·7	–	–	–	–	–	–	10·7	–	–	–	–
	26	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	27	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	10·3	–	–	–	–
	28	–	–	–	–	–	–	–	–	–	–	–	–	9·1	–	–	–	–	–	–	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	9·5	9·7	–	–	–	–	–
	30	–	–	–	–	–	–	8·7	7·9	8·3	–	8·6	8·6	8·9	8·[illegible]	8·9	9·2	9·1	–	–	9·2	–	–	–	–
	31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	32	–	–	–	–	–	–	7·2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8·1	–	–	–	–	–	–
	34	–	–	–	–	–	–	6·8	7·0	7·0	–	6·9	–	7·2	7·2	7·2	7·2	7·4	–	7·2	7·0	–	7·1	–	–
	35	6·8	6·8	6·7	6·9	6·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
AUGUST 27, 1911.	0	16·1	16·1	16·1	16·1	16·1	–	16·1	16·1	16·1	15·9	16·1	16·0	16·1	16·2	16·4	16·3	16·3	16·2	16·1	–	16·1	–	16·0	–
	4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	–	–	–	–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	6	–	–	–	–	–		–	–		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	10	–	–	–	–	–	–	–	–	–	–	16·0	15·8	15·8	16·2	15·8	15·8	15·8	15·8	–	–	–	–	–	–
	11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	13	–	–	–	–	–		15·8	15·6	16·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	14	–	–	–	–	–	–	15·3	14·0	15·6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	15	15·8	–	–	–	–	–	14 2	13·2	13·3	15·7	15·8	15·7	15·7	–	–	–	–	–	15·7	–	15·7	–	15·7	–
	16	15·5	–	–	–	–	–	12·2	12·2	12·7	14·3	15·4	15·7	15·7	16·0	–	–	–	–	–	–	–	–	11·9	–
	17	11·9	15·6	15·8	–	15·8	–	11·9	11·8	11·9	12·2	12·8	12·9	15·4	–	–	–	–	–	–	–	–	–	11·5	–
	18	11·9	12·7	15·8	–	15·8	–	11·5	11·6	11·5	12·0	12·0	12·1	14·5	15·8	15·6	15·6	15·8	–	15·7	–	15·7	–	10·7	–
	19	11·2	12·1	13·4	15·6	14·9	–	11·2	10·7	10·3	11·6	11·8	11·3	12·1	15·5	15·3	15·3	15·4	15·5	14·0	–	12·8	–	9·3	–
	20	11·2	11·7	12·8	14·3	13·3	–	10·6	9·0	9·0	9·2	9·5	10·0	11·8	12·2	12·2	11·9	12·0	12·1	12·2	–	12·0	–	8·5	–
	21	11·2	11·3	–	12·2	12·2	–	8·9	8·9	–	–	8·5	8·4	10·9	11·9	11·2	11·3	11·7	11·7	11·4	–	9·8	–	–	–
	22	10·8	11·3	11·8	12·0	11·5	–	–	–	–	8·1	7·8	8·2	10·1	11·2	9·9	9·8	9·3	10·1	10·0	–	9·0	–	8·0	–
	23	9·7	10·3	11·8	11·9	11·5	–	–	–	–	–	–	–	9·4	10·0	8·7	8·7	8·7	9·3	9·0	–	8·1	–	–	–
	24	9·5	11·1	11·4	11·2	10·3	–	–	–	–	–	7·6	8·2	8·2	8·9	8·3	7·9	8·2	8·4	–	–	7·9	–	–	–
	25	–	9·3	10·2	10·2	9·5	–	7·8	7·7	7·5	7·7	–	–	–	–	–	7·7	7·9	8·1	–	–	7·7	–	7·5	–
	26	–	9·1	9·5	9·2	9·2	–	–	–	–	–	–	–	7·8	7·6	–	–	7·6	7·7	–	–	–	–	–	–
	27	–	–	–	9·2	–	–	7·5	7·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	28	–	–	–	8·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	30	–	8·0	7·8	–	7·8	–	–	–	7·2	–	7·2	7·2	7·1	7·2	7·2	7·1	7·0	7·0	7·2	–	7·0	–	7·0	–
	31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	34	–	7·4	–	7·2	–	–	–	–	–	–	6·9	6·9	7·0	7·2	6·8	6·9	–	6·9	–	–	–	–	–	–
	35	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6·8	–	–	–

TABLE II.—*continued.*

OBSERVATIONS AT STATION V.—*continued.*

AUGUST 28, 1911.

DEPTH. METRES.	HOUR OF OBSERVATION.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	16·0	–	16·0	–	16·0	–	16·0	–	16·1	–	16·2	–	16·3	–	16·5	–	16·7	–	–	–	–	–	–	–
4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	16·7	–	–	–	–	–	–	–
6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	–	–	15·9	–	15·8	–	15·6	–	15·7	–	15·8	–	–	–	–	–	–	–
12	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
13	–	–	15·7	–	–	–	–	–	–	–	15·7	–	–	–	15·2	–	–	–	–	–	–	–	–	–
14	–	–	13·7	–	–	–	–	–	14·6	–	15·2	–	14·8	–	14·8	–	–	–	–	–	–	–	–	–
15	15·7	–	12·6	–	15·6	–	15·4	–	13·4	–	13·9	–	13·4	–	13·2	–	15·2	–	–	–	–	–	–	–
16	12·5	–	–	–	13·8	–	12·6	–	–	–	–	–	–	–	13·0	–	13·6	–	–	–	–	–	–	–
17	10·4	–	–	–	12·5	–	–	–	–	–	13·0	–	–	–	–	–	13·1	–	–	–	–	–	–	–
18	9·5	–	11·6	–	12·0	–	12·2	–	12·4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	10·5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	8·4	–	10·1	–	11·2	–	11·5	–	12·0	–	12·3	–	12·2	–	11·8	–	12·3	–	–	–	–	–	–	–
22	–	–	–	–	10·6	–	–	–	–	–	11·8	–	11·7	–	10·7	–	11·5	–	–	–	–	–	–	–
23	–	–	–	–	–	–	–	–	–	–	–	–	11·0	–	9·2	–	9·9	–	–	–	–	–	–	–
24	7·3	–	–	–	10·0	–	10·8	–	10·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
25	–	–	–	–	–	–	–	–	–	–	10·5	–	9·6	–	8·7	–	9·1	–	–	–	–	–	–	–
26	–	–	8·5	–	9·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	9·4	–	–	–	9·5	–	–	–	–	–	–	–	–	–	–	–	–	–
28	–	–	–	–	7·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	7·0	–	7·4	–	7·4	–	8·6	–	8·9	–	8·3	–	7·7	–	7·9	–	8·1	–	–	–	–	–	–	–
32	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	6·8	–	6·9	–	7·0	–	7·4	–	7·1	–	–	–	–	–	7·2	–	7·4	–	–	–	–	–	–	–
35	–	–	–	–	–	–	–	–	–	–	6·9	–	6·8	–	–	–	–	–	–	–	–	–	–	–

AUGUST 29, 1911.

DEPTH. METRES.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	–	–	–	–	–	–	16·2	16·1	16·1	16·2	16·2	16·2	16·2	16·2	16·2	16·2	16·1	16·1	–	–	–	–	–	–
10	–	–	–	–	–	–	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
15	–	–	–	–	–	–	16·0	–	–	–	–	–	–	–	–	16·0	–	–	–	–	–	–	–	–
16	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
17	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
18	–	–	–	–	–	–	15·8	16·0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
19	–	–	–	–	–	–	14·8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
20	–	–	–	–	–	–	12·7	15·7	15·7	15·9	15·9	–	–	–	–	–	15·9	15·8	–	–	–	–	–	–
21	–	–	–	–	–	–	12·3	14·0	14·5	–	–	–	–	–	–	–	14·6	11·1	–	–	–	–	–	–
22	–	–	–	–	–	–	11·2	12·7	12·5	15·1	15·8	15·8	15·9	–	–	15·5	10·9	9·1	–	–	–	–	–	–
23	–	–	–	–	–	–	10·7	12·1	11·7	14·8	15·4	–	15·8	15·8	15·7	13·3	9·6	8·7	–	–	–	–	–	–
24	–	–	–	–	–	–	–	10·5	10·5	12·7	15·2	14·5	13·9	15·3	12·7	9·9	8·8	–	–	–	–	–	–	–
25	–	–	–	–	–	–	9·1	9·7	9·7	10·6	11·7	12·1	11·2	11·9	10·3	9·0	8·3	7·9	–	–	–	–	–	–
26	–	–	–	–	–	–	–	9·0	9·2	9·8	10·6	10·3	10·1	9·7	9·4	8·5	–	–	–	–	–	–	–	–
27	–	–	–	–	–	–	8·2	–	–	–	9·5	9·3	9·2	9·3	8·6	–	–	–	–	–	–	–	–	–
28	–	–	–	–	–	–	–	8·4	8·7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
29	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
30	–	–	–	–	–	–	7·6	7·6	7·7	7·9	8·1	7·8	7·9	7·8	7·8	7·5	7·2	7·2	–	–	–	–	–	–
31	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
33	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
34	–	–	–	–	–	–	–	–	–	–	–	–	7·2	7·2	7·2	7·0	6·9	–	–	–	–	–	–	–
35	–	–	–	–	–	–	7·0	7·1	7·0	7·0	7·1	6·9	–	–	–		–	–	–	–	–	–	–	–

OBSERVATIONS AT STATION VI.

AUGUST 29, 1911.

DEPTH. METRES.	HOUR OF OBSERVATION.																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
0	–	–	–	–	–	–	16·3	16·3	16·3	16·3	16·4	–	–	16·3	16·4	16·3	16·1	16·1	–	–	–	–	–	–
1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2	–	–	–	–	–	–	16·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
4	–	–	–	–	–	–	16·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	–	–	–	–	–	–	16·3	16·3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
8	–	–	–	–	–	–	16·2	16·2	16·1	16·1	16·1	–	–	–	–	–	–	–	–	–	–	–	–	–
9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
10	–	–	–	–	–	–	15·9	16·1	16·1	15·8	15·9	–	–	16·1	16·2	16·1	16·1	16·1	–	–	–	–	–	–
11	–	–	–	–	–	–	–	15·1	15·0	15·3	15·2	–	–	15·6	15·7	15·6	15·7	15·7	–	–	–	–	–	–
12	–	–	–	–	–	–	–	14·1	14·1	14·2	14·4	–	–	14·0	15·6	15·3	15·1	14·2	–	–	–	–	–	–
13	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	13·9	14·0	–	–	–	–	–	–
14	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

NATURAL HISTORY

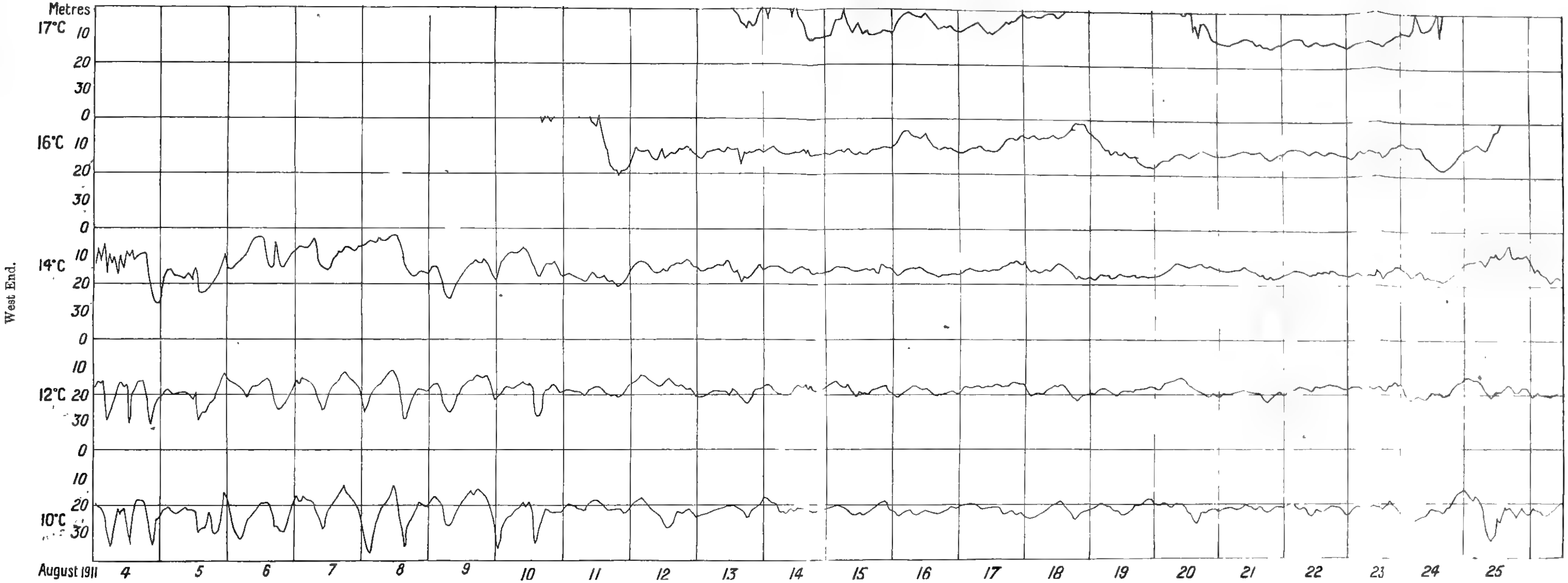

FIG. 11.—Position of isotherms at Station I.

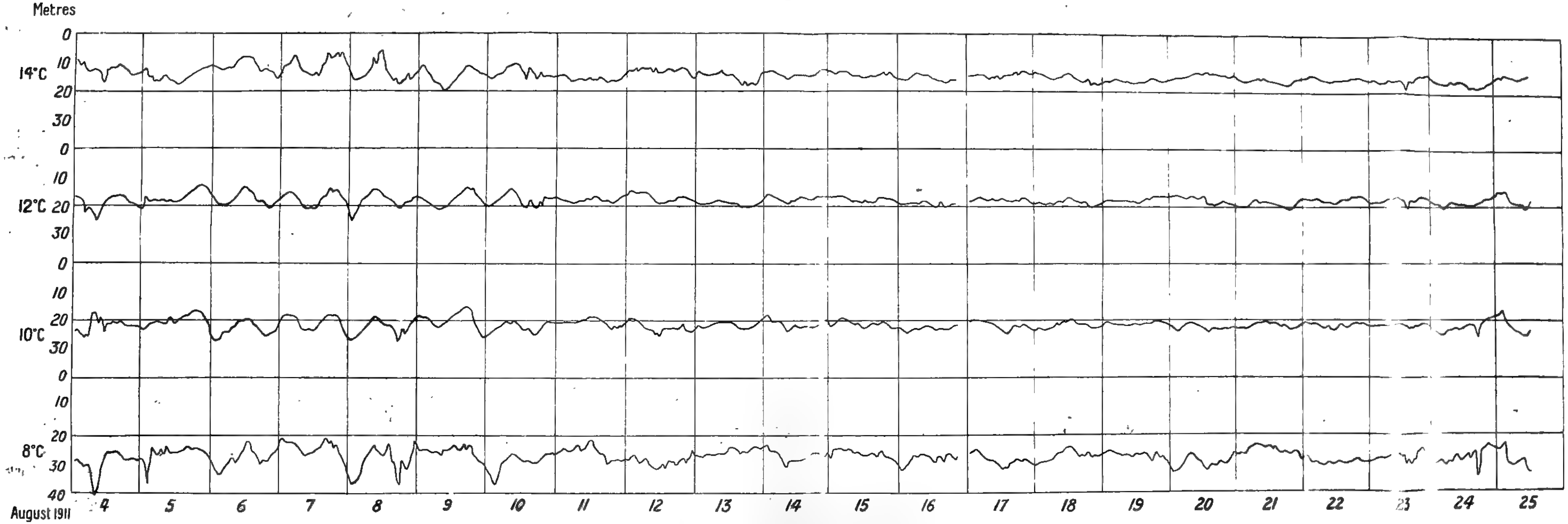

FIG. 12.—Position of isotherms at Station II.

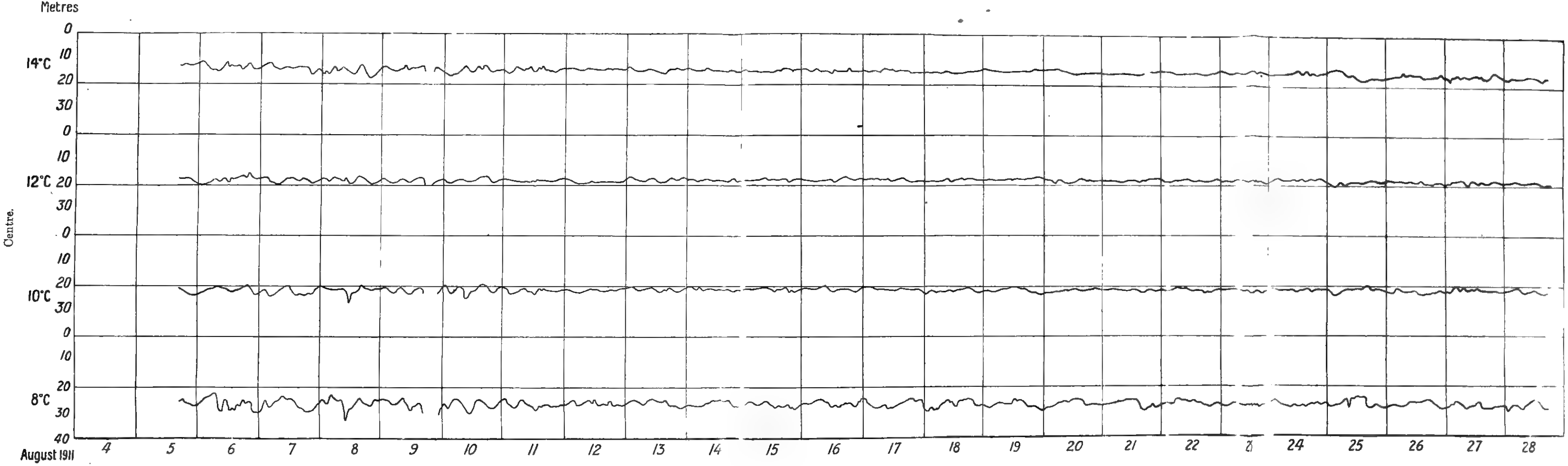

FIG. 13.—Position of isotherms at Station III.

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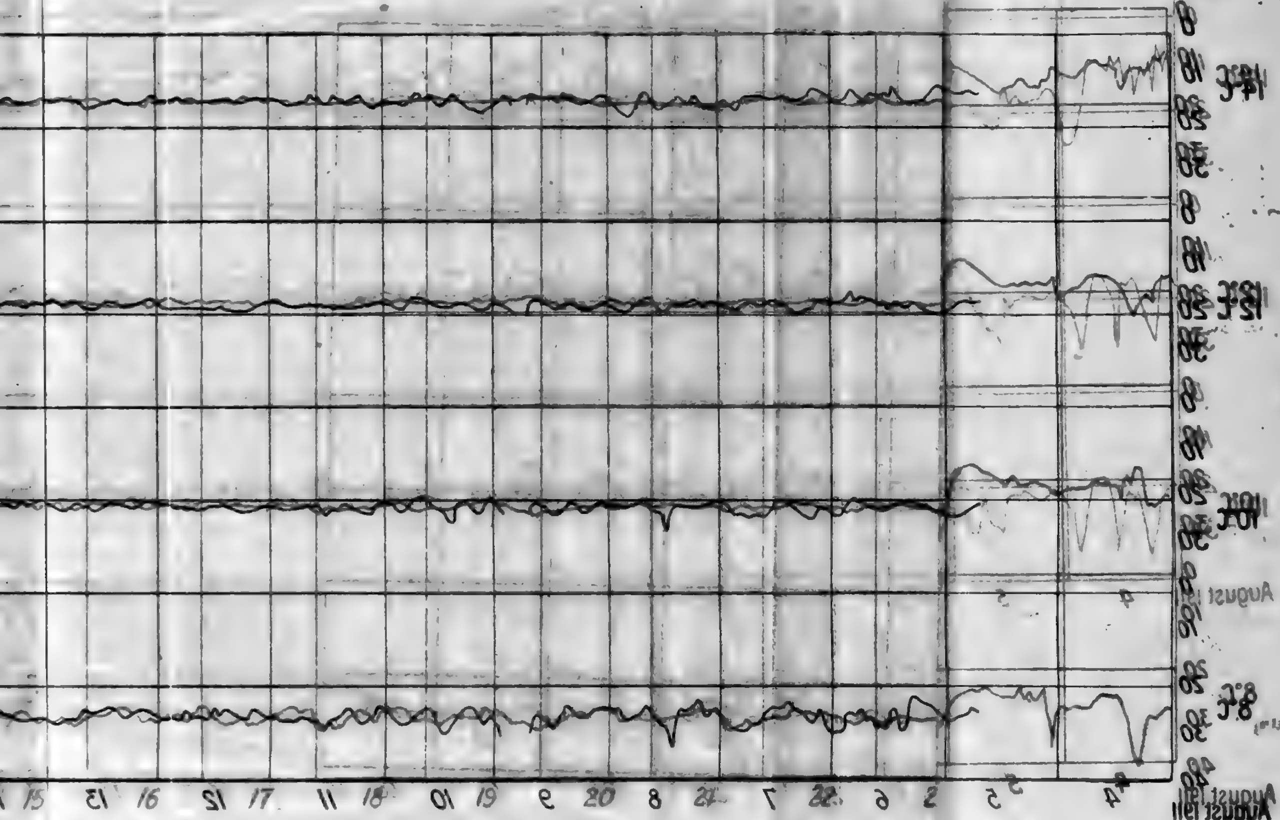
Observations in Loch Earn."



of isotherms at Station III.

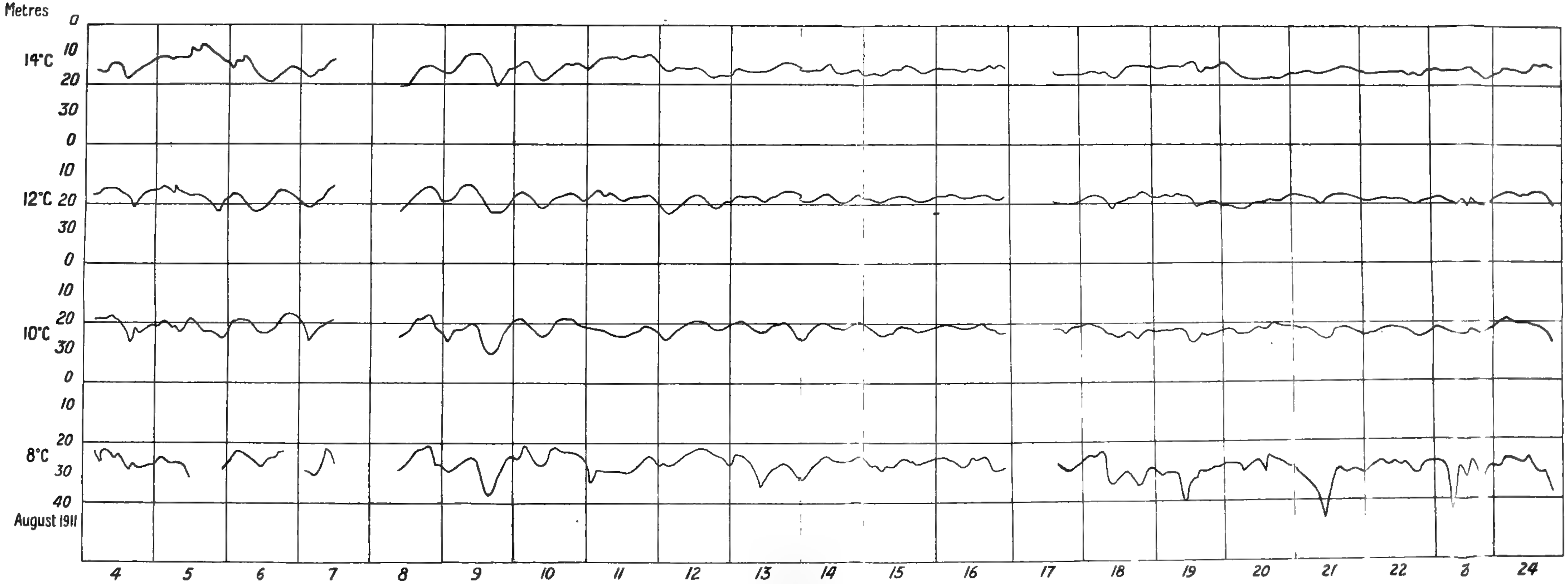


Fig. 14.—Position of isotherms at Station IV.

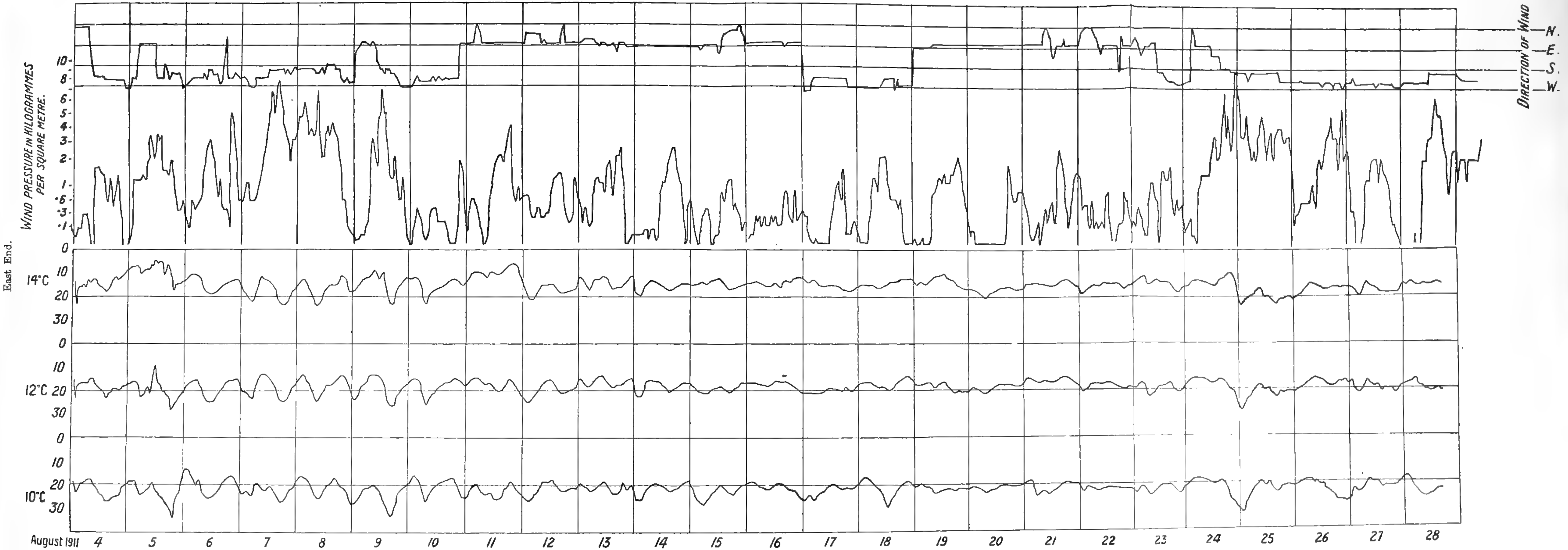


Fig. 15.—Position of isotherms at Station V., and direction and force of wind.

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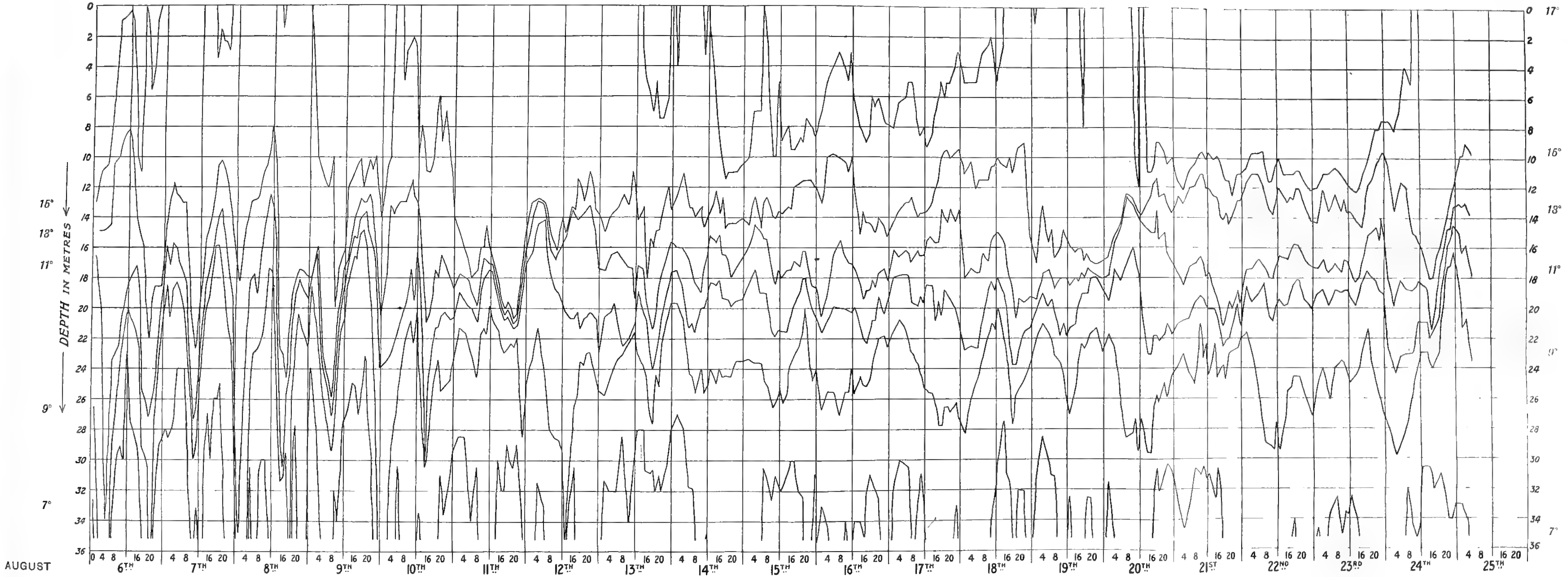
NATURAL HISTORY



LOCH EARN 1911

ISOTHERMS AT STATION No I

FIG. 17.—Isotherms at Station I. for 7°, 9°, 11°, 13°, 15°, and 17°.

BRITISH MUSEUM NATURAL HISTORY

XXVII.—Multiple Neuromata of the Central Nervous System: their Structure and Histogenesis.* By the late **Alexander Bruce**, M.D., LL.D., F.R.C.P.E.; and **James W. Dawson**, M.D. (Carnegie Research Fellow). *Communicated by* A. Ninian Bruce, M.D., D.Sc., M.R.C.P.E. (From the Royal College of Physicians' Laboratory, Edinburgh.) (With Eight Plates.)

(MS. received April 23, 1912. Read July 1, 1912. Issued separately January 9, 1913.)

CONTENTS.

Recent investigations have profoundly modified our conception of the value of the histological elements of the nervous system. Conflicting opinions are still held on many points of primary importance, perhaps the chief of which is the relation of the nerve fibre to the nerve cell. The origin of the nerve fibre is a problem of vital interest not only to the embryologist, but also to the physiologist and the pathologist. It has long been the subject of controversy, and, in spite of numerous valuable researches, we are still far from knowing the relation of the nerve fibre to the central neuroblast, a relation of essential importance in the understanding of all neuro-pathological questions.

Researches on the embryogenesis and mode of regeneration of the peripheral nerves

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* [Note by Dr James Ritchie, Superintendent, Royal College of Physicians' Laboratory.—During Dr Alexander Bruce's lifetime a full investigation had been made of the spinal cord of the case which is the subject of this paper. The characters of the neuromata and their connections with the aberrant nerve fibres present had been considered and were the subject of a preliminary communication before the Pathological Society of Great Britain and Ireland in 1910 (see *Journ. Path. and Bacteriol.*, Cambridge, vol. xv. (1911), p. 127). It was not until after Dr Bruce's death, however, that the medulla was examined and the younger nodules present discovered. Dr Dawson is thus responsible for that part of the paper which deals with the bearing of these later observations on the origin of the tumours and on the significance of the underlying processes in relation to the question of the embryology of nerve fibrils generally.]

have led, amongst other things, to a new interpretation of the nature and mode of development of the new growths which arise in relation to nerves. They have given a new significance and a new conception to the term "neuroma," as they have also reaffirmed the existence of the "true" neuroma as a definite group of tumours.

The term neuroma conveys to many minds no definite conception. ODIER, in 1803, suggested the name to designate "deep-seated tumours which are characterised by painful swelling of the nerves involved." The term came into use to indicate any tumour in relation to a nerve, thus indicating its most important clinical feature, whatever its histological structure might be. Early writers ascribed their origin to an overgrowth of the connective-tissue sheaths of the nerve, and apparently took it for granted that a tumour composed of nerve tissue could not exist. VIRCHOW, in 1863, placed the pathology of neuroma on a histological instead of a clinical basis, when he distinguished between true neuroma (neuroma verum) and false neuroma (pseudo-neuroma). True neuromata arise in the nerve tissue, and nerve tissue enters into them as an essential constituent. False neuromata arise in the interstitial connective tissue of the nerves. True neuromata were further divided into "neuroma ganglio-cellulare," containing newly formed nerve cells; neuroma fibrillare amyelinicum, containing chiefly non-medullated nerves; and neuroma fibrillare myelinicum, consisting chiefly of medullated fibres. VIRCHOW stated that the nervous nature of many neuromata had been overlooked because the non-myelinated fibres had been mistaken for connective-tissue fibres, and because many of the fibres, both medullated and non-medullated, had disappeared through pressure and had been converted into connective-tissue-like elements. This classification was regarded as unsatisfactory, especially by those who considered nerve fibres as the processes of ganglion cells, and who thought, therefore, that there could be no fasciculated neuroma without ganglion cells, because nerve fibres are elements incapable of proliferating independently of the cell with which they have a direct connection.*

The present paper is founded on material derived from a patient who had suffered from spastic paraplegia, and in whose spinal cord, medulla oblongata, and pons, multiple fasciculated neuromata were found. In these nodules no ganglion cells could be traced, and nerve fibres, of the structure of peripheral nerves, were present in different stages of development. Inasmuch as the elements of a tumour differ from the tissues in which they take their origin, and the diversity frequently consists in a return to the embryonal phases of the elements themselves, it seemed necessary, in considering the case, to study the literature bearing upon the development of peripheral nerves in order to arrive at a true solution as to the genetic relation of the elements. Further, as in regeneration of nerves these embryonal phases of development are often reproduced, the literature on the regeneration of nerves after section was next investigated. And, finally, as patho-

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* For a further consideration of this subject, see under I. (3), p. 730.

logical histology has often shed light on normal tissue development, the literature bearing on tumours related to nerves has passed under review. Aided thus by collateral evidence adduced from the three sources of embryogenesis, regeneration, and tumour formation, an endeavour has been made in the following paper to give an interpretation of the histological picture which a study of numerous nodules revealed. The consideration of our work will thus be carried out under the following headings :—

I. The Genesis of Peripheral Nerves :
  (1) Embryogenesis : with a note on the genesis of fibres in the central nervous system.
  (2) Histogenesis in Regeneration after Section : with a note on regeneration of fibres in the central nervous system.
  (3) Histogenesis in Tumour Formation :—(*a*) ganglio-neuroma ; (*b*) neuroma ; (*c*) neuro-fibroma : with a note on genesis of fibres in tumours of the central nervous system :—(*a*) glioma and neuro-glioma ; (*b*) neuroma.

II. Histological Study of Multiple Neuromata of the Central Nervous System.

III. Interpretation of Observations and Conclusions.

I.—THE GENESIS OF PERIPHERAL NERVES.

GENERAL REMARKS ON THE STRUCTURE OF THE PERIPHERAL NERVOUS SYSTEM.*

Almost the whole of neuro-pathology rests on the neurone doctrine, which sees in the axis-cylinder a prolongation of a central cell. The problem of the relation of the nerve fibre to the nerve cell involves a consideration of facts relating to the continuity or independence of the central cell and its peripheral ramifications. The old reticular theory of **GUERLACH**, who saw in the nervous system an uninterrupted protoplasmic network, was destroyed by the findings of **GOLGI** in 1875 and **CAJAL** in 1891. These observers, by specific staining methods, showed the existence of free terminations of the processes of the ganglion cells and of the axis-cylinder ramifications—a mere relation of contiguity of elements being thus indicated. In 1891 **WALDEYER** put forward the view that the nervous system is constituted of an infinity of anatomical units which, embryologically, are independent of each other. He proposed the term "neurone" to designate the cellular unit formed each of a ganglion cell, its nerve fibre process, and protoplasmic processes with their terminal ramifications. The simplicity of this view is greatly in its favour, for the *ensemble* constitutes a cytological unit developed from a single central neuroblast.

The conception of the cell-chain theory is opposed to the neurone doctrine. The nerve fibre, according to this view, represents a chain of special cells (segmental neuroblasts) secondarily brought into relation to the central cell. In each element there has differentiated from its individual protoplasm a fatty substance (myelin) and a

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* Based on "Nerfs," by G. **DURANTE**, in *Manuel d'Histologie Pathologique*, Cornil et Ranvier (Paris), 1907.

fibrillated substance (axis-cylinder). DOGIEL, APATHY, and BETHE have shown that the fibrils within an axis-cylinder can be related not alone to one ganglion cell but to several, and also to the peri-cellular network, and that, reciprocally, the network of a ganglion cell can be in relation to the fibrils of several axis-cylinders.

DURANTE, to whose work we desire to acknowledge our indebtedness, sees in this functional grouping of central and peripheral elements an analogy to a gland lobule. He proposes the term "neurule" to designate this physiological, polycellular *ensemble* a true primitive nervous lobule. The ganglion cell, charged not to create but to receive, perhaps to modify or accumulate, then to expedite the nervous impulse, is compared to a gland acinus. The segmental neuroblasts, charged to transmit from place to place this impulse to its destination, are compared to the excretory canals. In the neurule the elements have a reciprocal dependence in functioning, but may be individually independent (*e.g.* in toxic or infectious conditions). This conception of a primitive nervous lobule allows of the nervous system being brought into line with other organs and simplifies the understanding of pathological lesions.

The neurone view teaches that the interannular segment of the peripheral nerve is composed of two distinct parts: one, the axis-cylinder, a prolongation of a central cell; the other, the rest of the segment, consisting of myelin sheath, sheath and nucleus of Schwann. The cell-chain theory teaches that the interannular segment represents a single complete cell element (*le neuroblaste segmentaire*), whose protoplasm has elaborated *in situ* the differentiated substances, axis-cylinder and myelin. The axis cylinder is regarded no longer as a gigantic cell prolongation of central origin, but simply as a bundle of fibrils differentiated in each segmental cell, the myelin also being a product of the differentiation of the cell substance. The condensed outer layer of the cell substance forms the sheath of Schwann; the original nucleus, pushed to the periphery, lies in the thin zone of the remaining undifferentiated protoplasm. In the normal functioning nerve tube the differentiated substances preponderate greatly over the non-differentiated substance, but the former have, properly speaking, no life of their own and disappear in pathological conditions. The non-differentiated substance, on the other hand, represents the living element of the cell, and on it devolves the rôle of nutrition, defence, and reproduction; in pathological conditions it takes up its vegetative rôle, and the cell returns to its embryonic condition.

The normal histology of the peripheral myelinated nerve fibre, according to this view, is the following: In each nerve tube we recognise (1) axis-cylinder, (2) myelin, and (3) the sheath of Schwann, a thin membrane limiting the nerve tube on the outside; between it and the myelin lies (4) the nucleus of Schwann in a thin zone of undifferentiated protoplasm—normally scarcely visible. The myelin is interrupted at regular intervals at the nodes of Ranvier, and the portion of the nerve fibre comprised between two constrictions constitutes the interannular segment. Each segment contains usually only one nucleus and has the import of a highly differentiated cell.

The axis-cylinder is formed of two substances, conducting fibrils (the primitive fibrils of Apathy and Bethe) and interfibrillar substance (the axoplasm of Schiefferdecker). Between axis-cylinder and myelin is a thin zone of undifferentiated protoplasm, which SCHIEFFERDECKER regards as a peri-axial lymph-space.

The myelin is composed of protoplasm of specific characters and is constituted by a network of neuro-keratin, whose meshes contain a phosphorised fat. The continuity of the myelin is broken by oblique notches arranged in an imbricated manner, the incisures of Lantermann, which stain by Strahüber's method similarly to the axoplasm of Schiefferdecker and probably represent a portion of the undifferentiated protoplasm. Some observers, however, look upon both incisures and network as artefacts, others regard them as a stage in the evolution of the nerve fibre—as they are much more evident in the early stages of development, and still others compare them to the canals met with in other cell protoplasms. According to SCHIEFFERDECKER and DURANTE, both incisures and network are present in the fibres of the central nervous system.

The sheath of Schwann is the thin condensed outer border of the protoplasm of the interannular segment. It is often difficult to distinguish it from the endoneurium which surrounds each individual nerve fibre. The nucleus of Schwann is the nucleus of the original cell lying in a thin zone of undifferentiated protoplasm in which, in early stages of development, fine granules, comparable to Nissl's granules in the nerve cell, can be recognised.

Remains of undifferentiated protoplasm are thus found in the interfibrillar substance of the axis-cylinder, in the periaxial zone, in the incisures of Lantermann, and in the perinuclear zone. It is the nucleus and this undifferentiated protoplasm which increase so greatly in pathological conditions.

A nerve trunk is surrounded by a connective-tissue envelope, the epineurium, and around each funiculus is the perineurium. The endoneurium passes between the nerve fibres of the funiculus, and its finest ramifications, lined by flattened endothelial cells, form round each nerve fibre a fibrillar network (the sheath of Henle).

DURANTE has also emphasised the complete analogy, according to this view, between muscle and nerve elements. The muscle fibre consists of (1) myoplasm—the fibrillar contractile substance,—which is a product of the internal differentiation of the sarcoplasm, (2) the remaining undifferentiated sarcoplasm, (3) the sarcolemma, the condensed outer layer of the non-differentiated sarcoplasm, with (4) its peripherally placed sarcolemma nucleus in a thin zone of undifferentiated protoplasm. Under normal conditions the differentiated substance greatly preponderates over non-differentiated, but in pathological conditions the differentiated substance degenerates and the nucleus and non-differentiated substance take on a vegetative rôle and return to their embryonic condition.

(1) EMBRYOGENESIS.

Regarding the initial stages of the development of the peripheral nerves, there is far from any agreement amongst embryologists. At present three different theories hold the field, to which DURANTE has given the names of central budding, cellular lengthening, and cell migration with the formation of cell-chains. Others have called them the outgrowth theory, the protoplasmic or intercellular bridge theory, and the cell-chain theory.

1. *Theory of Central Budding.*—BIDDER and KUPFER, in 1857, put forward the view that the peripheral nerves develop by the budding of a central cell, whose prolongation—a homogeneous axis-cylinder without nuclei—reaches to the periphery and is only secondarily surrounded by mesodermic elements to form its sheath. HIS, KÖLLIKER, and others have supported this view.

2. *Theory of Cellular Lengthening.*—In numerous animals we find at the limit of ectoderm and mesoderm certain elements possessing the characters of nervous and muscular elements. These neuro-muscular cells become constricted in the middle, the part remaining in the ectoderm becomes sensory, the part remaining deeper purely contractile, and the protoplasmic bridge uniting them differentiates into a rudimentary nerve. This view is associated with the name of HENSEN, and, with certain modifications, has been supported by SEDGWICK, HELD, and GRAHAM-KERR. Some of its supporters think that the cell connection is a secondary formation and is not due to an incomplete division, as HENSEN believes.

3. *Theory of Cell Migration and the Formation of Cell-Chains.*—BALFOUR, BEARD, DOHRN, HOFFMANN, and others have demonstrated during the first days of embryonal development, especially in Selachians, the migration of neuroblasts from the nerve centres into the mesoderm. At the level of the lateral line of the neural tube it is possible to distinguish three kinds of neuro-epithelial elements. These three, primarily identical, are derived from the invagination of the dorsal epithelium, and later differentiate into cells each of which elaborates a specific substance: (*a*) ganglion cell—the neuro-chromatin granules, (*b*) glia cells—the glia fibrils, (*c*) neuro-formative cells or peripheral neuroblasts—the conducting fibrils. These last alone give origin to nerve fibres by migrating and in their further proliferation arranging themselves into uninterrupted cell-chains. The evolution of the nerve fibre according to this view shows three phases: fusiform embryonic cells, the union of these into long nucleated plasmodial bands, and the subdivision of these into segmented elements—the interannular segment.

It is necessary to note, firstly, that the supporters of the first view do not deny the importance of the periphery in forming the path for the nerve fibres, and, secondly, that the supporters of the second view do not disclaim the influence of the ganglion cell upon the differentiation of the primary protoplasmic connections into nerve fibres.

Hensen (1864) thought that it was almost impossible to believe that the nerve filament found the muscle fibre without a guide. He supposed that the junction is effected early, whilst the two are in contiguity, and that the subsequent elongation of the nerve fibres is due to the change in the situation of the muscle. Primary tracts were thus laid down in the embryo which, later on, by some unknown process transformed themselves into nerve paths. **Ranvier** held that the axis-cylinder is uninterrupted from ganglion cell to periphery but that it passes through a series of cells. His position, therefore, approaches **Hensen's**, and **Gedoelst** agrees with **Ranvier's** point of view.

His (1879–1886) describes the first rudiments of the nerve under the form of chromogen material, without nuclei, passing out from the spinal cord. He showed that special differentiated cells in the medullary tube—primitive neuroblasts derived from the *Keimzellen* —send out processes which form the anterior root-bundles, which, when they reach the limit of the medullary tube, are surrounded by mesenchyme elements that later penetrate the bundles. According to **His**, the spinal ganglia are not outgrowths from the medullary tube, but have at first no attachment to it. **His** and **Kölliker** state that the connection is established by the ganglion cells sending out processes which reach the cord. Before the attachment takes place the ganglionic *anlage* of each side divides into two portions, the spinal ganglion and the sympathetic ganglion. **His** did not definitely establish the precise origin of the *Keimzellen.*

Kölliker (1884) showed that the *Keimzellen* of **His** are derived from the original epithelial layer of the primitive tube, that these *Keimzellen*, through mitotic division, give rise to ganglion cells and glia cells, and that the fibres arise as non-nucleated processes of the ganglion cells and are continued as nerve fibres without any participation of cells in their course. By means of frontal longitudinal sections of the cord with developing nerves **Kölliker** has shown the naked compact bundles of nerve fibres. He states that the capsule cells of the spinal ganglia are mesodermic elements, and that these grow into the ganglion and gradually surround each individual cell. It is to be noted that **Kölliker** in his last paper has admitted that the Schwann cells are ectodermic elements and also that the growing nerve fibre at its tip is surrounded by a capsule of Schwann cells.

Balfour (1888), in Elasmobranchs, has shown that cells, migrating from the spinal cord, become arranged into string-like groups with a wide attachment to the spinal cord. In these cells the nerve fibres develop. He remarks: "The cell structure of the embryonal nerve is a point on which I should have thought that a difference of opinion was impossible." **Balfour** was one of the first to note the structure which is generally called the neural crest. He also pointed out that the sympathetic ganglia arise as swellings on the posterior groups of the spinal nerves and soon become removed from the latter to form isolated masses.

Dohrn (1888–1892) has investigated the development of the nerves in Selachians, and states that the first rudiments of the nerve roots appear as protoplasmic columns uniting the spinal cord to the muscle segments before any differentiation of the cells of the early neural tube has taken place. In these protoplasmic columns were found numerous nuclei which DOHRN believed had migrated from the primitive medullary tube: the protoplasmic column later individualises into separate fusiform cells, which unite by their tapering extremities to form moniliform bands, and the protoplasm afterwards undergoes a differentiation into fibrils. The cells nearest the medullary tube fuse with the centrifugal process of the nerve cells in the cord. In this first stage there is no enveloping of the bundles by mesodermic cells; the latter penetrate later with the vessels and have no rôle in the formation of the nerve tube. V. VIJHE likewise considers that the nerve fibres are produced through a differentiation of the protoplasm of cell strands, which he, like DOHRN, saw extending from the cord to the muscle segments in Selachians. It is necessary to add that DOHRN, in continuing his work on Selachian embryos, saw appearances which he felt might be used for or against his previous views. The mesodermic elements lie so close to the emerging ganglion cell process that any distinction between the two is lost, especially as mesodermic cells predominate. DOHRN also thinks that an early penetration of mesodermic elements into the emerging zone of the motor fibres may have misled him.

BEARD (1892), in embryos of Raja batis, has shown that the transient ganglion cells are the first-formed ganglionic elements from the neuro-epithelium, and that their nerves are mere transformations of chains of nerve-forming cells, *i.e.* migrated ganglion cells. The motor end-plates are also derived from migrated ganglion cells. He also early noted the great resemblance between muscle fibre development and nerve fibre development. BEARD has also shown that the lateral nerve in Raja is formed by a chain of nerve-forming cells arisen from the neuro-epithelium at the level of the lateral line, and that axis-cylinder and myelin are differentiated in these cells. He thinks that the histogenesis of motor spinal nerves simply repeats the history of such a nerve as the lateralis if the region which will become the anterior horn of the spinal cord be looked upon as the parent neuro-epithelium. The chain of cells leaves the cord in the same manner, and the terminal cells form the motor end-plates and must therefore also be looked upon as ganglionic in character. The attachment of the spinal ganglia to the cord takes place by a chain of undifferentiated ganglion cells from the spinal ganglionic *anlage* developing into nerve-forming cells. These short cell-chains reach upwards from the ganglion and form a continuous chain of several rows of cells along the route of the future posterior columns, and BEARD's observations lead him to conclude that whenever a column or tract of fibres arises in the nervous system its development, as in this case, is initiated by the laying down of a chain of nerve-forming cells.

APATHY (1892–1907) believes that there is a primary differentiation of neuroblasts into central and peripheral groups; the latter migrate and develop into the nerve fibres, and the continuity between centre and periphery takes place later. Each individual cell, central and peripheral, consists, according to APATHY, of protoplasm and an intercellular differentiation of the cell protoplasm—the transmitting substance—fine fibrils.

Sedgwick (1895) has strenuously upheld the view that the mesenchyme is not a tissue of branched cells but a reticulum with nuclei at the nodes. He believes that the neural crest gives rise to nuclei, which spread out in the mesoblast reticulum, and that the nerves are developments of the reticulum, *i.e.* that the nerves are, as it were, a gathering up into bundles of the reticular strands. The development of a nerve, therefore, arises from the differentiation of a substance which was already in position, and this differentiation takes place from centre to periphery. The nerve roots are simply special enlargements of the connecting strands of the original reticulum joining the embryonic medullary wall to the general mesoblast reticulum. Sedgwick's position approaches, therefore, very near to that of Hensen.

Schaper (1897), together with Kölliker, was one of the first to prove the precise origin of the *Keimzellen* from the original epithelial layer of the primitive medullary tube. He further showed that these *Keimzellen*, by mitosis, give rise to nerve cells (neuroblasts) and indifferent cells, and that the latter may differentiate in very various directions, *e.g.* into the cells of the granular layer of the cerebellum. Glia cells and peripheral neuroblasts may also arise from a further differentiation of the indifferent daughter cells of the primary cell groups. Schaper thought that in certain primitive conditions, *e.g.* in amphioxus, the indifferent cells might possibly differentiate into nerve cells. Such indifferent cells may remain in an undifferentiated condition and later on might possibly play a rôle in regenerative processes in the central nervous system. This term "indifferent cells" has been largely used by later writers on the embryogenesis of nerves.

Kolster (1899), Gurwitsch (1900), Bardeen (1902) all agree that the first stage of the nerve bundle is an entirely non-nucleated one. Kolster chose as objects of study the embryos of Salmo, because here the first phases of development pass slowly. In Salmo the first *anlage* of the peripheral nerves is a narrow bundle of very fine fibrils proceeding from the spinal cord: the bundle shows no nucleus but pushes before it the layers of connective tissue, so that a single sheath covers the bundle. Later, the connective-tissue cells proliferate and penetrate the bundle. Kolster stated that the first traces of myelin appear before any nuclei are present in the bundle, and that the myelin development progresses peripheralwards. The first myelin appearance within the central nervous system is likewise before the differentiation of the glia cells, when there is present only a framework of ependymal cells and processes.

Schultze (1904–1906) takes up a quite independent position. A pronounced supporter of the cell-chain constitution of the peripheral nerves, he holds also a modification of the protoplasmic bridge theory, for he denies the migration from the medullary tube. Schultze's very extensive studies have covered the development of peripheral nerves in Amphibia, fowl, and mammal. His observations in a sheep embryo of 8 mm. show that the early motor roots consist of bundles of primitive fibrils converging towards the myotome and that these are traversed by innumerable elongated nuclei. In later embryos only the distal end of the nerve shows many nuclei, and this end may split up into a brush of fibrils amongst which lie typical elongated nuclei. The picture is that of a syncytium, for cell limits cannot be recognised. Regarding the sensory nerves, SCHULTZE states that below the corium in amphibian larvæ he finds a network of very delicate bipolar and multipolar cells with long processes continuous with nuclear rich nerve fibres. Here there is no fusion of individual cells into chains but a continuous sensory syncytium spreading over the whole surface of the body by the continued preservation of intercellular connections, following mitotic division of the nucleus. SCHULTZE regards the nodal points as peripheral neuroblasts, and as he finds them beneath the skin in all mammals, he concludes that the whole nervous system in its specific elements is constructed out of millions of central and peripheral neuroblasts. This becomes clearer the further back we go in phylogeny, for the diffuse nervous system of the vertebrates and invertebrates, as far as it is known, consists of networks of cells and processes. This continuous integumental network of nerve-forming cells proves the analogy of the nervous system in all animals and gives the key to the understanding of the morphogeny of the nervous system from the Coelemterates to man. SCHULTZE's very careful and exhaustive studies have convinced him that the present-day neurone teaching rests on no indisputable observation; that a right understanding of the nervous system in its ontogenetic and phylogenetic relations can be gained only on the ground of its cellular or syncytial structure from elements, central and peripheral, which are termed neuroblasts; that these elements are originally of equal significance and become partly central and peripheral ganglia or nerve-cells, and partly elements which serve for the syncytial structure of the peripheral fibres, *i.e.* peripheral nerve fibre cells. The chief point is that neuro-protoplasm does not grow out, but represents *ab ovo* a "continuum" formed by a few cells and their intercellular bridges. Whether the neuro-fibrils or the interfibrillar substance is the conducting part SCHULTZE does not decide. In his latest paper he states that the impetus to the formation of the neuro-fibrils may proceed from the central organs as from a dominating centre—proceeding peripheralwards into the preformed syncytial channel.

KOHN (1905).—KOHN's researches into the development of the dorsal nerve root in mammals and the development of the sympathetic nervous system mark a distinct advance in our knowledge of the structure of the peripheral nervous system. After his work appeared even KÖLLIKER and LENHOSSEK admitted the ectodermal origin of the sheath of Schwann cells. KOHN looks upon the problem of the origin of the sheath of Schwann cells as the crux of the question. If these were really acquired mesodermic elements, it would be impossible to defend the view that they have a share in the formation of the peripheral nerve fibre, but if they were of ectodermic origin the chief bulwark of the theory of the unicellular origin of the peripheral nerve fibre fell to the ground. It need hardly be said that the question is by no means settled, and distrust of the ectodermic origin, and specially of the nervous nature, of the Schwann cells is deeply rooted; and even those who admit their ectodermic origin, *e.g.* Kölliker, Lenhossek, and Harrison, are still pronounced adherents of the outgrowth theory, and say that the ectodermic or mesodermic origin of the Schwann cells has nothing to do with the question whether the axis-cylinder is an outgrowth or not. Kohn, however, was not blind to the distinction between the problems of the origin of the sheath of Schwann cells and the development of the axis-cylinder, but he felt that a clear proof of the ectodermic origin of the cells in question would be a very strong argument in favour of their participation in the building up of the nerve fibre.

Kohn, studying the development of the dorsal nerve root in the rabbit embryo, found that the spinal ganglionic *anlage* is from the beginning in direct continuity with the medullary tube. At first this is only a protoplasmic connection which later develops into a cellular stem composed of the very same cells which form the ganglionic *anlage.* A further stage is the differentiation of the cells in the ganglion into more and more typical ganglion cells, and the cells of the stem into elongated tubes with oval nuclei which, as the nerve root lengthens, become more and more the typical cells of the sheath of Schwann with a differentiation of their protoplasmic substance into nerve fibres. Later on, and at first sporadically, connective tissue penetrates the root. Therefore, from the cells of the embryonic *anlage* arise two types of cells, ganglion cells and nerve fibre cells. The Schwann cells of the posterior nerve roots, therefore, have not only an ectodermic origin but are of true nervous nature—nerve-forming cells. To give the name *Scheidenzellen* to such elements, Kohn considers a serious mistake, which has contributed greatly to their want of recognition as nerve elements. He suggests the name "neurocytes" for the early undifferentiated cells.

Kohn similarly traces the development of the sympathetic ganglia and its nerves to the migration of embryonal undifferentiated neurocyctes to form the sympathetic ganglionic *anlage.* In the *anlage* these cells can be recognised to differentiate into sympathetic ganglion cells and nerve fibre cells and the latter to form nerve tubes. Before the characteristic ganglion cells have become differentiated, *i.e.* while they are a-polar, the early nerve tubes appear as elongated band-like syncytia with numerous nuclei. The presence of ganglion cells in relation to cerebro-spinal nerves can thus be traced to the migration of embryonal neurocytes. It is thus seen that Kohn contests the view of the origin of the sympathetic ganglia directly from preformed ganglion cells cut off from the distal pole of the spinal ganglia. In the rabbit embryo, and also in Selachians, he has traced embryonal neurocytes bending ventralwards from the path of the mixed nerve. By their proliferation we get cell accumulations which form the *anlage* of the sympathetic cord, and by their further differentiation we get the ganglion cells and the nerve fibres of the sympathetic. The significance of this view in relation to the formation of ganglio-neuroma will be discussed later. Froriep (1905) admits the ectodermal origin of the sheath of Schwann cells, but considers the axis-cylinders to be outgrowths of a central cell. In Selachian embryos he has been able to trace simultaneously the ganglion cell processes passing out as naked fibres, which then became covered with cells which have also emigrated from the wall of the medullary tube.

Lenhossek (1906) considers the question of the origin of the sheath of Schwann cells to be not immediately connected with that of the mode of formation of the axis-cylinder. Though a convinced centralist, he derives the Schwann cells, which he terms lemnoblasts, from the spinal ganglionic *anlage.* In the fowl embryo and in a very early human embryo he has shown that the cells of the spinal ganglionic *anlage* differentiate into ganglion cells and cells which pass along the nerve root as sheath of Schwann cells, but that these latter do not form the fibres of the sensory root. The lemnoblasts thus correspond to the glia cells of the central nervous system. Lenhossek's illustration of the glosso-pharyngeal nerve with its ganglion, corresponding to a posterior root ganglion, shows that through the whole extent from the ganglion to the medulla the bundle of fibres is entirely non-nucleated but is ensheathed by a single layer of cells, whose nuclei are quite distinct from the surrounding mesenchyme elements. Later, cells, proliferated and migrated from the side of the ganglionic *anlage*, penetrate both motor and sensory roots, and future lemnoblasts are formed by an independent increase of those already penetrated. He believes that the spinal ganglionic *anlage* provides the sheath of Schwann cells for the whole peripheral nervous system including the sympathetic. Lenhossek says that the supporters of the cell-chain theory cannot get over two facts: the one, the absolutely non-nucleated condition of the white substance of the central nervous system; the other, the almost non-nucleated condition of the peripheral nerves in certain stages of their development. Lenhossek admits that it is conceivable that under pathological conditions the sheath of Schwann cells, in virtue of their origin from the neural crest, may become nerve builders.

Bethe (1906), whose work on the regeneration of nerves we shall refer to later, endeavours to answer Lenhossek in the following terms: The first *anlage* of the peripheral nerve consists only of a cell syncytium with nuclei arranged as a border; later, the nuclei of this syncytium proliferate and penetrate the protoplasm, giving rise to cells arranged in rows, and in the protoplasm of these cells the first axis-cylinders form. Bethe argues that the developing nerve is just as little non-nucleated as the cylindrical epithelium of many gland tubes, and that Lenhossek and others have used methods which revealed the axis-cylinders but not the development of them within the cells.

Held (1906).—No review of the work on the development of nerves can afford to ignore Held's important memoir and later papers founded on an exhaustive investigation of the embryos of trout, shark, frog, rabbit, etc. It is almost impossible to give an abstract of his views. They are so far a modification of Hensen's that they are referred to as the Hensen-Held hypothesis, which may be stated thus:—(1) the cells related to an embryonic nerve path are (*a*) neuroblasts of His, which form the neuro-fibrils and drive them forward, (*b*) conducting cells (*Leitzellen*), in the interior of which the neuro-fibrils pass. (2) The neuro-fibrils, which arise in the fibrillogenous zone of the neuroblasts, are continued into the interior of a system of pre-existing protoplasmic bridges, represented in the central nervous system by the network of the spongioblasts and in the mesoderm by the anastomosing expansions (plasmodesmata) of star-shaped conducting cells (*Leitzellen*). (3) These *Leitzellen*, which may possibly be of ectodermic origin and have the function of nourishing and protecting the axons, would become ultimately the cells of the sheath of Schwann: yet they are not capable of producing the neuro-fibrils. (4) In the earliest stage a nerve is non-nucleated; the primitive neuro-fibrils are enveloped in a granular neuroplasm which forms a broad and entirely non-nucleated zone. (5) The process of neuro-fibrillation is an intraplasmatic progression from the neurogenetic centre. (6) There scarcely exists any neurone independence, for the neuro-fibrils of one neuroblast penetrate into the interior of other neuroblasts, producing a diffuse network.

The HENSEN-HELD hypothesis, therefore, is opposed to the unicellular genesis of the nerve fibre and the neurone teaching of the genetic unity of the ganglion cell and its ramifications, but it agrees with HIS in looking on the neuroblasts as the chief participators in the formation of the nerve-path, *i.e.* from them proceeds the genetic impulse for the formation of nerve tissue. If we have read HELD aright, he does not seem to have decided whether the neuro-fibrils formed in the initial nerve-path by the neuroblast go on being formed progressively by their influence on the plasma of the intercellular bridges, or whether the neuro-fibrils grow out within the plasma of the intercellular bridges by the driving forward action of the neuroblast.

CAJAL (1907).—The classical illustrations in all modern text-books of the development of the embryonic nerve fibre are taken from CAJAL's works, and CAJAL's views are too well known to need any detailed statement. HIS has had no more loyal and convincing supporter than CAJAL, whose beautiful silver preparations have conclusively proved to so many that the developing nerve fibre is the result of the continuous outgrowth of the principal prolongation of the neuroblast of HIS. CAJAL has shown that this prolongation has a free thickened end (*cône de croissance*) which glides between the cell interstices. This intercellular progression, in contrast to HELD's intraplasmatic progression, takes place both in the interior of the embryonic nerve tube and in the depths of the mesoderm. The primary axon and the terminal cone have a neuro-fibrillar structure with an unstained neuroplasm and a fine limiting membrane. He has further shown that the *cônes de croissance* are entirely naked in their passage across the perimedullary space. The first axons emigrating into the mesoderm are isolated, the latter are in intimate relation to one another. The adventitial cells (*Leitzellen* of HELD, lemnoblasts of LENHOSSEK) are always between the bundles. To explain why the nerve fibres traverse the mesoderm and also their relation to the myotome and epithelium, CAJAL finds it necessary to suppose the existence of specific chemiotactic substances, secreted by the myotome and the epithelium, which excite the amœboidism of the cone of growth. As early as 1892 CAJAL had compared the *cônes de croissance* with their terminal filaments to nerve pseudopodia which have amœboid movement and a certain impulsive force.

CAJAL explains HELD's pictures of the penetration of the terminal cone into the interior of cells of the cord and mesoderm (plasmodesmata) as due to the shrinkage of the tissue and the agglutination of the embryonic axons to the tissue elements. He thinks that HELD's view simply places the question of the orientation of the nerve paths and the peripheral connections on new ground. "Au point de vue de cette théorie, la question se réduit à ces termes : en vertu de quelles conditions physico-chemiques se sont produits, dans certains endroits de l'embryon et avant l'apparition des axones, des chemins directs et parfaitement congruents entre tous les organes qui doivent ultérieurement contracter des connexions anatomiques et fonctionelles ?"

HARRISON (1905–1910) thinks that the attempt to answer the question of the development of nerves in normal embryos has been largely a matter of individual interpretation. He has therefore carried out a series of valuable investigations, along the line of experimental embryology, to eliminate all possible sources of error in coming to a conclusion as to the relation of the nerve fibres to the nerve cells. By his final work he claims to have conclusively established, on the basis of direct observation, the HIS teaching of the outgrowth of the nerve fibre from the central neuroblast.

HARRISON's earlier embryological researches had led him to the conclusion that the sheath of Schwann cells arise from the neural crest, and, taking this as the starting-point, he tried first to answer the question of the source of the elements of the nerve fibres. In amphibian larvæ, before any differentiation of nerve cells and fibres has occurred, he removed the source of the sheath of Schwann cells, *i.e.* the ganglion crest, and found that the motor nerves developed as naked fibres without sheath cells. HARRISON then removed the source of the motor nuclei—*i.e.* the ventral half of the cord, leaving the dorsal portion of the cord and the ganglion crest—in order to answer the question : Can sheath cells without ganglion cells form the nerve fibres ? The result was that sensory fibres and sheath cells appeared but no purely motor rami. Therefore, sheath cells by themselves cannot form fibres and ganglion cells by themselves can form naked axis-cylinders.

HARRISON next set himself to answer the question : What are the factors that influence the laying down of the nerve paths during embryonal development ? Is the nerve fibre a product of the ganglion cell, or formed *in situ* in the peripheral path ? He therefore first removed portions of the nerve centres and found that no peripheral nerve developed in relation to the absent ganglion cells. The second step consisted in the transplantation of undifferentiated portions of the nerve centres to abnormal positions of the embryo body, with the result that they gave rise to nerve fibres which followed paths in which normally no nerves were present. He concluded, therefore, that the nerve fibre is a product of the ganglion cell and not a mere activation of indifferent extra-ganglionic substance. In order to confirm this observation HARRISON carried out a further series of experiments. BRAUS and BIANCHI had previously transplanted buds of larval extremities, in which there were no nerves at the time of transplantation, and had found nerves developed autochthonously with no connection with the nerves of the host. Similar experiments carried out by HARRISON and LEWIS led them to the conclusion that nerves are not formed *in situ* in the transplanted limbs but grow into them from the nerves of the host, and that there is no evidence that any specifically formed or localised structures, essential to the formation of nerve fibres, are present.

HARRISON's final step was to answer the question: Is the nerve fibre entirely the product of the nerve centre? He recognised that in all his former experiments the nerve fibre had developed in surroundings composed of living organised tissue which might possibly contribute organised material to the nerve elements. He initiated, therefore, what he describes as a really crucial experiment. This consisted in the placing of pieces of embryonic tissue, taken before any histological differentiation has taken place, in hanging drops of clotted frog's lymph, and keeping the sealed preparations under observation for a number of days. The cells when taken were rounded, without any sign of differentiation, and were found soon to manifest amœboid movement—resulting in the formation of long threads of hyaline protoplasm with free filaments which continually change their form and are exactly similar to the pictures by CAJAL in normal embryos. It is to be noted that cilia of neighbouring epidermic cells remained active and embryonic mesoblast cells became transformed into striated muscle fibres, so that there was no doubt that even under artificial conditions life and growth and differentiation were continuing. The development of the nerve fibre is thus brought about by one of the primary properties of living protoplasm common to all cells—amœboid movement, and HARRISON points out that he had substituted for the supposedly-essential protoplasmic bridges only unorganised fibrin threads which could afford merely a mechanical support for the growing nerves. The elementary factors in nerve development are therefore two—the one, protoplasmic movement, the other, the differentiation of this protoplasm by the formation within it of neuro-fibrils.

HELD and HARRISON differ as to the source of the protoplasm within which the neuro-fibrils develop. HELD believes that it is formed of cells scattered all through the embryonic body: HARRISON that it flows out from the central cells and thereby establishes the path in which the necessary fibrils are formed. It is this laying down of the path by means of a form of protoplasmic movement, rather than the process of differentiation into neuro-fibrils, that constitutes the problem in the development of nerves.

CARPENTER and MAIN (1907), in pig embryos, have traced cells which migrate from the medullary tube, pass into the ventral nerve roots, and form the sheath cells. KUNTZ (1909), also in pig embryos, has made similar observations in relation to both ventral and dorsal roots. He states further that these migrated cells pass along the spinal nerves and ventral rami to form the *anlage* of the sympathetic ganglia. All these writers refer to the cells as the "indifferent" cells of SCHAPER.

Graham-Kerr (1910) has emphasised the necessity of selecting suitable material, so that one does not become lost amongst the details of observation. He chose the Lepidosiren on account of the coarseness of its histological structure and the size of the cell elements. He has come to the following conclusions: that the motor nerve trunk is already present as a protoplasmic bridge, placing spinal cord and myotome in organic continuity, at a period so early that these structures are in immediate contact, thus placing His's outgrowth theory out of account; that this protoplasmic nerve trunk, at first merely granular, gradually assumes a fibrillated structure; that the at-first naked and non-nucleated nerve trunk acquires a sheath, the heavily yoked material of whose protoplasm demonstrates it to be of mesenchyme origin; that if the conception of units is to be used as a working hypothesis, the unit should be the complex consisting of nerve cell, nerve fibre, and muscle cell—a myo-neurone; and that all the possibilities seem to point to the nervous system having become evolved out of a sub-epithelial plexus of the type which still persists in Cœlenterates. The facts of development in Lepidosiren thus give strong support to the protoplasmic bridge theory.

Graham-Kerr looks upon the differentiation of the neuro-fibrils from the physiological standpoint and regards their specialisation in structure to be correlated to the repeated passage of impulses along them. Each particular impulse as it is repeated between a central cell and its end cell beats out, as it were, its own special pathway. This we term a neuro-fibril. Referring to the recent work of Harrison, he asks if these experiments have really the finality which is claimed for them, and suggests the question: Has Harrison excluded the possibility that the excised fragments of the embryonic spinal cord included the nerve trunk rudiments? He thinks that they simply prove that the young nerve grows in length—a self-evident fact quite independent of any particular theory.

Note on the Genesis of Nerve Fibres in the Central Nervous System.

Most of the observations upon the origin, development, and structure of nerve fibres have been made upon the peripheral nerves. The fibres of the central nervous system are described as having no cells either as sheath cells or in any way related to their course. Up till recently the theory that each nerve cell and fibre in the central nervous system was developed from a single unit was generally accepted. Many writers have indeed asserted that it is inconceivable that the fibres of the central nervous system can have any cells in relation to them except the central cell of origin. This has been one of the strongest arguments of the centralists, that the peripheral nerve fibre also had arisen solely from a central cell. Fragnito, Capobiancho, and others, however, have recently brought forward evidence in favour of the multicellular origin both of the nerve cell and central nerve fibre.

Capobiancho (1904), in kitten embryos and in the human fœtus at the third month, has described successive stages in the development of nerve cells from the neuroblasts in the cord and spinal ganglion. The small groups of neuroblasts become approximated, their protoplasm fuses into a single mass, and certain of the nuclei undergo regressive changes and finally disappear. Not only the body of the nerve cell but also its processes are formed by this fusion of neuroblasts.

La Pegna (1904) has used chiefly Cajal's and Donaggio's staining methods for neuro-fibrils. He supports the view of the independent origin of nerve fibres and nerve cells. His conclusions are as follows:—The nerve cell does not take part in the formation of the nerve fibre; the nerve fibre in the first stage of its development has no connection with the nerve cell; the peripheral and central nerve fibres are developed from cell-chains; the protoplasmic processes, like the axis-cylinder processes, are also derived from cell-chains; and the neuro-fibrils of the nerve cell are a late product of differentiation—in the chick they do not develop before the tenth day of incubation.

Fragnito (1905), in the chick embryo, has given a description of the genesis of the central nerve fibre from chains of nucleated cells. By the use of Donaggio's intracellular fibril method he was able to follow the disappearance of the nuclei and the formation of the neuro-fibrils. The fibre resembles a ribbon or thread with fusiform swellings at regular intervals. It is inferred that each swelling of the thread represents a cell, whose nucleus is quite evident and whose protoplasm is elongated into two filaments which unite with the filaments of two contiguous cells. The nucleus tends gradually to disappear, and probably its substance is diffused into the protoplasm and transformed into the axis-cylinder. In the cells of the same thread the nuclei are seen in various phases of transformation, and as they fade the fusiform swellings disappear and the margins of the thread tend to become parallel. Fragnito agrees with La Pegna that the axis-cylinder is never seen in connection with the nerve cell before the tenth day. This differs from the observation of Cajal, who states that by the fifth day all the axis-cylinders have reached their destination and can be traced emerging from the cord by the anterior roots as well-formed tubes of white matter.

Cantelli (1907) has examined the structure of the neuro-fibroblasts in the central nervous system of the chick by means of Donaggio's neuro-fibril method and subsequent staining with neutral red. There were found in the spinal cord long bands with uniform spindle-shaped swellings, in the middle point of which were dark granules: these granules stained intensely with the nuclear stain and were thus taken to correspond to nuclear substance.

Hardesty (1905), studying the developing spinal cord of the pig, noted the presence of half-moon or signet-ring-shaped cells encircling the nerve fibres. In early stages the axis-cylinders run as fine fibrils in a syncytium in which nuclei lie. During the period at which the process of myelination is at its height, these are distinct cells with considerable protoplasm lying in relation to the developing nerve fibre. The protoplasm of the cells at first often completely encircles the growing myelin sheath, but with its further growth the protoplasm of the cells is used up. It is suggested that the signet-ring cells represent elements derived from the syncytium and that the protoplasm represents endoplasm which is gradually transformed into exoplasm, which in its turn is transformed into the lamellated reticulum of the central nerve fibre by a process similar to that described in the development of connective tissue fibres. The signet-ring cells, therefore, diminish in number and size with the age of the embryo, and later can scarcely be distinguished, even if present, from flattened neuroglia cells.

BARILE (1910) records the investigations of PALUDINO in trygon violaceus, in which he found nuclei in relation to the axis-cylinder within the spinal cord, and also the examination of a teratoma from the neck in which NIOSI found a nodule of the structure of the central nervous system, with the axis-cylinders developing in relation to a chain of cells.

(2) THE HISTOGENESIS OF NERVE FIBRES IN REGENERATION.

It has long been recognised that the manner of regeneration of any tissue follows very closely its first development, *i.e.* that the first stage of each newly produced anatomical element is an embryonal one, and this undergoes successive transformations. We would thus expect to meet with the same diversity of views regarding the origin of the new-formed fibres in regeneration of a nerve after section as we found in regard to its embryogenesis. The possibility of connective tissue cells, in virtue of some mysterious adaptation, taking over the rôle of embryonic nerve cells and forming new nerve fibres, is too improbable to be discussed. We therefore pass at once to state the two main opposing views :—

(1) The classical teaching is that a budding of the axis-cylinder takes place from the last preserved segment of the central end. This corresponds to the central budding or outgrowth theory of development, and has also been named the monogenist, or unicellular, or centralist view.

(2) The newer teaching is that regeneration takes place by means of the differentiation of new-born cells which have arisen from the proliferation of the sheath of Schwann nuclei. This corresponds to the cell-chain theory of development, and has also been named the autogenist, or multicellular, or peripherist view.

We may here note that though complete agreement has not by any means yet been reached, a certain accord, as we shall see later, has been attained. Many centralists have yielded the ectodermic origin of the sheath of Schwann cells, thus eliminating the most serious objection that mesodermic elements shared in the regeneration of nerve fibres; they have also allowed the constant presence of cell-chains in regeneration, denying only the actual genesis of the nerve fibres from them. The peripherists, on the other hand, whose common standpoint is the conception of the peripheral genesis of the nerve fibre, have nearly all conceded that the ultimate differentiation comes only after the establishment of a connection with the centre.

Waller, in 1851, communicated to the *Academie de Science* the first facts regarding the secondary degeneration of peripheral nerves after section, and the term "Wallerian degeneration" is a permanent record of this historical fact. He also enunciated the law of the dependence of the nerves for their nutrition on trophic centres. Waller believed that the new nerve fibres in regeneration are formed as outgrowths from the central end and that regeneration could occur only when the peripheral end was joined to the central end. Phillipeaux and Vulpian, in 1863, showed that a distal end separated from the centre could regenerate, and also that a portion of a nerve transplanted under the skin of another region contained nerve fibres after six months. They believed that the axis-cylinder was not destroyed during degeneration and that regeneration consisted simply in a re-accumulation of the myelin. Neumann (1868) maintained that during degeneration the axis-cylinder and the myelin of the nerve fibre were only modified chemically and that they fused into a specific nucleated protoplasmic substance which retained in some form the actual nervous elements.

Ranvier (1871) maintained, on the contrary, that the actual nervous elements disappeared *in toto*. He definitely placed the theory of budding from the central end on a firm basis by showing that the new fibrils are formed by a longitudinal division of the axis-cylinder of the preserved central end. These newly formed fibres reach the distal segment and pass into the old preserved sheaths of Schwann. For nearly twenty years this view was generally accepted, and Vulpian himself, admitting that possibly branches of nerves in the vicinity took part in the regeneration in the distal end, withdrew from his former position.

In 1891 Von Büngner's fundamental memoir marked a new phase, for he demonstrated the practical significance of his findings. Clinical observation, which had stimulated interest in this line of research, seemed to indicate that the time required for such a process as budding was not in accordance with clinical experience. This was specially the case in secondary suture, where the rapid return of sensation and the re-establishment of conductivity seemed to indicate the re-union of the nerve. Von Büngner, using aniline dyes, asserted that the nerve fibre did not degenerate but was simply transformed into a nucleated protoplasmic band (*Axialbandfasern*), or into individualised fusiform cells which arose from the mitotic division of the nucleus of the sheath of Schwann. These spindle-shaped cells unite end to end as in embryonal development and again take the form of protoplasmic bands. The proliferated and enlarged nuclei group themselves in the direction of the fibres, and the homogeneous protoplasm lying between them soon assumes a fibrillar striation—the commencing axis-cylinder formation. Von Büngner has therefore modified and completed Neumann's view, and his work in turn has been completed by Durante, who has shown that the so-called Wallerian degeneration is really the formation of these *Axialbandfasern* of Von Büngner. To this process Durante has given the name of "cellular regression," as it is due to the abnormal activity of the nucleus and the undifferentiated protoplasm of the interannular segment, which, when the differentiated substances have disappeared, take on a vegetative activity. The protoplasmic or plasmodial bands have thus arisen from the mitotic division of the sheath of Schwann nucleus and the augmentation of the protoplasm, while if each nucleus surrounds itself with protoplasm and individualises, instead of a plasmodial nucleated band we get the formation of fusiform cells.

During the ten years following VON BÜNGNER's fundamental work, a very marked tendency set in towards this new teaching, and so much did the peripherist view seem destined to replace the outgrowth theory, that many writers did not hesitate to speak of the death of the old view and by implication the death of the neurone doctrine. The writers whose names must be mentioned during this decade are, with one or two exceptions, peripherists.

STROEBE (1893) strongly opposed VON BÜNGNER's views. By a new axis-cylinder staining method he showed that the peripheral end and the intervening scar-tissue were neurotised by young fibres which passed from the old axis-cylinders. His contribution to this subject, in addition to the introduction of the aniline blue and safranine staining method, was his insistence on the completely passive rôle played by the peripheral end as a conducting path or scaffolding for the young fibres.

GALEOTTI and LEVI (1895) studied the regeneration of nerves in the newly-formed tails of salamander. The tails were cut off in sunny weather, and new tails grew in about fourteen days. These cold-blooded animals were chosen because it was found that in mammals the inflammatory reaction was so intense as to make it impossible to distinguish between the young neuroblasts and the cells which had arisen from the proliferation of Henle's sheath, the epi- and peri-neurium, or immigrated leucocytes. GALEOTTI and LEVI found among the newly-formed muscle fibres more or less long chains of slender elongated cells, the chains usually ending in a cluster of radiating similar cells. The cells of the end cluster in their turn proliferate, elongate, and gradually become arranged in a chain amongst new muscle fibres. In the cytoplasm of each cell, by means of the gold chloride method, a granular filament could be recognised, and as this increased in amount the nucleus was pushed more and more to one side. This differentiation could often be observed in different stages in the same chain of cells. At first every element retains its individuality, then the processes of each cell unite in an imbricating manner and fuse to form nucleated bands which show a bulging opposite the nucleus. The granular filaments of each original cell unite when the cell borders disappear. The outer layer becomes condensed and forms a definite membrane to the band—the later sheath of Schwann. Specific myelin sheath stains were not used, but its development could be followed by means of aniline dyes which showed the double contour and constrictions of the fibres.

The authors were convinced that these fusiform elements, in which the granular filaments form, arise from the proliferation of the nucleus of the sheath of Schwann. In the salamander the connective tissue cells could be easily distinguished from these cells, and there were few connective tissue elements and immigrating leucocytes between the developing muscle fibres. It is important also to note that the regeneration of the nerve fibres was later than that of the muscle fibres, so that the neuroblasts could not be confounded with the developing myoblasts. The authors finally refer to the remarkable analogy between nerve fibre and muscle fibre regeneration: an analogy to be emphasised by DURANTE and LUSTIG. GALEOTTI and LEVI later traced the development of muscle fibres and nerve fibres in the tail of newly hatched lizards, and found that regeneration had proceeded along lines exactly comparable to the stages in the first development.

KENNEDY (1897–1904), in the microscopic examination of portions of nerves removed previous to secondary suture, found in both central and peripheral ends irregularly arranged groups of nerve fibres. The fibres cut longitudinally showed a delicate axis-cylinder in the centre, a granular deposit of myelin around it, a homogeneous protoplasm zone around the myelin, and oval nuclei arranged at intervals. The transversely cut fibres appeared as clearly defined circles, each containing an axis-cylinder in the centre and many with an attached nucleus. The arrangement of the bundles was very irregular, and there were found transversely cut bundles with longitudinal and oblique fibres coursing around them. The enormous number of spindle-shaped nuclei amongst the nerve fibres indicated that these elements had arisen by proliferation from the nucleus of the sheath of Schwann, and KENNEDY believes that these new nerve fibres in the peripheral stump of a still-severed nerve—showing axis-cylinder and commencing myelination—could have arisen only from the nucleus and protoplasm of the interannular segment, which must therefore be regarded as a neuroblast. Further steps to complete differentiation of the nerve fibre probably depend on a restoration of continuity. A fibre may remain in this incompletely differentiated stage for a very long time, and this resting-stage, as it were, affords an explanation of the very rapid return of sensation after secondary suture, for the nerve path is practically ready to transmit impulses and needs little further differentiation.

BALLANCE and STEWART (1901) have made a very thorough histological investigation of the process of regeneration in nerves after section, both with and without suturing of the proximal to the distal segment, and also of the changes which occur in nerve grafts. The experiments were carried out on monkeys, dogs, and cats, and the histological methods used were very complete:—Weigert's medullated sheath stain, the Golgi and Stroebe methods for axis-cylinders, and Van Gieson's method for cellular and protoplasmic structures. The neurilemma cells commenced to proliferate on the second day after section; the resulting cells preserved the longitudinal direction of the parent cell, and from their opposite poles sent out fine protoplasmic processes. These proliferated neurilemma cells play only a transient rôle in the absorption of the fatty débris of the degenerated myelin, and the chief part in phagocytosis is carried out by immigrated cells from connective tissue and blood.

The proliferated neurilemma cells in both central and distal ends take on an active neuroblastic function. They secrete short lengths of axis-cylinder which increase in length and diameter, and the imbricating ends fuse together to form a continuous axis-cylinder. Ballance and Stewart were able to assure themselves that the neuroblasts, demonstrated by the Golgi method shooting out beaded axis-cylinders from opposite poles, were identical with the proliferated neurilemma cells, which, with Stroebe's method, showed the earliest stage of a new axis-cylinder as a deposition along one side of the cell. The Stroebe method showed axis-cylinder intensely blue against a pink background. The new myelin sheath is also laid down by a process of secretion along one side of a spindle-shaped neurilemma cell, probably being wrapped round a pre-formed axis-cylinder. It grows in length, shows like the axis-cylinder a beaded appearance, and ultimately anastomoses with adjoining sheaths. The beaded appearance of the myelin sheath is due to the presence of the nucleus of the cell in which it is developed: as the sheath grows in size the nucleus becomes less conspicuous and finally can be found only in each internode. Within a graft the neuroblasts are developed from the proliferation of neurilemma cells of the proximal and distal segments. They travel into the graft alongside the blood-vessels, for the embryonic sheaths are found in greatest abundance in the immediate vicinity of the vessels. The graft is therefore a scaffolding invaded by neurilemma cells, predisposed to assume a longitudinal direction, within which new axis-cylinders and myelin sheaths are secreted.

The difference between the changes which characterise regeneration in a re-united nerve and in the distal segment of a non-united nerve is one merely of degree and not of kind. Even in the latter case regeneration of the axis-cylinders and the myelin sheaths takes place, although full maturity of the nerve fibre is not attained unless the distal segment be joined to the proximal so that their fibres may become functionally continuous. In both axis-cylinder and myelin sheath the beaded stage is apparently the limit of development in cases where functional conductivity is not re-established.

Ballance and Stewart are convinced upholders of the view of the multicellular structure of the peripheral nerve fibre and of the neuroblastic function of the neurilemma cells. They believe that the peripheral nervous system is to be considered as made up of a chain of cells, and further, that the activity of one variety of cell, and one variety only—the neurilemma cell,—is responsible for the regeneration of a peripheral nerve, not only for its axis-cylinder but also for its myelin and neurilemma sheaths.

Bethe (1901–1907) is at present the most prominent and strenuous supporter of the peripherist theory, and his work since the beginning of the century has formed the main point of attack of the centralists. After a very complete series of experiments, which has seemed to exclude every possible fallacy, he sets himself to answer the following questions:—Can regeneration be purely central? Or purely peripheral? Or does it rest upon a co-operation of both central and peripheral influences? If this last, how can the share of each be determined? It is impossible to give a complete review of his numerous articles, in which answers to these questions are given with the most elaborate detail. We endeavour to present only the main conclusions and hint at how they were reached. (1) The ganglion cell of the anterior horn, deprived of its axis-cylinder process, cannot form a new nerve process if it is not in connection with a cell of the sheath of Schwann. All experiments which seem to prove this had always left a considerable part of nerve root with attached Schwann cells, so that it was impossible to state how much was to be put down to the central cell and how much to the Schwann cell. Bethe severed the anterior nerve bundle just within the pia, thus leaving no sheath of Schwann cells, and found that the ganglion cells never produced a new axis-cylinder process. If any sheath of Schwann cells were left, *i.e.* if section was extra-medullary, Bethe found that small neuromata developed in the pia and that this production was more marked the further from the cord section had taken place. Therefore the central end alone cannot produce a new axis-cylinder process, and the production of the new nerve is in the first degree the function of the Schwann cells. (2) In young animals nerve fibres permanently severed from their trophic centre, *e.g.* by the excision of 4–6 cm. of the nerve trunk, regenerate autogenously and become capable of excitability and conductivity. Bethe enclosed the upper end of the distal segment of the cut nerve in a capsule, and in several other ways avoided the possibility of a connection of the peripheral with the central end. He therefore concluded that in young animals the peripheral end could regenerate autogenously. In adult animals he admitted that regeneration never went beyond the stage of protoplasmic bands, *Axialbandfasern*, or embryonic fibres, unless union with the central end was effected. He is convinced, however, that the growth of the axis-cylinder and myelin sheath in these embryonic fibres is definitely a cell differentiation and not an outgrowth from the central end. Bethe's searching criticism of the centralists' position must be very carefully considered by anyone taking up an opposite opinion. It has seemed to us that none of those who during the past ten years have sought to answer his objections have sufficiently recognised the pains he has taken to fulfil the very conditions they have themselves laid down as essential. We can mention only one or two out of many points which Bethe has emphasised. Cajal and Perroncito, as we shall see later, show that Schwann cells form the outermost part of the bulbous end of the young central axis-cylinder, and yet claim this fact as supporting the outgrowth theory. Bethe explains this as a regeneration proceeding from the proliferation of the last-preserved Schwann cells nearest the point cut through. Again, the impossibility of the functional reunion of motor and sensory fibres, also of pre-ganglionic and post-ganglionic fibres, proves that the remains of the nerve fibres retain, after degeneration is accomplished, a certain degree of their specific function. This is against the indifferent character attributed by the centralists to the cells of Schwann sheath.

Fleming (1902) holds an opinion which he describes as midway between that held by the central and peripheral theorists. In numerous sections from the peripheral ends of divided nerves in rabbits—"nerves so divided that all regeneration from the central end was prevented by every possible means"—he found what he believed to be a limited peripheral regeneration of axis-cylinders. The neurilemma nuclei were proliferated and had formed chains, and definite young axis-cylinders had appeared in connection with these neurilemma nuclei which, in consequence, he looked upon as neuroblasts. The immature axis-cylinders tended to join on end to end with other axis-cylinders to form nerve fibres. Similar changes were found in portions of the sciatic nerves of rabbits divided, proximally and distally, by double sutures. These appearances were not seen until twenty days had elapsed after section or suture. These peripherally formed nerve fibres, or at least axis-cylinders, do not become myelinated or capable of functionating until they are joined on to the central segment—in other words, to their central and trophic neurones.

Fleming also accepts central regeneration and has often seen evidences of it, but he does not and cannot believe that central regeneration alone can ever explain the phenomena of secondary nerve suture. No explanation given by the centralists of those undoubted cases in which conduction of nerve impulses followed within a few days of secondary suture seems to him reasonable or possible.

Langley and Anderson (1904) have objected to the conclusions of Kennedy, Ballance and Stewart, and other autogenists, on the ground that there is no satisfactory evidence in their experiments that the peripheral end of a nerve, remaining ununited with a central end, had not united with the nerve fibres of the central end of other nerves cut through at the operation. They carried out a series of experiments to settle this point, and found that, when the peripheral end of a cut nerve was sewn into the skin or left lying amongst muscles, it made connection with the central nervous system by means of the nerves of the surrounding cut tissue, although it made no connection with its own central end. They have demonstrated that all the medullated nerve fibres which reform in the peripheral end of a cut nerve degenerate when the nerves which run to the surrounding tissue are cut, or when the original nerve is again cut across on the central side of the original point of section. They have further noted that the number of medullated nerve fibres found in the peripheral end of a cut nerve is very variable: a fact easily explained by the naturally varying connection with the central nervous system, but not explained by the autogenist view. It will be remembered that the difficulty in proving the absence of central connection with neighbouring nerves was the determining factor which led Vulpian to give up his earlier position.

Langley and Anderson conclude from their experiments that the peripheral ends of cut fibres exercise a chemiotactic influence on the central ends and that this chemiotactic influence has numerous gradations, *e.g.* it is greater between fibres of one class, as it is well known that afferent fibres of one nerve can unite with the afferent fibres of another, but they cannot unite with the efferent fibres so as to produce any functional result. The evidence is still insufficient to show whether nerve fibres giving rise to one sensation can unite with the fibres giving rise to another sensation.

Mott, Halliburton, and Edmunds (1904–1906) have also exposed what they consider the fallacy underlying the work of Kennedy, Ballance and Stewart, and others. Their own experiments were carried out in such a way as to obviate the possibility of new nerve fibres "finding their way by devious channels" into the peripheral stump. The incisions were very small, and the upper end of the distal segment of the cut nerve was enclosed in a capsule of sterilised guttapercha. After 100–150 days there was found no response of any kind to stimulation, and the microscopic examination of the peripheral end showed no trace of regeneration, and in many parts no nervous structure could be recognised. Two of Vulpian's experiments were repeated, one in which the segments of nerve were transplanted to a part devoid of nerves, *e.g.* the peritoneal cavity, and no autogenous regeneration could be proved; the other was an experiment in which the nerve was again cut across on the peripheral side of the original site of section, and it was found that the degeneration took place solely peripheral to the second section. As it was assumed that the direction of regeneration is always the direction of growth, this experiment proved that the growth of new fibres had started from the centre peripheralwards and not in the reverse direction.

It is, however, admitted that the activity of the neurilemma cells has some definite relation, perhaps nutritionally, to the development of new nerve fibres; that the proliferation leads to the formation of what seem embryonic fibres; but that this is only the scaffolding for the axis-cylinder which has an exclusively central origin.

Kennedy has criticised the objections raised by these observers and also by Langley and Anderson to his experiments and those of Ballance and Stewart. He thinks that the possibility of fibres from surrounding cut nerves growing into the distal end is a far-fetched explanation, and that it assumes an extraordinary affinity between young nerve fibres and the old nerve trunks—an affinity which if it existed would assure spontaneous union after accidental division. Kennedy also, referring to the doubt that Mott, Halliburton, and Edmunds throw on the very early return of sensation after secondary suture, explains the care with which the clinical facts of the return to conductivity and sensory impulses are ascertained.

Head and Ham (1904) have shown that an ununited distal end may remain in the "resting stage" (Kennedy) for 540 days if the blood supply is sufficient. If even then united to the central end, it is completely restored. Shortly after union the spindle-shaped cells lengthen, form definite fibres, and are able to conduct stimuli to the central nervous system—even before axis-cylinder and myelin sheath can be demonstrated histologically. The first axis-cylinders and myelin sheaths are well formed, yet are thin and stain lightly, but later they stain deeply with specific stains.

Head, Rivers, and Sherren (1905).—As this paper deals chiefly with histological data, we can only briefly refer to the important clinical investigations of Head, Rivers, and SHERREN. These observers state that the return of function and sensation in man, after secondary suture, coincides closely with the data obtained in animals for the reappearance of new and fully-formed fibres. They think that earlier observers, who had deduced from a rapid return of sensation the presence of pre-formed fibres, had been led into error by the vague nature of certain kinds of sensation.

BARFURTH (1905) has carried out a series of sections of the sciatic nerve of the dog, and has come to conclusions almost identical with those of BETHE. He criticises LANGLEY and ANDERSON's acceptance of the presence of degeneration in the distal end after a second excision in the central stump as a proof of the ingrowth of fibres from the centre. He shows that this occurred in LANGLEY and ANDERSON's experiments only after 119–737 days, and remarks that surely some central fibres could in that time grow into the peripheral end. In his own experiments a second portion was excised 69 days after the first excision, and no trace of degenerated fibres could be found in the peripheral stump. His conclusions are that in favourable circumstances a regeneration of nerve fibres can take place in a peripheral nerve cut off from its central end, that this can go on to all the essential constituents of the nerve (axis-cylinder, myelin sheath, and neurilemma sheath), and that it takes place essentially by means of the nucleus of the sheath of Schwann cells. His closing words are too interesting to omit quoting: "These nuclei can therefore be no plebeian mesenchyme cells, but are neuroblastic elements of aristocratic ectodermic nature."

LAPINSKY (1905) also supports the peripherist view. His contribution to this question is twofold: firstly, he shows that the regeneration in the central end is emphatically the same as that in the peripheral end—a point not quite so clearly brought out by previous writers; and secondly, he draws a marked distinction between autochthonous regeneration and neurotisation. In the former case the newly arising axis-cylinders remain unconnected with the centre, and microscopically they are very thin, show no fibrillar differentiation, have no resisting power, and soon degenerate; the myelin sheath also develops only incompletely and soon degenerates. In neurotisation the peripheral end is connected with the centre; there is therefore complete myelin sheath and axis-cylinder differentiation and complete functioning power. "Obviously through this connection with the anterior horn cells the sluices are opened to the special stimuli which supply to the regenerated tissue its complete structure."

RAIMANN (1905) and LUGARO (1905) have used the most radical methods to exclude the influence of the centre. RAIMANN, in newly born dogs, removed the spinal cord from the 2nd lumbar segment downwards together with the spinal ganglia as far as possible. In the single dog surviving, out of seven operated upon, in the sciatic nerve on the right side, which, of course, had been left untouched in its bed of tissue and in which therefore there could be no ingrowth of fibres from the neighbouring tissue, he found so large a number of fibres that they could not be explained except by regeneration. He drew the conclusion that the cells of Schwann's sheath had produced a second nerve tube, which, however, he admits leads a transitory life. LUGARO, in adult dogs, removed the whole lumbo-sacral cord and spinal ganglia, thus including the nuclei of origin not only of the sciatic nerve but also of the crural and obturator nerves, and three months later he found no regeneration. The sheath of Schwann cells had arranged themselves in protoplasmic bands, but these contained neither axis-cylinder nor myelin. There were present fine axis-cylinders, so numerous that they seemed to speak in favour of autogenous regeneration, but LUGARO assumed that they were sympathetic fibres. In one dog, therefore, he completely severed the central end of the sciatic from its connections with the sympathetic nerves, but he left the sympathetic attachments to the obturator and crural nerves. By means of Cajal's reduced silver method, a hundred days after the operation, he was able to demonstrate large numbers of axis-cylinders in the obturator and crural nerves, but none in the sciatic nerve.

MODENA (1905), MUNZER and FISCHER (1905), VON KRASSIN (1906) and BESTA (1906), must be mentioned amongst those whom BETHE's results stimulated to an experimental endeavour to solve this difficult question. MODENA and BESTA relate the development of the new fibres to the Schwann cells, but insist on the necessity of the central influence for their complete differentiation. The others are centralists. VON KRASSIN used the intravital methylene-blue method of Ehrlich, up till then scarcely applied in the study of regeneration.

MARINESCO (1905) performed section of the sciatic and crural nerves both in newly-born and adult animals. He states that reunion of cut ends is not essential to regeneration, and that this can arise in both central and peripheral ends through the proliferation of the sheath of Schwann cells. The details are those which we have seen in VON BÜNGNER's work: the formation of fusiform cells and protoplasmic bands with at first fine, almost invisible, lines within the cell protoplasm; later, thicker black lines stained with Cajal's silver method and the development of the myelin sheath and sheath of Schwann. An illustration given by MARINESCO in this paper is a very striking proof of the spiral formations having arisen within cells. Around an old axis-cylinder of the central end coils spirally a thin fibre, and the components of the spiral are within cells in the protoplasm of which they have developed: the cells are arranged transversely to the old fibre.

In the following year, however, MARINESCO and MINEA carried out a new series of experiments which led MARINESCO to change his views on autogenous regeneration. Both authors look upon the cells within which the axis-cylinders were thought to have developed only as an advance guard to provide for the nutrition and orientation of the new fibres. They attribute the young fibres to outgrowths from the central end, the axis-cylinder of which, by longitudinal dissociation, has formed fibrils each of which terminates in a *cône de croissance.* Collateral division of the central end axis-cylinder may also take place, and such collateral fibres tend to assume a spiral direction round the old fibres. These authors part company from CAJAL in attributing no phagocytic rôle to the proliferated cells, which they term *cellules apotrophiques.* In a further series of experiments MARINESCO grafted small pieces of nerve into animals of the same and different species. In the homo-transplanted series there was no new axis-cylinder formation, as the apotrophic cells were present only in small numbers, and in the hetero-transplanted series the grafts were entirely removed by phagocytosis on the part of polymorpho-nuclear cells—just as the blood corpuscles of one animal are destroyed by the body fluids of an animal of another species.

PERRONCITO (1907) divided the sciatic nerve in dogs, and observed, by means of Cajal's reduced silver method, the changes which occur from the very earliest period onwards. He was the first to show that the signs of regeneration described by CAJAL occur very early. Twenty-four hours after section PERRONCITO found traces of collateral and terminal ramifications, and already, in two days, newly-formed fibres which spring from the central stump have reached the scar-tissue and show a very fine fibrillar structure, with end thickenings and terminal balls. He has also described a process of the unravelling of the thickened central end axis-cylinder which precedes the development of the new fibres, an appearance which CAJAL has termed "the phenomenon of PERRONCITO." Axis-cylinders may later grow out as compact axis-cylinders, become dissociated into fibrils, and unite again into a compact axis-cylinder. On the tenth day after section the connection between the separated ends of a non-united nerve is completed by newly-formed fibres, many of which show forkings with terminal balls. PERRONCITO also draws attention to the length of time that old axis-cylinders may be recognised in the peripheral stump, and concludes that they are non-medullated or Remak's fibres.

CAJAL (1904–1907).—It is impossible in a short review to do justice to the work of CAJAL, which has been the source of inspiration to so many. It is the less necessary to attempt this, as many of his beautiful illustrations, showing stages in the regeneration of the axis-cylinder, are reproduced in the more recent text-books, and all are familiar with his terms—*cône de croissance*, *massue de croissance*, and *boules terminales.* As in the early development, so in the genesis of the new fibres in regeneration the work of CAJAL was the first that seriously opposed the new teaching that set in with VON BÜNGNER's researches and that seemed destined to replace the outgrowth theory. This reaction in favour of the outgrowth theory must be associated with the names of CAJAL, PERRONCITO, and LUGARO. It need therefore scarcely be added that CAJAL's researches have demonstrated that the nerve fibres of the scar-tissue and peripheral end are always formed by growth from the central end. In the peripheral segment near the cut portion, preceding the degeneration of the axis-cylinder, CAJAL noted signs of regeneration—indicating that the axis-cylinders do not die immediately that they are cut off from their trophic centres, but that during the short period of their survival they attempt regeneration. By the eighth day all the axis-cylinders in the peripheral segment have undergone a granular degeneration except the fibres of Remak, which resist longer.

In the central end the axons commence to modify on the first day, the first change being a terminal *massue de croissance*, from which filaments proceed; other axons show a reticulated or dissociated appearance. The filaments and the dissociated fibrils increase in length and penetrate the exudate between the cut ends, each filament and fibril having a terminal cone or ring. Collateral intratubular regeneration may also occur, the short collaterals being provided with buds or thin tangential collaterals, more frequently with rings. The collateral fibres tend to form spirals or groups round the old axon. CAJAL has laid great stress on the important fact that during these early stages of degeneration there has been no proliferation of cells within which the young axis-cylinders could develop, but he adds that from the third day onwards each terminal cone appears enclosed by a few cells.

The passage of the new axis-cylinders across the scar-tissue and into the old sheath of Schwann is regulated by chemiotactic substances elaborated by the proliferated cells of the sheath of Schwann which have been transformed into the *Axialbandfasern* of VON BÜNGNER. CAJAL attributes three functions to the proliferated nuclei: firstly, a phagocytic function; secondly, that of secreting a chemiotactic or neurotrophic substance to attract the young fibres from the central end and guide them into the sheaths; and thirdly, the function of maintaining the nutrition of the young fibres when they arrive. CAJAL reproaches all who are in favour of autogenous regeneration with having used methods "unreliable or insufficient." It is impossible to avoid noting here that LUGARO, PERRONCITO, and MARINESCO—on the strength of whose observations, together with his own, CAJAL claims that the cell-chain conception has been definitely refuted—have all used only impregnation methods.

POSCHARISKY (1907), who has used Cajal's and Bielschowsky's silver methods, confirms many of CAJAL's observations, but has come to different conclusions regarding the significance of the early phenomena observed in the two ends. While not denying the possibility of growth from the central axon, he looks upon the terminal cones, balls, and rings as signs of a dying condition of the axis-cylinder. He believes that regeneration commences only on the third day, *i.e.* after the proliferation of the cells of Schwann's sheath is in full activity. He thinks that silver impregnation methods are not sufficient to lead to any definite conclusion, whether the new axis-cylinders have arisen within these proliferated cells or are outgrowths from the centre.

MARGULIES (1908) found, after permanently separating the distal end of a cut nerve in the rabbit, that a new tissue arose which agreed in many respects with certain embryonal stages of development, *i.e.* the *axialbandfasern* stage of VON BÜNGNER. In the young animal this neurogenous tissue led to a spontaneous regeneration, but in the adult never advanced to completely differentiated fibres. MARGULIES, taking his stand upon the fact of the undisputed proliferation of the Schwann nuclei and on the generally accepted opinion of their ectodermal nature, concluded that under all circumstances an autogenous regeneration takes place even without the influence of the central ganglion cell. It is incomplete, however, till the functional activity of its elements is brought into play, and this can be only when it is anew related to the centre. Even in young animals, where a complete regeneration takes place, the new-formed fibres do not remain long in this complete condition, but tend to reassume the *axialbandfasern* stage.

Durck (1908), who has made a very exhaustive microscopic investigation of the peripheral nerves in beri-beri, has found in numerous cases a transformation of the nerve fibre into a nucleated neuroplasmatic cylinder, *i.e.* a cellular regression to the *axialbandfasern* stage. Segments showing this have become functionally incompetent, but are none the less specific neurogenous tissue. This specific tissue, Durck was convinced, had arisen from the proliferation of the sheath of Schwann cells, and he believes that the changes in the nerves in such conditions as beri-beri form a striking confirmation of the multicellular structure of peripheral nerves.

Alzheimer (1910) has studied regeneration in experimentally produced lead neuritis of guinea-pigs and rice neuritis of fowls. In such neuritis the axis-cylinders may remain preserved for a long time after the myelin sheath has not only degenerated but after the degenerated products have been removed. When the axis-cylinder itself has disappeared there is found a Wallerian degeneration distally. Alzheimer studied the regeneration which occurred at such a point of the interruption of the axis-cylinder and found numerous terminal divisions of the old axis-cylinder of the central end, also numerous collateral branches, and that each new fibril ended in a ring or club. These new fibrils grow preferably, but not exclusively, within the intercellular plasmatic bridges of the proliferated Schwann cells. Osmic acid preparations show that these new fibrils rapidly assume a thin myelin sheath. He believes that the sheath of Schwann cells are in the peripheral nervous system the biological equivalents of the glia cells in the central nervous system, and that they play, like glia cells also, only a transient rôle in the phagocytosis of degenerated elements.

Throughout the works on regeneration we have heard only faint echoes of the intercellular bridge theory of development in the discussion of the genesis of fibres in regeneration, but we close this section with the work of Alzheimer—a supporter both of the outgrowth and intercellular theories of development.

Note on the Regeneration of Fibres in the Central Nervous System.

A complete anatomical and functional regeneration of fibres has been proved for the peripheral nervous system. Similar proof is wanting for the fibres of the central nervous system, but there is evidence both from experimental work and pathological conditions that there is a considerable effort at regeneration. In this attempt at regeneration a specially important rôle seems to be taken by the blood-vessels, which act as a conducting path for the new fibres.

Nageotte (1899–1906) has described a special type of regeneration in tabes, which he has designated "collateral regeneration." According to Nageotte, the initial lesion in tabes is a transverse neuritis of both anterior and posterior roots, starting from the point where the nerves pass through the dura mater. In the anterior roots, in addition to the secondary descending degeneration, there is a retrograde degeneration extending to a greater or lesser extent towards the cord, and from the point where this may be arrested there is an attempt at regeneration. If the old sheaths are uninjured the new fibrils grow out into the old sheaths, each leash of new fibrils representing a destroyed nerve tube. If the degeneration is arrested just within the pia and if the old sheath is injured, the new fibres grow into the pial spaces, forming neuroma nodules. The posterior root shows a similar regeneration, but here the fibres are not myelinated. The Weigert stain shows only a few fibres, while Cajal's silver method reveals numerous fine fibrils reaching up to the cord. NAGEOTTE finds it difficult to explain why the posterior fibres of regeneration are without myelin. He states that the new-formed fibres may start from three points: the cell-body, the intra-capsular, and the extra-capsular portions of the axon. The fibres are not terminal but are actual new processes of the cell or collaterals of the preserved portion of the axon. The term "collateral regeneration" in tabes is thus used. Many of the new fibres, even those within the capsule, may show *cônes* and *massues de croissance.* Similar appearances are found under normal conditions in the posterior root ganglia: in tabes and other pathological conditions there is only an exaggeration of the normal. NAGEOTTE has also carried out a series of transplantations of the spinal ganglia to the peritoneal cavity and other parts of the body, and has found that the change of nutrition has caused the new protoplasmic processes to change in type, *e.g.* to take on the aspect of the sympathetic. Under these abnormal conditions, the peri-cellular and peri-glomerular arborisations were also reproduced.

NAGEOTTE states that the regeneration in tabes cannot re-establish function, as the terminal *massues* and *cônes* are arrested at the area of inflammation where the first fibres were destroyed.

FICKLER (1900) examined two cases of compression of the cord at the lower dorsal region, in both of which there had been a great amelioration of the cord symptoms for some time before death. He found above the compressed part numbers of fine axis-cylinders, especially in the adventitia of the small vessels of the cord. These appeared first in the vessels at the periphery of the grey matter in the corner where the anterior and posterior horns meet. At a slightly lower level the fibres passed in the vessel walls to the commissural vessels and thence to the vessels in the anterior fissure. Just above the point of greatest compression the fibres filled the anterior fissure and overflowed into the adjoining pia. Opposite the compressed part there were no fibres at all within the cord—all had passed into the anterior fissure and pia. Below the area of compression the fibres, collected into small groups, passed again from the vessels of the anterior fissure to the commissural vessels and were distributed in the grey matter. On their whole course they were surrounded by a sheath of Schwann. FICKLER states that these are new-formed offshoots of the fibres of the crossed pyramidal tract above the lesion, which in this way have restored connection between the fibres above and the ganglion cells below the level of compression. In the second case there were present nerve fibres in the posterior septum, which were looked upon as new-formed sensory fibres. FICKLER concluded that the nerve fibres of the cord are capable of regeneration, even to the complete restoration of function, as long as the blood-vessel apparatus of the cord is intact. The fibres had arisen by the axis-cylinder breaking up into its primitive fibrils; one axis-cylinder could therefore become connected with several ganglion cells below the point of compression. In a recent paper FICKLER considers that the new-formed fibres were derived, not from the pyramidal tract above the lesion, but from the ganglion cells of the grey matter and of the spinal ganglia. The appearance of the sheath of Schwann as soon as the fibres enter the vessels, argues in favour of the mesodermic nature of the sheath of Schwann. BIKELES (1904), in a case of rupture of the cord, where the patient survived ten months after the injury, found a certain amount of regeneration. Continuous with the regenerated fibres of the proximal portion of the posterior root, there were present very delicate irregular fibres in the posterior columns, though no other nerve fibres were present. CLARK (1906), after section of the cord, noted that regeneration is limited solely to fibres of peripheral character. He thinks, therefore, that the cells of the sheath of Schwann are necessary to regeneration.

BIELSCHOWSKY (1906–1909) has made a very careful examination, by the aid of his new silver method, of the axis-cylinder formations found within tumour nodules in the brain and cord and in the zones bordering areas of compression in the cord. His investigations have confirmed him in the conviction of the capability of regeneration of the central nerve fibres. The numerous fine fibres ending with rings or button-shaped swellings, and the fact that similar fibres were found in the vessel walls—especially of the marginal zones—could, he thought, be nothing else than a new formation of fibres. In the white matter of the cord the new fibres were present in a direction corresponding to the fibre systems of the cord displaced by the tumour, and had arisen from the dissociation of old nerve fibres persisting within the tumour mass and of fibres of tracts interrupted by the tumour. In a case where the posterior nerve roots were penetrated by cancer cells and Weigert's medullated sheath stain showed empty nerve tubes, BIELSCHOWSKY found in the transition zone between healthy and diseased parts very fine fibrils with exactly similar appearances growing from the stump of the interrupted fibres. The collateral regeneration of NAGEOTTE, found in tabes, must be related to the influence of the ganglion cell, though it is admitted that the capsule cells and the cells of Schwann's sheath take their share in the formation of the new fibres. BIELSCHOWSKY, in opposition to NAGEOTTE, holds that it has not been proved that the fibrils represent the most essential constituent, but thinks rather that they must be looked upon as supporting axes for the conducting neuroplasm.

BIELSCHOWSKY concludes that for the regeneration of the fibres in the central nervous system two factors are essential; the one, sufficient vascularisation; the other, the presence of special decomposition cells. Such cells may possibly exert a chemiotactic influence, but more likely, by means of their syncytial connections, exercise a plastic function as pre-formed cell bridges. They have therefore the same significance as the proliferated sheath of Schwann cells in the regeneration of peripheral nerves. BIEL-

SCHOWSKY thus declares himself to be a supporter both of the outgrowth and intercellular bridge theories of development.

MARINESCO and MINEA (1906–1909) have looked for evidence of regeneration of central nerve fibres in cases of experimental section of the cord in dogs and in compression of the cord in man. They believe that a certain amount of restoration may take place through the formation of new fibrils, but that this can rarely go on to functional restoration as the re-establishment of the inter-neuronal connections of the new fibres would be almost impossible. Both in experimental and pathological conditions fibres of new formation can pass into the cicatrix from both upper and lower ends. The new fibres are of fine calibre, show moniliform swellings, and end in *cônes* and *massues.* They are derived, as in peripheral nerves, from the dissociation of the preserved axis-cylinder with successive ramifications: collateral branches may also be given off and these divide and ramify. The vessels, especially at the periphery of the cord, are surrounded almost with a plexus of new fibres.

MARINESCO and MINEA attribute an important rôle to the presence of the *cellules apotrophiques* which are found in the tissue between the interrupted fibres. These are fusiform cells which frequently form protoplasmic bands as in the peripheral nerves. They have chemiotactic and nutritive properties in relation to the new fibres which may be found even within the protoplasm of the cells. CAJAL has stated that in hemisection of the cord in cats the new fibres atrophy in consequence of the absence of cells capable of secreting a chemiotactic substance. MARINESCO has also described the neurotisation of areas of cerebral softening, tubercular and syphilitic nodules, and gliomas by means of bundles of fine fibres which form a reticulum around the lattice and tumour cells or within the vessel sheath. Here again there can be no functional restoration, and there is no intimate relation between the new fibres and the actual elements of new formation to register a symbiosis.

MIYAKE (1908), using Cajal's silver methods, compares the changes of the axis-cylinder in pathological processes and in experimental sections of the cord. He found at the margin of cerebral tumours vacuolation and terminal varicose swellings of the axis-cylinders. Such swellings often showed the dissociated fibrils ending in rings and buds. In a sarcoma of the dura, which had no association with the brain, similar appearances were found in the vessels. To determine whether the above changes were degenerative or regenerative MIYAKE carried out a series of experimental sections of the cord in rabbits. In the necrosed zone and the zone of reaction the axis-cylinders showed terminal swellings and vacuolation, but adjoining the healthy zone there was a dissociation of the axis-cylinder into fibrils with terminal cones—probably regenerative. The author has come to the conclusion that only terminal buds and rings following a fine axis-cylinder can be looked upon as signs of regeneration, and that even these must be accepted with great caution as they were found in the dural sarcoma.

ROSSI (1909) found, in aseptic hemisection of the cord in young rabbits and dogs, that there was a very manifest production of new fibres which pass the zone of degeneration of both stumps, reach the cicatricial zone and are there arrested by the proliferation of the supporting elements. After intra-cranial section of the optic nerve the fibres in connection with the central (retinal) cells show during the first month considerable regenerative activity. Rossi holds that fibres separated from their central cells could not regenerate spontaneously.

Perrero (1909) considers that the question of the regeneration of the fibres of the central nervous system may be counted as solved, thanks to the methods of Cajal and Bielschowsky. By means of these methods it is possible to avoid the fallacy which underlay previous observations of those who used methods which stain axis-cylinder and glia fibres alike. Perrero examined the cord from a man who died with symptoms of complete transverse lesion 29 days after fracture of the 5th and 6th cervical vertebræ. Immediately above and below the completely softened segments of the cord, corresponding to the injured vertebræ, numerous formations were found which were regarded by the author as undoubted phenomena of regeneration, *e.g.* divisions of fibres, cones, rings, and balls. From some of the terminal balls fine black threads could be traced; other axis-cylinders were found dissociated into fibrils which frequently formed a plexus formation around the vessels. These appearances were noted especially in relation to the pyramidal fibres of the cord above the lesion and to the posterior columns and posterior roots immediately below the lesion. The regeneration was not sufficient to pass through the zone of softening.

(3) Genesis of Fibres in Tumour Formation.

The histogenesis of nerve fibres has been discussed from the developmental aspect and from the experimental aspect in the regeneration of the divided nerve, but it has very rarely been considered in pathological conditions. Here we have to do not with the first development of the embryonal nerve fibre, nor with the restoration of the distal end of a severed nerve, but with the new formation of nerve fibres in a pathological tissue. Regarding tumours in relation to nerves, we have in general two opposite views: the one teaches that the tumours arise from the connective tissue and have only a local relation to the nerves; the other accentuates the nervous nature of the tumours.

Virchow, in 1863, as we have already seen, had emphasised the nervous nature of these growths, but his views did not gain general acceptance, and the conception continued to prevail that the tumours designated by the name "neuroma" arise from the connective tissue sheaths and have only a secondary relation to the nerves.

Von Recklinghausen, in 1882, noted the frequency of the relation of multiple neuromata with skin fibromata. He looked upon the tumours as essentially of the same structure—fibromata arising in the connective-tissue sheaths of the nerves, especially the endoneurium; the difference lying in the difference of the site, the nerve trunks, and the fine cutaneous twigs respectively. VON RECKLINGHAUSEN used the name "neurofibroma" as a compromise with the old-established term "neuroma," but he thought this terminologically incorrect, though it served to indicate the nature of the tumour (fibroma) and its relation to a nerve. After the appearance of VON RECKLINGHAUSEN's work multiple tumours of the nerves were generally regarded as fibromata, and the existence of VIRCHOW's supposed neuromata were more and more discredited, except by a few authors amongst whom must be mentioned KNAUSS and ASKANAZY. These writers believed that many of the tumours described as neuromata, with numerous spindle-shaped nuclei, really contained non-medullated nerve fibres. They considered, however, that the presence of ganglion cells was essential to true neuroma formation, and ascribed the starting-point to the minute sympathetic ganglia and branches present in the vessel walls.

ALEXIS THOMSON (1900) divided neuromata into true and false, basing this classification on the anatomical structure. Under true neuromata he identified only those tumours which contained ganglion cells, and he doubts whether true neuromata without ganglion cells can occur. Under the term false neuromata he classes (1) all circumscribed or solitary tumours growing from the connective tissue of nerve trunks or of the ganglionic enlargements of nerves. They resemble similar tumours originating in other tissues and organs, and are subdivided into innocent and malignant. (2) Traumatic neuroma. (3) Enlargements of nerves in leprosy, syphilis, and tuberculosis. (4) Diffuse overgrowths of the connective tissue sheaths of nerves and of ganglionic enlargements of nerves, embracing a number of lesions affecting skin as well as the nervous system, and capable of assuming very different forms. French authors suggested the name "Von Recklinghausen's disease" for this group, and THOMSON has given to it the general term "neurofibromatosis." It includes the following forms:—

(*a*) Multiple neurofibroma (generalised neurofibromatosis).—The endoneurial connective tissue between individual nerve fibres is the chief seat of the pathological process, and its increase may cause visible thickenings and tumours of the nerves with a dissociation and wavy course of the nerve fibres. The formation of new nerve fibres is "unlikely in the absence of nerve cells." In addition to the tumours on the nerve trunks, the terminal filaments of the nerves exhibit the same fibromatosis, so that the tissue of the true skin may be studded with innumerable minute tumours. The sympathetic system is frequently extensively involved, and the enlargement here also is stated to be due to an overgrowth of the delicate connective tissue which supports the nerve fibres and ganglion cells.

(*b*) Plexiform neurofibroma.—The pathological lesion here is essentially the same as in the more generalised form, except in its distribution and localisation. It is to be regarded as a fibromatosis confined to the distribution of one or more contiguous nerves or of a plexus of nerves. The nerve filaments in the pars recticularis of the cutis may also be irregularly thickened and studded with fibromatous nodules, in which the perineurium of the affected nerve bundles may, however, not be defined from the surrounding connective tissue.

(*c*) Cutaneous neurofibroma (*molluscum fibrosum*) are of the nature of soft fibroma related to the terminal filaments of cutaneous nerves, and may be distributed over the whole body.

(*d*) Elephantiasis neuromatosa.—In addition to the fibromatosis of cutaneous nerves there is here a pronounced and diffuse overgrowth of the connective tissue of the skin and subcutaneous tissue, *i.e.* an extension of the fibromatosis from the endoneurial connective tissue of cutaneous nerves to the tissue surrounding them.

(*e*) Pigmentations of skin associated with neurofibromatosis.

(*f*) Secondary malignant sarcoma, *i.e.* a sarcomatous transformation of one or other of the forms of neurofibromatosis.

THOMSON presents neurofibromatosis as a disease which, while confined to the peripheral nervous system, may be distributed throughout its whole extent, viz. the cerebro-spinal nerves, the sympathetic nerves, and the nerve terminations in the skin. These may be regarded as constituting one organ alike from developmental, structural, and functional points of view. He agrees with GOLDMAN, BRUNS, and others that the condition is a form of gigantism or elephantiasis of the connective tissue elements of the peripheral nervous system, and that it appears to be a developmental disease dating from intra-uterine life. THOMSON significantly adds that a more accurate knowledge of the development of the peripheral nervous system may shed some light on the origin of neurofibromatosis.

During the past ten years careful research into the embryogenesis and regeneration of nerve fibres has given an altogether new view to the structure of tumours related to nerves, whether circumscribed or diffuse.

DURANTE (1906) has related this new view to his conception of the multicellular structure of the nerve fibres. According to it the tumours represent true neuromata, and owe their origin to a cellular regression of the segmental cells of the nerve fibre. The differentiated substance of the interannular segment of the nerve fibres disappears, and the undifferentiated vegetative protoplasm increases in quantity; and, with a simultaneous proliferation of the nuclei, forms homogeneous tubes or individualises into spindle-shaped cells. These cells may again fuse and form protoplasmic bands which have a great similarity to Remak's fibres, and must be looked upon as young nerve fibres. In proportion as they persist at the stage of undifferentiated protoplasm or differentiate further to elaborate myelin, they represent amyelinated or myelinated neuroma. If the new elements that have arisen through cellular regression remain as individual cells and proliferate further, then there arises an embryonal malignant form of neuroma, which in appearance resembles a sarcoma, and might be, in contrast to the others, termed a cellular neuroma. Again, the new-formed elements might undergo various metamorphoses, *e.g.* atrophy, and take the appearance of connective tissue, or imbibe mucin, or absorb fat; the tumours would then appear as fibromata, myxomata, or lipomata, respectively, but would remain in their nature essentially neuromata. In one and the same individual the tumours might appear under various forms. In all the various forms of neurofibromatosis the neoplastic element is the segmental cell which undergoes cellular regression. Neurofibromatosis, or Von Recklinghausen's disease, is a *polynévrome*, the elements of which for the most part undergo a fibrous transformation instead of differentiating themselves into young nerve fibres, or of remaining at the stage of cells of myelinogenous type.

Durante's conception of the nervous nature of these lesions is in direct contrast to **Von Recklinghausen**'s conception of a progressive fibrosis beginning in the perineurium and evolving in the endoneurium. **Thomson**, while agreeing with **Von Recklinghausen**, has pointed out that the fibrillar tissue had no tendency to compress the nerve trunks, and was thus distinguished from other connective tissue new formations, *e.g.* cirrhotic conditions. To numerous factors has been attributed a share in the pathogenesis, and nearly all writers have invoked a primary developmental malformation of the connective tissue elements related to nerves as the essential cause. **Durante** thinks that the exaggerated vegetative activity of the segmental cell must be due to an inherent instability in the differentiation of the nerve fibre, which renders it liable to be affected by determining causes.

(a) *Ganglio-Neuroma.*

The great majority of observations referring to ganglio-neuromata have related these tumours to the sympathetic nervous system. Their frequent occurrence in the medulla of the adrenal is explained by the generally accepted view of the invasion of the *anlage* of the cortex of the adrenal by "indifferent" cells of the sympathetic to form the medulla. In a few cases cranial nerves have been the starting-point of ganglio-neuroma.

Busse (1898) has described a very large diffuse ganglion-celled neuroma involving the entire abdominal portion of the sympathetic. Microscopic examination of the tumour proved the presence of large ganglion nerve cells similar to those found in the normal sympathetic ganglion, numerous non-medullated, and a few medullated nerve fibres. **Busse** thought it probable that the tumour had arisen in the lumbo-sacral sympathetic cord, and on account of its diffuse character allied it to the plexiform tumours of spinal nerves.

Knauss (1898) records a case of very numerous ganglio-neuromata in the subcutaneous tissue of the thorax, abdomen, and thighs. The tumours were of very various size, and the microscopic investigation showed that all represented tumours of nerve tissue consisting of ganglion cells, medullated and non-medullated nerve fibres. The ganglion cells were found isolated and in groups embedded amongst the nerve fibres: the non-medullated fibres formed the great mass of the tumour, and the medullated fibres showed a weakly developed myelin sheath. KNAUSS thought the presence of the medullated fibres a confirmation of VIRCHOW'S statement that myelinated neuromata have a first non-myelinated stage. None of the non-medullated fibres could be traced to the ganglion cells, nor was there any visible connection with any filaments of cerebro-spinal nerves. He regarded the tumours as having arisen from the minute ganglia intercalated on the fine terminal fibres of the sympathetic system in relation to blood and lymph vessels. KNAUSS thought that a true neuroma without ganglion cells could not occur, though in this case he could trace no connection between the nerve fibres and the processes of the ganglion cells.

BENEKE (1901) records two cases of ganglio-neuroma: the one related to the cervical sympathetic, the other to the semilunar ganglion. Microscopically the tumours consisted of a felt-work of nerve bundles with groups of ganglion cells between them. The cells had in general the character of sympathetic ganglion cells: some were very small with no processes, while others were large with very numerous processes. The neurite of many cells could be traced in direct continuity with the nerve fibres, and indeed a direct continuation of the cells of the capsule with the cells of the sheath of Schwann was frequently noted. The non-medullated character of the nerves was in proportion to the non-medullated constitution of a normal sympathetic ganglion, and the development of the nuclei was *pari passu* with the development of the nerve bundles. The question whether mature ganglion cells are capable of division cannot be answered affirmatively from Beneke's work, but he derives all the nerve fibres from the ganglion cells of the tumour. The fact that the nerve fibres preponderate is explained by the division of one axis-cylinder into its primitive fibrils.

OBERNDORFER (1907) describes a ganglio-neuroma in the medullary substance of the adrenal which contained groups of cells separated by septa of non-medullated nerve fibres and connective tissue. The cells were of all sizes, from that of a lymphocyte with all possible transitions to cells four or five times the size of ordinary sympathetic ganglion cells. Some of the cells, therefore, have the same morphological structure as the primitive cells from which both the sympathetic nervous system and the medulla of the adrenal develop. Ganglion cells were found in the meshes formed by interlacing naked axis-cylinders, and only in the marginal part of the tumour were there any axis-cylinders with sheaths of Schwann. The presence of medullated fibres could not be proved. The naked axis-cylinders with ganglion cells reminded OBERNDORFER of an embryonic nerve tissue, *i.e.* neuroblasts with their offshoots. He concluded that the smaller cells were the earlier forms of the ganglion cells and thought it possible that in early embryonal life these had separated themselves, retaining their embryonic condition, till later some influence awakened their slumbering developmental possibilities, and they developed their morphological form of sympathetic ganglion cells. OBERNDORFER believes that every true neuroma must be a ganglio-neuroma.

Falk (1907) describes a ganglio-neuroma whose origin was traced to the solar plexus. The essential constituents of the tumour were non-medullated fibres with interstitial connective tissue. The fibres were very delicate and undulating, with regularly situated, elongated nuclei along their course. Ganglion cells, isolated and in groups, were also found amongst the nerve bundles. The cells were of very various size and shape, mostly in various stages of degeneration, and all allowed to be recognised their derivation from one common parent cell. Axis-cylinder processes could be traced in only a very few ganglion cells: the great majority gave the impression of being a-polar cells. The author noted also the presence of small round or oval cells with metachromatic staining granules similar to the chromotrope cells found in the medulla of the adrenal and in the carotid gland.

The nerve fibres stained distinctly by Bielschowsky's method. Numerous sections were observed which contained only a few ganglion cells, and nerve fibres formed the great mass of the tumour. In teased preparations the fibres showed clearly that the nuclei were within the nerve tube. Falk found it impossible to believe that this great mass of fibres was derived from the ganglion cells, which were not only mostly a-polar but degenerated. He therefore turned his attention to the possibility of the Schwann cells being the formative cells of the new nerve fibres: he found that these were present in great abundance, that the direction of their growth was parallel to the new axis-cylinder, and that within the cells a continuous plasmatic stripe, which later became the specifically staining axis-cylinder, was present. With Bielschowsky's silver method the axis-cylinders showed no differentiation into actual fibrils. Falk felt justified in coming to the conclusion that the new axis-cylinders had arisen by the differentiation of the protoplasm of the proliferated sheath of Schwann cells. He adds that with medullated sheath staining the axis-cylinders took on the myelin stain, and that if the sections were only slightly differentiated a weakly-staining myelin sheath was evident in the nerve tubes. The non-medullated character of the great majority of the fibres, therefore, does not seem quite proved. Falk thinks it possible that the degenerated ganglion cells constituted the chemiotropic influence which caused the marked proliferation of the nerve fibres.

Wegelin (1909) records a case of ganglio-neuroma at the level of the lower margin of the kidney. The cells again were of very varied size, the fibres again greatly preponderated, and numerous sections consisted exclusively of nerve fibres. These were collected into interlacing bundles to form a dense felt-work. In longitudinal sections the fibres appeared as bright undulating bands, with distinctly marked sheath and nucleus of Schwann. Most of the fibres were non-medullated and showed a dark thread in the centre corresponding to the axis-cylinder. The medullated fibres stained pinkish and showed numerous varicosities. In contrast to Falk's case, Wegelin found no proliferation of the sheath of Schwann cells, *i.e.* no increase over the normal nuclei of the sympathetic fibres. He also found no spindle-shaped cells forming protoplasmic bands which could be looked upon as the early stages of non-medullated fibres.

He thinks that the presence of the completely naked axis-cylinders, found by **Beneke** and **Oberndorfer**, argues against the possibility of the origin of the nerve fibre from the sheath of Schwann cells. In both axis-cylinder and medullated sheath numerous degenerative phenomena could be ascertained, which showed a definite dependence upon the degree of degeneration of the ganglion cells. **Wegelin** therefore finds no reason to depart from the generally accepted view that the nerve fibres had arisen from the ganglion cells. He relates the starting-point of ganglio-neuroma to cell displacement in early embryonal life.

Homer Wright (1910) has drawn attention to a group of tumours which, at first sight, are apt to be mistaken for round-celled alveolar sarcomata. The tumour tissue consists of cells and fibrils. The cells have the same morphology as the cells from which the sympathetic nervous system develops : they are generally small, with round, deeply-staining nuclei and little cytoplasm, or they may be pyriform with the cytoplasm prolonged into filamentous processes. The fibrils are often of considerable length : they do not stain like neuroglia or connective tissue fibrils, and are like the fibrils occurring in the *anlage* of the sympathetic nervous system. The fibrils may be arranged in bundles or ball-like formations of cells may occur, enclosing a meshwork of fibrils and filamentous processes of the cells. The tumour tissue, therefore, presents the appearance of being composed of aggregations of more or less a-typical embryonic sympathetic ganglia bound together by connective tissue stroma. The essential cells of the tumour are considered to be more or less undifferentiated nerve cells or neurocytes or neuroblasts, and hence the terms neurocytoma or neuroblastoma applied to the tumours. The occurrence in a variety of situations, and especially in the adrenal, is explained by the migration of undifferentiated nerve cells from the embryonic central nervous system to form the nerves and ganglia of the sympathetic nervous system.

(b) *Circumscribed Neuroma.*

Barile (1910) records the careful microscopic examination of an egg-shaped tumour of the forearm. At the operation the tumour, which was 5 × 4 cm. in size, was found surrounded by a capsule, but at both poles seemed to have fibres of the radial nerve attached to it. The tumour consisted entirely of bundles of nerve fibres with scarcely any interstitial tissue, and was without ganglion cells, therefore a true fibrillated neuroma. In the periphery of the tumour the bundles had a parallel course, but in the central parts the bundles interlaced in very varied directions. The fibres are only in part myelinated, and these are distinguished from normal adult fibres by their delicacy. They are found mixed with some that have an axis-cylinder and nucleus but no myelin sheath, and with others that correspond to the plasmodial bands of **Durante**, in which are present filaments that take the axis-cylinder stain. In addition, there are also fusiform cells, the elements from whose fusion in a chain a great part of the protoplasm bands are formed. There appear to be also fibres growing into the tumour from the radial nerve, that after a short course are modified in such a manner as to be transformed into elements similar to the above-mentioned protoplasmic bands. And, finally, there are present germ areas which seem to consist entirely of fusiform cells with elements a little further evolved.

Barile concluded that in this tumour were to be found all the various phases between the fusiform elements, from whose fusion protoplasm bands have arisen, to the complete nerve fibre which had arisen from the differentiation of these protoplasm bands. The fibres of the radial nerve have undergone cellular regression, and the individualised cells—from the proliferation of the nucleus of the sheath of Schwann—had again formed protoplasm bands which were found in a greater or lesser degree of differentiation from the formation of granular filaments to the constitution of the true axis-cylinder and myelin sheath. Here the new-formed fibres take their origin from a nerve that retains its normal connection with the centre.

Traumatic Neuroma must be included in this section. The bulbous enlargements which form in relation to the ends of a nerve that has been injured, or to nerves in a stump, have been proved to consist of a dense plexus of nerve fibres. The origin of these new fibres has been usually accepted to be from the dissociation of the old axis-cylinder into its primitive fibrils and their prolongation onwards. Kennedy, however, has shown that the young nerve fibres have arisen within the proliferated cells of the sheath of Schwann, and that they form interlacing bundles in the scar-tissue.

(c) *Neuro-Fibroma.*

Verocay (1910), in a long article "Zur Kenntnis der Neurofibrome," discusses with very great detail the microscopic structure of multiple neurofibromata occurring in the same individual and the relation of these tumours to each other. After shortly referring to a previously published case in which he found multiple tumours of the cerebral and spinal dura, true gliomata of the cord, multiple neuromata of numerous cerebro-spinal nerves, and tumours of sympathetic nerves in the stomach wall, he passes to the description of a most remarkable case. In a man thirty-one years old, who was admitted to hospital with symptoms of cerebral tumour and died one month after the operation for its removal, there were found multiple tumours on the inner surface of the cerebral dura of the nature of fibro-endotheliomata, small gliomata in the medulla oblongata and cord, tumours in both cerebello-pontine angles of the nature of very cellular neuro-fibromata, multiple tumours of the lumbo-sacral plexus, and finally, multiple tumours of peripheral nerves. It is to the last group that we wish to draw attention in this section. The relation of the groups to each other will be referred to later.

The microscopic structure of the multiple tumours of the nerves consisted of bundles of nerve fibres in the condition of protoplasmic nucleated bands, together with ganglion cells in various stages of development. VEROCAY starts from the assumption that ganglion cells and nerve-fibre cells (cells of Schwann's sheath) are derived in normal development from the same mother-cell (embryonal neurocytes of Kohn). He looks upon the ganglion cells as integral constituents of the tumour-development, and believes that they and the nerve-fibre cells which have produced the nucleated bands have developed from the same undifferentiated cell. The undifferentiated nerve-fibre cells, he thinks, had proliferated greatly, and by their increase and differentiation nerve-fibres were developed on the one hand and ganglion cells on the other. He thinks that the assumption of the pre-existence of ganglion cells in such cases is altogether unsatisfactory and unnecessary.

To VEROCAY the tissue of multiple neuro-fibromata, considered by most writers as a connective tissue, is a specific neurogenous tissue. Nerve fibre cells (peripheral neuroblasts) which have not been used up in the normal construction of the nerve fibre are to be regarded as the parent cells of both ganglion cells and nerve fibre cells present in the tumour; he suggests the name "neurinoma" for tumours of this nature. Such tumours may undergo certain modifications, and to the term neurinoma might be added a qualifying word signifying the dominating elements, *e.g.* neurinoma-gangliosum, -gliosum, -fibrosum, -sarcomatodes, etc. VEROCAY's views thus differ from those of previous writers on neuro-fibroma, who have regarded the developmental disturbance as affecting the connective tissue in nerves. It seems quite unintelligible to VEROCAY that only the connective tissue of the nerves is affected, when this in early development is in direct association with the other connective tissues of the body. He finds it much easier to believe that the primary disturbance lies in ectodermal elements, the connective tissue in relation to which may be secondarily affected.

VEROCAY has described the tumours in the cerebello-pontine angle as cellular neuro-fibromata. This agrees with the term "acoustic neuroma" frequently applied to some of these tumours. FROENKEL and HUNT (1903) have also pointed out that histologically these tumours are neuro-fibromata, arising in relation to the intracranial portion of the cranial nerves. In advanced stages they may become sarcomatous, fibro-sarcomatous, or glio-sarcomatous. The glia elements may be explained by the fact that glia tissue accompanies the intracranial nerve trunks for a short distance, or, according to VEROCAY, who has investigated four such cases, the tumour formation relates to a developmental disturbance of the specific elements of the nerve tissue, affecting undifferentiated cells (neurocytes) which are capable of differentiating along three lines to form ganglion cells, glia cells, or nerve fibre cells.

NOTE ON GENESIS OF FIBRES IN TUMOURS OF THE CENTRAL NERVOUS SYSTEM.

(a) *Glioma and Neuro-glioma.*

VEROCAY (1910).—In the previous section we have seen that VEROCAY regards the early embryonal neurocytes as capable of differentiating to form ganglion cells, glia cells, and nerve fibre cells. From this it will be readily understood that the combination of glioma with multiple tumours of nerves found in both of his cases is looked upon, not as an accidental occurrence, but is traced to the same developmental disturbance. He believes that when multiple tumours of nerves are more minutely investigated this combination will be found more frequently.

SCHMINCKE (1910) has described a case of ganglio-neuroma of the brain in a man seventeen years old. The tumour was the size of a large nut, was situated in the anterior portion of the temporal lobe, and was not defined from the surrounding tissue. Microscopically, the tumour consisted of the several components of the nerve tissue, all in varying degrees of differentiation: (1) ganglion cells in different stages of development, distinctly recognisable as ganglion cells by their characteristic nucleus and general morphological structure; (2) numerous glia cells of various form and size and glia fibrils; (3) syncytial neuroblast chains consisting of fibres with inserted nuclei, showing a definite axis-cylinder but no myelin sheath, and therefore representing nerve fibres in different stages of development. SCHMINCKE considers that the presence of these syncytial neuroblast layers may shed some light upon the development of fibres within the central nervous system. SCHMINCKE holds that proof has been given in favour of the formation of the peripheral nerve fibres from neuroblast chains, but as yet no proof of a similar origin of the fibres within the central nervous system. For an explanation of this tumour SCHMINCKE goes back to the detachment of a portion of embryonic nerve tissue and believes that the embryonic neurocytes have differentiated along the three lines to form ganglion cells, glia cells, and nerve fibre cells. He suggests that the powers slumbering in this tissue have become active and have succeeded in completing their differentiation. Neuro-gliomata have thus the same origin as gliomata; there being no proliferation on the part of pre-existing ganglion cells, but all the cells of the tumour representing earlier or later stages of development of original indifferent embryonic cells in which the process started. These cells are often far from any normal type.

(b) *Neuroma of the Central Nervous System.*

The literature referring to neuroma of the central nervous system is very scanty and scattered. Early findings of tumours consisting of nerve cells and medullated nerve fibres refer chiefly to small nodules on the surface of the ventricles in hydrocephalus. As the microscopic technique was at the time very deficient, their value has been much discounted, and COURVOISIER, in his monograph, "Die Neurome," 1886, makes no mention of them. Recent observations are almost entirely limited to neuromata of the spinal cord.

RAYMOND (1893), in a case of syringomyelia, found at different levels of the cord numerous small fasciculated nodules in the connective tissue septa of the posterior columns. The fine fibres composing these nodules had the structure of peripheral nerves and were grouped parallel to each other or intertwined. In addition to the central gliosis, there were present gliomata at various levels forming diffuse and circumscribed infiltrations of the white matter. The posterior roots, which were healthy outside the cord, were interrupted in their intra-medullary course by these infiltrations, and in serial sections a direct connection could be traced between the entering posterior roots and the fibres composing the nodules. RAYMOND looked upon the nodules as neuromata of regeneration which had developed as a consequence of the interruption of the centripetal posterior roots by glia tumour tissue.

SCHLESINGER (1895) found similar nodules in two cases of syringomyelia and one such nodule in a case of tabes. In the tabetic cord the nodule was found in the upper cervical region and passed through only six successive serial sections. It was situated at the periphery of the cord lateral to the posterior horn, and was surrounded by a thin layer of dense glial tissue. The interlacing fibres of the nodule were thinner and stained less clearly than the fibres of the surrounding white matter. In the cases of syringomyelia several microscopic nodules were found in the central glious tissue: they were sharply contoured and composed of bundles of very fine fibres showing a spiral arrangement. Numerous elongated nuclei with their longitudinal axes parallel to the longitudinal axes of the fibrils were found in the nodules. Nowhere could any connection be traced with fibres of any of the columns of the cord or of the posterior roots, and in none of the nodules were any ganglion cells present. SCHLESINGER attributed the neuromata to a proliferative process, the result of a long-continued irritation. He came to this conclusion because the nodules were found always in a pathologically changed tissue with a chronic proliferation of the supporting elements.

WAGNER (quoted by SCHLESINGER) produced neuromata experimentally in cats by dividing the anterior spinal roots. The neuromata always developed at the point where the anterior roots left the cord. In one case, where the roots were divided intra-medullarily, the nodules developed within the cord. Similar procedure at the posterior roots produced no neuroma.

SAXER (1896), in syringomyelia, found in the central gliosis numerous nerve fibres, isolated or in bundles, partly in the adventitia of vessels and partly free in the glious tissue. The fibres could be traced to the anterior longitudinal fissure and had the structure of peripheral nerves. In the obliterated central canal in the lumbo-sacral cord were numerous medullated nerves. SAXER ascribed the presence of these fibres to a regenerative process, but admits that he finds it impossible to explain how this had come about. HERVEROCH (1900), also in a case of syringomyelia, BISCHOFSWERDER

(1901), in two similar cases, and Hauser (1901), in three, mention the finding in the central glious tissue of isolated nerve fibres or definite nodules composed of tortuous medullated fibres with the structure of peripheral nerves. In all of the above the nodules were often sharply delimited, and nowhere did the fibres of the periphery seem to be prolonged into the surrounding tissue. Bischofswerder draws attention to the frequent presence of vessels in the centre or at the periphery of nodules, and suggests that this fact may throw some light upon their origin.

Nageotte (1899), in tabes and in a case of hemisection of the cord, has found nerve fibres, isolated and in bundles, in all parts of the pia, but especially near the point of emergence of the anterior roots. Fickler (1900), in a case of compression of the cord, has found medullated fibres filling the anterior fissure from the adjoining pia. The significance of these findings of Nageotte and Fickler has already been referred to in the note on regeneration of fibres in the central nervous system.

Pick (1900) has described nodules composed of unstriped muscle fibres around the spinal cord vessels. Pick had previously, in 1895, described similar formations around the vessels of the pia, and had explained them as circumscribed proliferations of muscle fibres of otherwise normal vessels. Hellich later drew attention to the possibility of Pick's leio-myoma of the pia and cord being true neuroma, which on account of their fascicular structure and elongated nuclei gave the appearance of leio-myoma.

Thomas, Touche, and Jacob (1901) described a case of Pott's disease following a fracture two years before death. The 8th cervical segment was compressed, and in the anterior fissure, immediately above the point of compression, were found very numerous nodules composed of fibres with the structure of peripheral nerves. Small neuromata composed of a few bundles of fibres were found also in the pia round the whole circumference of the cord at this level, and in the lateral column of the right side there was present a small nodule which at one point reached the pia. In none of the nodules could the origin of the fibres be traced, but the writers ascribe their formation without doubt to regenerative processes and believe that the new fibres have their origin from the fibres of the tracts interrupted at the level of the compression. Dercum and Spiller (1901) have described non-myelinated fibres in the pia covering the posterior columns in a case of adiposis dolorosa. The posterior roots were not degenerated and the origin of the fibres could not be traced, but as there was an alteration in the columns of Goll the fibres in the pia might arise from a regenerative process in the posterior roots.

Hellich (1902) has placed the whole question of neuroma of the cord in a new light. In six cases of different affections of the cord he found formations similar to those described by Raymond, Pick, and others. Nerve fibres with myelin sheath and sheath of Schwann could be traced in the adventitia of vessels from the periphery of the cord to the central canal vessels, whence they radiated into Clarke's column. Here and there the fibres develop into nodules which, under a low power, appear as leio-myomata. Hellich considers that they must be looked upon not as tumour formations but as abnormal sensory centripetal nerves.

Rebizzi (1903), in a case of neuroma of the cord, found ganglion cells with abundant formation of new nerve fibres which could be traced to the ganglion cells. Rebizzi thought that a part of a nucleus of grey matter had been cut off in early fœtal life.

Switalski (1903), in the cord of a patient with the clinical history of disseminated sclerosis, states that in addition to the degeneration of the fibre systems there were present numerous neuromata, especially in the lower dorsal and middle cervical segments. The nerve fibres composing these nodules were of very varying thickness, often with varicosities: they had no sheath of Schwann, nor could an axis-cylinder be stained. Oval vesicular nuclei, which gave the nodules a very characteristic appearance, were always present. In the lower dorsal region the nodules were altogether in the grey matter and always in relation to blood-vessels. In the cervical region the nodules were found in the posterior columns and in the pia, and often continued from the pia into the septa. In both regions they lay always in a completely normal tissue, and in spite of very exhaustive examination, Switalski could trace no connection of the fibres composing the nodules with fibres in the neighbourhood. He therefore sees no reason to think that these are neuromata of regeneration. He grouped together from literature eleven cases of true neuroma of the spinal cord, nine of which had appeared in syringomyelia, and thinks that this association of neuromata with syringomyelia points to the possibility of a developmental anomaly or disturbed development accounting for these formations.

Orzechowski (1908), in a case of malformation of the lateral recess of the 4th ventricle together with tabes, found neuromata in the region of the central canal and in the pia of the cord from the 2nd lumbar segment downwards. The fibres which ran spirally round one another to form dense tufts had a delicate axis-cylinder, myelin sheath, and distinct neurilemma sheath and nucleus. In serial sections it could be proved that the pial fibres arise from the anterior nerve roots, for near the emerging anterior roots small bundles of fine fibres could be found passing into the adventitia of the pial vessels or free into pial spaces. The fibres could be traced to the base of the anterior fissure, and formed nodules in the region of the central canal. The distribution of the pial fibres coincides with the localisation of the posterior root affection in the lumbo-sacral region. Orzechowski considers that these aberrant anterior root fibres represent a developmental anomaly.

Reich (1910) investigated eight tabetic cords, and found typical pial neuromata in three cases. Isolated fibres and bundles and nodules were found distributed through the thickened pia, chiefly of the lumbo-sacral cord. No distinction as to the origin of the fibres could be drawn between the isolated fibres, the bundles, and the nodules, and Reich confirms Orzechowski's observations that the fibres arise from anterior roots. He further states that the pial nerve bundles unite together and leave the pia laterally as nerve trunks. He therefore regards them not as aberrant anterior root fibres, but as true anterior roots leaving the spinal cord in an a-typical way. Both ORZECHOWSKI and REICH suggest that the frequent presence of medullated fibres in the pia in tabes represents one of the stigmata of the increased vulnerability of the tabetic cord.

In reviewing these findings of neuroma of the spinal cord it will be seen that all writers refer to miscroscopic nodules that lie in the grey or white matter or in the pia and its septa, that are perceptible in only a few successive sections, and that contain medullated nerve fibres with a sheath and nucleus of Schwann. The nerve fibres are finer than those of the surrounding tissue, and present numerous varicosities. ORZECHOWSKI has classified neuromata of the spinal cord into two groups. The one is related to a regeneration of fibres of the central nervous system. This origin of neuroma is probable where any lesion of the cord or roots is present, causing an interruption of the fibres, *e.g.* FICKLER's case (*spondylitis tuberculosa*), WAGNER's experiments on cats, NAGEOTTE's in hemisection of the cord and in tabes, THOMAS, TOUCHE, and JACOB's in Pott's disease, possibly also in the cases of syringomyelia of RAYMOND, SCHLESINGER, SAXER, HERVEROCH, BISCHOFSWERDER, and HAUSER. The other group includes those cases in which there was no fibre interruption, and consequently could be looked upon not as a reparatory process but as abnormally placed nerve fibres. This interpretation was the more plausible as there were frequently present other malformations. To this category belong SWITALSKI's case in which the neuromata were accompanied by aplasia of the cerebellum, the cases of pial neuromata which must be regarded as aberrant or abnormally placed nerve fibres, and to this group also more probably belong the neuromata found in syringomyelia. ORZECHOWSKI thinks that to the neuromata described by HELLICH as abnormally placed centripetal tracts an independent position may be ascribed on account of their functional character.

II.—HISTOLOGICAL STUDY OF MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.

Introduction.

Clinical History.

We are indebted to Dr R. A. Lundie for the following clinical notes on the case:—

The patient, H. S., died at the age of 30 on 11th November 1909. Her father, on that date, was alive and well, aged 46; her mother had died at 36 during childbirth; and she has four brothers and two sisters all alive and well.

At the age of seven she had "water in the head." Three years later she began to lose power gradually in both legs, the left leg being first affected. This gradually progressed, until at the age of 22 she became bedridden. Urinary troubles began with incontinence and continued throughout life; the bowels were very constipated, and she required aperient medicine regularly. She complained often of headache; her sight was very dim, and she could not see to read. No view of the fundus could be obtained on account of a diffuse opacity of the vitreous. She had often complained of pain in the left side, and had frequent attacks of gastritis and stomatitis.

Post-mortem report (by Dr Harvey Pirie, about 24 hours later):—

Body much emaciated; arms flexed at the elbow and wrist, but flexion could be overcome. Left leg fully flexed at the knee, flexed and markedly abducted at the hip (contracture). The right leg slightly abducted at the hip; fixed in fully extended position. Lumbar spine in position of marked lordosis.

Spinal Cord.—Dura somewhat thickened, especially in the cervical region, the cord as a whole being very atrophied. On the surface no obviously sclerotic patches to be seen, but on section bluish gelatinous patches were seen to involve a large part of the sectional area of the cord throughout its whole length.

Brain.—The medulla, and even more so the pons, show great general atrophy. On section this appeared to be diffuse, there being no appearance of any special sclerosed patches. The cerebellum also appears atrophied; there is no apparent atrophy of the cerebrum, which appears pale on section.

Abdomen.—Intestines chiefly in pelvis, as the lordosis has almost abolished the upper part of the abdomen in its antero-posterior diameter. The large intestine is so shrunken that it is smaller in diameter than the small intestine. The stomach is small and contained coffee-ground-looking material; no ulceration.

Eye.—Posterior half of left globe removed.

Methods.—Portions of the cord, medulla oblongata, and pons were fixed in Zenker's solution and in 10 per cent. formalin solution for the examination of cell and protoplasmic structures, in 96 per cent. alcohol for Cajal's reduced silver method for axis-cylinders, and in 10 per cent. formalin solution with after-hardening in Müller's fluid for medullated sheaths. The paraffin sections were cut at 7μ, and were stained with hæmatoxylin and eosin, Van Gieson's stain, Heidenhain's iron-hæmatoxylin, and Unna's polychrome methylene-blue. Weigert's elastic tissue and Mallory's connective tissue stains were also used. The celloidin sections were stained with the Kulschitzky-Pal modification of Weigert's medullated sheath stain, with Van Gieson's stain, and with the Bielschowsky-Williamson axis-cylinder method.

The following regions were examined in serial paraffin or celloidin sections:—the whole of the pons, medulla oblongata, the 7th and 8th cervical and 1st dorsal segments, and the whole lumbo-sacral cord. Portions from each of the remaining segments of the cord were prepared both for paraffin and celloidin: two segments in the upper and two in the lower dorsal regions being cut in serial longitudinal, frontal section.

The preliminary investigation was confined entirely to the cord. Subsequently the medulla and pons were examined, and as the formations in these regions seemed at first sight essentially different from those in the cord, it is natural that the subject should be considered under the two headings: the one, the spinal cord; the other, medulla oblongata and pons.

I.—SPINAL CORD.

Enormous numbers of nodules of neuroma were found distributed in the cord substance throughout its whole length, except in the upper five cervical and in the 2nd and 3rd dorsal segments. In those segments cut serially (7th cervical to 1st dorsal inclusive, and the lumbo-sacral), nodules could be traced in every preparation, often indeed numerous nodules in each section. All the remaining segments showed definite nodule formation or indications that such had existed.

Throughout the whole of the spinal pia abnormal, medullated fibres were found. In the upper cervical region these were very scattered and cut mostly transversely, so that they appeared as fine dots bordering especially the outer layer of the pia. In the cervical enlargement and dorsal cord they became more numerous and strands of fine fibres could be traced, cut longitudinally or transversely, both in Van Gieson- and Weigert-stained preparations. In the lumbo-sacral cord the pia was infiltrated with fibres forming strands, tufts, and nodules. These were very markedly accumulated in the region of the anterior fissure and of the ligamentum denticulatum, and in the latter situation they formed frequently a nodule as large as the cross-section of the ligament itself. The pial fibres in the lumbo-sacral cord were so numerous that the whole circumference of the pia was seamed with strands of four to twelve fibres cut longitudinally, or obliquely, or transversely, and in the adventitia of the pial vessels they formed an encircling reticulum. It was specially noted that throughout the whole of the pia covering the posterior columns and in the posterior median septum there was scarcely any evidence of any abnormal fibres: the only sections noted as showing such were in the 5th cervical segment and in the lower dorsal cord. These were very few in number and passed through only a few sections.

Most of the previous observations on such fasciculated neuromata have been confined to abnormal fibres or small nodules in the pia and very isolated nodules in the cord substance. ORZECHOWSKI has recorded the existence of very numerous nodules in the pia and in the region of the central canal in the lumbo-sacral cord in a case of tabes with a malformation of the lateral recess of the 4th ventricle. In his description he remarks that it is sufficient to give the details of one segment, as all showed similar characters. In our sections the great variation in the histological picture is amongst its most prominent features, for each serial section showed successive changes, and in preparations, even six or eight celloidin sections apart, the change was so distinct that without the intervening sections it would have been impossible to relate them to one another. It will be concluded from this that the nodules were microscopic: even so large a nodule as that represented in fig. 29 passed, as a nodule, through at most twelve to fifteen paraffin sections. Its formation and breaking up could be traced in two or three sections on either side.

Other points in which the neuromata in this case differ are that, with few exceptions, in those previously described the neuromata, when they existed in the cord substance itself, seem to have been defined, almost encapsuled, by dense glia tissue. Again, many writers have spoken of having been quite unable, even in serial sections, to trace any connection of the fibres of the nodules with fibres of the surrounding parts. Others have definitely traced the nodules to fibres arising in relation to anterior nerve roots (ORZECHOWSKI), or posterior nerve roots (RAYMOND). The nodules present in this case showed no encapsulation with glia tissue, and, almost without exception, the origin of the fibres composing them could be followed for some distance.

The neuromata were present free in the pial spaces, in the walls of vessels of the pia, pial septa, and cord substance, forming either a nodule at one side of the vessel or surrounding the vessel as a more or less thick sheath; and finally, they were present lying quite free in the white and grey matter in definite contiguity with the nervous elements.

The term "neuroma" is here given to all abnormal fibres as well as nodules, for it is evident that the difference between them lies wholly in conditions of space and possibly of time. It is assumed that the fibres that have plenty of lymph space show few intertwinings, while the fibres which have met with any obstruction in their course, *e.g.* from a blockage of the lymph-path, necessarily become twisted and coiled into nodules, the most typical form of which gives the impression of a rolled-up ball of wool cut through the centre (figs. 8 and 29).

It would be quite impossible to give anything like a complete picture of the findings in the different regions. To attempt to do so would be to lose ourselves in a maze of detail, but an effort will be made to convey a clear conception of the chief forms with their structure and mode of formation, the disposition and origin of the fibres composing them, and their relation to one another and to the tissues around.

Before passing to this study it is necessary to refer to other pathological processes present in the cord. The clinical features were those of disseminated sclerosis, and at the post-mortem examination the naked-eye appearances of the cord seemed to confirm this diagnosis, for we have noted that on cross-section the characteristic bluish, gelatinous patches involved a large part of the sectional area of the cord throughout its whole length. Weigert preparations at different levels showed, under low power, areas of sclerosis, but under a higher magnification Weigert-fuchsin preparations indicated that these were not typical patches of disseminated sclerosis, but were rather areas of marked fibrosis.

Within these fibrosed areas were found evidences of neuroma formation, and it was assumed that the fibrosis was an accompaniment or a sequel to the nodule formation. Sections of the cord at certain levels showed a more or less normal structure, with the exception of the presence of small neuromata, either in the vessel-walls or in the cord substance. Such nodules seemed to be the earliest stage of a process which ended in a complete disappearance of the nodule and a replacement, not only of the nodule, but of the previously healthy surrounding nerve tissue by a fibrosis, whilst in the surrounding zone there was a sclerosis comparable to that found in disseminated sclerosis. Between this earliest stage of a nodule in the midst of otherwise healthy tissue and the stage of complete fibrosis of the area there existed all degrees of transition, from a slight thickening of the wall of the vessel, almost invariably present in some relation to every nodule, to a further stage which showed an increasing involvement of the intertwining nerve fibres of the nodule, so that more and more connective tissue appeared amongst them, to a still further stage in which the nerve fibres were compressed and separated by the increasing fibrosis, and a yet later stage, when the fibrosis was so intense as to have left scarcely any trace of nodule formation and only ghost-tubes of former nerve fibres could be recognised. Such interlacing ghost-tubes gave the impression of a fine meshwork which, under high power, at first appeared as very fine capillaries but could be definitely analysed as nerve fibres with scarcely a trace left of axis-cylinder and myelin sheath and peripherally-placed nuclei.

When such a stage was reached there were added two other elements to the picture, the one a very marked infiltration of lymphocyte-like cells accompanying the increased condensation of the fibrous tissue, the other, a very intense glia cell proliferation and hyperplasia in the immediately surrounding nerve tissue. Still later in a few sections a stage was reached in which the fibrosis was not only the most dominant feature, but the only one, for Van Gieson and Weigert-fuchsin preparations showed an extensive area of dense fibrous tissue with few structural elements recognisable except small round cells around the vessels. Even these were frequently absent, and the vessels themselves were completely involved in the fibrosis.

There were in addition areas of true sclerosis independent of those associated with the fibrosis: the most constant of these were the posterior column sclerosis and the area in the direct cerebellar tract.

To complete the histological picture it is necessary to refer to one very constant feature present throughout nearly the whole cord. The intra-medullary course of the posterior roots showed a very marked fibrosis. In Weigert preparations, the posterior root-entry zones were definitely degenerated, and in Weigert-fuchsin and Van Gieson preparations it seemed as if the neurilemma sheath in relation to the posterior roots were continued along the fibres right into the root-entry zone for a varying distance (fig. 53). The anterior nerve roots in their intra-medullary course also showed this change, but to a less extent and less constantly, except in the lumbo-sacral cord (fig. 54).

It will thus be seen that there were several distinct appearances present in the cord:—

(1) The neuroma nodules, and by neuroma again we refer to all stages in the development of a nodule from a few abnormal fibres in relation to vessels or the pial spaces to definite nodule formations;

(2) A fibrosis, in varying degrees of extension, involving areas in which neuromata had developed;

(3) A fibrosis of the intra-medullary portions of the anterior and posterior roots;

(4) The sclerosis which seemed independent of the presence of the fibrosis.

(1) Nodule Formation.

The detailed description of the nodules will be taken up in the following order:—

(*a*) Disposition of the fibres forming the nodules;
(*b*) Structure and mode of formation;
(*c*) Origin of the fibres;
(*d*) Distribution of the nodules.

A convenient introduction to this study will be given by a brief reference to the first microscopic preparations examined. These were Van Gieson-stained paraffin sections from the 1st dorsal segment. It will be remembered that the 2nd and 3rd dorsal segments were almost typical in appearance, and in this segment the normal architecture of the cord was retained with the exception of the presence of two symmetrical areas on either side in the white matter immediately adjoining the concave anterior and antero-lateral margins of the grey matter.

On the right side was the isolated oval nodule represented in fig. 19, and on the left side a larger nodule, not so defined however. Under high power the nodule on the right side was found to be composed of nerve fibres cut transversely, obliquely, and longitudinally (*cf.* fig. 6). The fibres had the structure of a peripheral nerve with axis-cylinder, myelin sheath, and neurilemma sheath, and had only a small amount of connective tissue between them. The nodule was defined from the surrounding healthy white matter by a deeply-staining layer of connective tissue, and through its centre ran a thin-walled blood-vessel.

On the left side the nodule was not defined from the surrounding tissue, and from its outer and anterior aspects radiated fine pink lines which, in their radiation, give off fine fibrils which enclose the adjoining normal fibres of the white matter with a pink zone—giving the impression that a very fine fibrillar connective tissue had in some way secondarily involved the fibres. Under high power the nodule had the same structure as that on the right side, and the pink lines were found to enclose very finely-calibred nerve fibres in which the yellow-staining myelin and central axis-cylinder could be recognised—the deeply-staining pink contours being gained by the increase of the connective tissue around these scattering fibres of the nodule. The vessel, found in relation to this nodule, was situated eccentrically, but in adjoining sections it assumed a more central position.

The very defined nature of the nodule (fig. 19) enclosed by a dense layer of connective tissue, staining intensely pink with the fuchsin, gave the impression, under low power, that we were dealing with a nodule that had arisen in relation to the vessel-wall itself, possibly of the nature of a leio-myoma or of an endarteritic process. Higher magnification, however, revealed the nervous nature of the fibres, and subsequent sections stained with Cajal's and Weigert's methods showed the presence of numerous similar nodules and confirmed their nervous nature.

The first silver preparations examined were a serial set in which the nodule represented in figs. 8 and 29 was found. A description of the very varied nature of the nodules will be attempted later, but meanwhile we may note the beautiful whorl-arrangement of the fibres composing this one.

The first Weigert preparations (figs. 26 and 27) also gave beautiful nodules with a marked intertwining of the fibres. High-power examination showed that the internodal segments were short and irregular, and that the myelin sheath, though staining specifically, was thinner and not so intensively stained as the surrounding fibres of the white matter.

(a) *Disposition of the Fibres forming the Nodules.*

To recognise this it will be necessary to compare Van Gieson, silver, and Weigert preparations. The smallest and simplest neuroma formations are mere strands of fibres running parallel to each other: not strictly straight, but usually sinuous. Such simple strands, composed of from six to twelve fibres, were most frequently met with in the pia lateral to the emerging anterior roots (fig. 39). An increasing complexity in the structure was initiated by an interlacing of the fibres as if these sinuous parallel fibres began to wind in and out amongst each other: such fibres were met with most frequently in the walls of blood-vessels cut longitudinally (figs. 32 and

33). A further stage in their evolution was reached by the convoluted course of the fibres, which seemed to coil spirally round other parallel longitudinal fibres or round a bundle of fibres cut transversely (fig. 38).

From these simpler formations we get all transitions to the tuft-like nodules, in which the interlacing is so dense as to appear an almost inextricable tangle (fig. 30), or to the whorl-arrangement, in which the fibres appear to have some definite plan—the most typical being the ball-of-wool appearance already noted (fig. 29). Sometimes the appearance was that of a ball of wool in which several successive threads had passed in the same direction and then suddenly the winding had commenced in another direction, so as to cross the former in varying degrees of obliquity; successive threads were then parallel for a time, till that direction again gave place to another. The increase in size of the nodule was accounted for by an agglomeration of bundles of fibres which simply repeated the primary groupings. At other times it seemed that each individual thread had wound in an independent direction, as if the ball had slowly revolved during the process of winding. On cross-section of such a ball, the fibres would then present an appearance much more uniformly transverse, while in the former case the fibres would be cut transversely, obliquely, and, even for short lengths, longitudinally (fig. 8).

It is impossible to give anything like an accurate description of the almost infinite variety in the disposition of the fibres. The fibres in their windings could sometimes be followed for a considerable distance, and at other times they seemed to bend at very sharp angles, often at right angles. The ball-of-wool appearance, in some form or other, was characteristic of the larger nodules—whether they were looked at, as it were, from the surface or on section.

(b) *Structure and Mode of Formation of the Nodules.*

Structure.—Van Gieson sections.—We have already indicated that by simple nuclear staining and superficial examination the nodules might have been mistaken for leio-myomatous new formations. Under a higher magnification, the fibres composing the nodules were found to have the structure of the peripheral nerves, differing from these only in the closer disposition of the neurilemma nuclei and the finer structure, in general, of the fibre. Longitudinally cut fibres were stained yellowish-green, with a central thread—corresponding to the axis-cylinder—taking sometimes the pink stain of the fuchsin or the dark stain of the hæmatoxylin, and with a very fine pink line which at frequent intervals showed an elongated nucleus in relation to it (fig. 6). Transversely cut fibres appear as discs with a central point—the axis-cylinder—and an outer zone staining homogeneously yellowish-green, and each with a pink ring which gives the disc a very sharp contour (fig. 6), and with an occasional nucleus applied to it. In nodules with fibres more closely arranged than in fig. 6, the cross-section of the fibres was angular and flattened from pressure.

Between the fibres was a varying amount, usually a very slight amount, of connective tissue.

The most striking feature of the nodules was the very characteristic and numerous nuclei. In some nodules they were more numerous than in others (*cf.* figs. 19 and 20). In all they were elongated on longitudinal section, with blurred ends, and with their long axis parallel to the long axis of the fibre. Further, the nucleus stained intensively, and a very distinct network and membrane and closely distributed, fine, chromatin granules could be made out, but, except in a few, no nucleolus. The cylindrical shape of the nucleus distinguished it from the oval nuclei of the endoneurium and of the endothelial cells, and they were further recognised by their arrangement and relation to the fibres. Sometimes, especially in the fibres breaking off from the nodules, long bands of fibres could be resolved simply into long stretches of nuclei, some of which showed a constriction in the middle. The nuclei belonging to the connective tissue stained less deeply, their longitudinal axis was not always parallel to the fibre, but often transverse, and further, they frequently showed nucleoli. The endothelial nuclei, which again might cause confusion, are larger, oval, less deeply stained, usually with nucleolus, and closely related to a lumen in which red blood cells could be recognised. It was impossible by means of any of the stains to distinguish the nerve fibre nuclei from the nuclei of the unstriped muscle fibres in the vessel-walls.

Cajal's silver stain.—The fibres stain intensely black and the longitudinal fibres show numerous irregularities and fine varicosities on their course. From the thicker fibres branch off delicate twigs, often at a sharp angle, and these fine twigs, twining round larger fibres, frequently end in a homogeneous bulb—similar to Cajal's *cône de croissance.* In the vessel-walls, especially of the smaller vessels, the fibres form a plexus of fine fibres with branchings ending in homogeneous cones or rings (figs. 10–12). Along the course of the fibres are numerous elongated nuclei, and in relation to the transversely cut fibres are similar nuclei showing a circular outline. Both on longitudinal and transverse sections, the nuclei show a very intimate relation to the axis-cylinder (fig. 8).

Weigert's medullated sheath stain.—The larger nodules under low power stain almost as deeply as the surrounding fibres of the white matter; under high power this is shown to be due to their very close disposition, for the individual fibres are much more faintly stained than normal fibres. It is thus seen that the fibres are made up of elongated, often bulging cylinders, with a very narrow connecting bridge: the cylinders are longer in the darker stained fibres and shorter in the faintly stained, and the latter are best seen in the walls of vessels forming a reticulum (figs. 13 and 25). When the strands of fibres are cut transversely, there are numerous fine points amongst the larger cross-sections: these points correspond in all probability to the connecting bridges between the cylinders. The fibres composing the strands are in all cases much finer than the fibres of a peripheral nerve, or even of the nerve roots.

The further structure of the nodules will be indicated in studying their mode of formation.

Mode of Formation.—In order to study the mode of formation, serial sections of very numerous nodules were investigated. The Weigert preparations were the most useful for this purpose, but silver and Van Gieson sections gave very valuable confirmatory results; the latter being specially helpful in indicating the mode of termination of the fibres. The method adopted was to trace such a nodule as that represented in fig. 35, stained with Weigert's method, or fig. 29, stained with silver, both upwards and downwards as long as any trace of it could be noted. The first nodules investigated were those in the above figures, and it will be convenient to take them as representative of a very large number of nodules which could with certainty be confirmed to have a similar origin and extension.

The large wedge-shaped and oval nodules represented in fig. 35, lying in the pia opposite the ligamentum denticulatum, and extending inwards from the periphery, when traced downwards by means of Weigert preparations, were found to change rapidly. The fibres diminished in the peripheral mass, and the nodule increased in size in the lateral vessel, and, later, was connected with the pia by means of only a few fibres. Lower still these were absent, and the nodule, still in relation to the vessel but diminishing in volume, was found on the border of grey and white matter (fig. 36). In the next sections it was independent of the vessel (fig. 37), and its fibres gradually unweaving, as it were, from the nodule mass, became lost in the meshwork of fibres of the grey matter; no definite connection between them could be traced. In the final section, only two or three strands were present, forming a very loose network of interlacing fibres, which in the next section could not be distinguished from the normal fibres of the part. Throughout its course from the periphery the fibres were found intertwined, and there were attempts at whorl-formation with strands of six to twelve parallel fibres.

If this series is traced upwards, it is found that the nodules which lie partly parallel to the periphery of the cord and partly at right angles (fig. 35) are wholly within the pia—forming one long elongated nodule in the centre, of which at one end a vessel is cut transversely. This elongated nodule shows many parallel strands and intertwining fibres, and can be traced in higher sections nearer and nearer to the anterior roots, the fibres becoming more parallel (fig. 39) and slightly more deeply stained as the emerging anterior root zone is reached. Here the appearance of the bundle of fibres conveys the impression that an anterior root bundle, instead of passing directly outwards, has curved round into the pia laterally. Going back on the former figures, we see that it has travelled either in the pial spaces or in the vessel-walls till it had been arrested opposite the ligamentum denticulatum, that it there passes inwards along the lateral vessel, till it reached the zone bordering the grey matter, into the general texture of which it had finally unwound its fibres. The successive stages of this evolution may be followed in figs. 35–39.

It will be necessary later to note the exact point of origin of these fibres, which could thus with certainty be traced into relation to the emerging anterior root zone. Meanwhile, having indicated that bundles of fibres have passed laterally in the pia from this region, we pass to observe similar bundles passing ventrally in the pia, and curving round the antero-mesial border of the white matter into the anterior fissure.

The large nodule, represented in fig. 29, stained with Cajal's axis-cylinder stain, when traced downwards, showed that it retained its whorl-arrangement and its size unreduced through several successive sections. This seemed to indicate that it had an elongated spindle-shape rather than a circular form. It then gradually lessened in diameter, and almost suddenly showed a commencing cleft which, in later sections, became almost complete. In each of the two nodules thus formed, there was a small vessel cut obliquely, an indication that the larger nodule had been in relation to a vessel and that this division was due to its branching. The two smaller nodules lasted through only two or three sections, and broke up into radiating fibres just at the border of the grey and white matter. Some of the fibres took the course almost exactly of fibres of the normal anterior root bundles, but none could be traced to the periphery of the cord. These radiating fibres are similar to those described earlier as finely calibred fibres with a pink outline of connective tissue.

If this nodule is traced upwards, it is found that it lessened in volume more rapidly, and in eight or ten paraffin sections had assumed the shape of a wedge in close relation to a vessel. In successive higher sections the commissural vessels, as they curved into the grey matter from the base of the anterior fissure, contained very numerous strands of fine fibres (fig. 31). These rapidly diminished in number in the anterior fissure, and in higher sections only two strands, composed each of from four to six fibres, could be found, and these were followed in the pial vessels between the anterior fissure and the converging anterior roots. A linking with anterior roots could not be traced in this case, but in numerous others it could with certainty be confirmed that the fibres seemed to emerge in the immediate vicinity of the anterior roots. These, the two first nodules which came under observation, stained respectively for medullated sheath and axis-cylinder, were typical of large numbers of nodules in the grey and white matter.

It is necessary to supplement this description by referring to Van Gieson-stained preparations. These showed that the fibres, immediately on their leaving the region of the anterior roots, had a similar but more delicate structure and an increased number of nuclei. The pia, especially opposite the ligamentum denticulatum, showed even more fibres than in Weigert preparations. Figure 22 represents the same nodule as that just traced serially (fig. 35), and shows the very large number of nuclei related to the fibres. Similar nodules in relation to a lateral vessel (fig. 20), and to a commissural vessel (fig. 21), could be followed in a manner exactly comparable to those already described, the strands of fibres in the commissural vessels in successive sections showing the increasing intertwining and nodule formation of fig. 21.

The pial fibres could thus be stated to arise from the region of the anterior roots and most probably only from their immediate vicinity. They then pass rapidly, laterally or medially, and during their transition undergo a change in disposition and structure. Becoming more closely intertwined, by the time they have reached the mid-point of the lateral surface they have assumed a nodule formation. The fibres passing ventrally seldom assume this compact form till they emerge from the base of the anterior fissure, but in the region of the central canal they often form a large, dense nodule (fig. 44). As the fibres pass from the region of the anterior roots they become finer, stain less intensely, and show a very distinct segmental structure, the segments being in the form of bulging cylinders or varicosities with connecting bridges (fig. 13). The very fine character of the fibres around the vessels at the base of the anterior fissure is well brought out in fig. 42, where the central vessel is seen dividing, and the fibres pass in later sections along commissural vessels into the grey matter of either side, and along the branches to the anterior (fig. 41) and lateral (fig. 43) horns as leashes of fine fibrils.

The fibres do not always pass to the base of the anterior fissure, but sometimes inwards along the lateral branches of the anterior fissure vessels. Fig. 40 shows a wedge-shaped mass of fibres passing into the direct pyramidal tract near its anterior mesial margin. These fibres could be traced along this vessel, ultimately to form the nodule (fig. 27). This nodule, when traced downwards, broke up into strands of fibres in the meshwork of the grey matter.

The fibres passing laterally in the pia could be traced passing inwards along almost every lateral vessel between anterior and posterior roots. If one section were taken and attention were concentrated on a strand of pial fibres in relation to the anterior roots, in successive sections that bundle could be followed as has been done above. Simultaneously, moreover, new bundles rise in their place cut transversely or longitudinally, and these, in their turn, can be followed to lateral vessels of the cord. We thus frequently get a radiation of the fine fibres in the peripheral vessels, or indications, marked by a fibrosis of the vessels, that such fibres have been present. The impression is given that if we could restore the picture to an earlier stage intra-medullary fibres in bundles or nodules would radiate inwards along all the lateral vessels to the circumference of the grey matter.

The pial fibres, passing inwards along peripheral vessels, result in the formation, speaking generally, of nodules within the white matter, and these, running horizontally, have their greatest diameter in transverse sections of the cord (fig. 35). The fibres passing along central vessels form nodules in the grey matter, and these have their long axis more oblique or parallel to the long axis of the cord (fig. 29). Strands of fibres also in the pia cut longitudinally when traced upwards frequently become more oblique or longitudinal as they reach the anterior roots.

The fibres of the nodules in relation to central and peripheral vessels frequently intermingle. As a rule by this time a very large nodule has formed at the base of the anterior horn, and from this nodules have branched off, with the vessel branches, to the different areas of the grey matter. When the secondary fibrotic changes, following the nodule formation, have not occurred to any marked extent, a very beautiful interlacing of the fibres or intermingling of fibres from different nodules takes place at the borders of white and grey matter. Such appearances are best understood from Van Gieson sections, where the fibres of each nodule, as it were, become unwound and the disentangled threads of each nodule intermingle to form an inextricable maze of fibres that break up at their extremities into whorls of individualised nucleated elements. Many of these isolated elements in the loose meshwork are distinctly the cut portions of these terminal strands, but many could be conclusively proved to be isolated fusiform nucleated cells. Sometimes these fusiform elements unite end to end to form chains of cells with imbricating processes (figs. 45, 46).

In the terminal ramifications of the fibres of each nodule all the transitions between nucleated fibres, chains of nucleated cells, and nucleated fusiform cells could be followed. The calibre of the nucleated fibres is greater than that of the fibres with which they are in continuity (fig. 45). In each nucleated fibre there can be recognised a distinct axis-cylinder, a homogeneous yellowish-green surrounding layer, with a fine pink outer border. In the fusiform elements forming the chains are darkly stained elongated nuclei, and a homogeneous—with polychrome-methylene blue—slightly granular protoplasm, and in some a faintly stained filament can be definitely demonstrated lying along one side of the nucleus or extending from its opposite poles. This appearance was more evident in preparations from the medulla and pons, and its significance will be dealt with in discussing the nodules in these regions.

In the structure of the compact nodules we noted that there was little interstitial tissue, but here, in the breaking up of the nodules, the fusiform elements were intermingled with an increasing fibrosis. As these elements scatter in this fibrous tissue they become more and more unrecognisable, and progressively may be confounded with connective tissue elements. It is only when this fibrosis is absent or very slight that the specific nervous nature of the nucleated chains and fusiform cells can be recognised.

(c) *Origin of the Fibres forming the Nodules.*

The majority of the nodules, it has just been stated, can be traced to fibres passing ventrally or laterally from the immediate vicinity of the emerging anterior nerve roots. It will now be necessary to discuss one or two points which are of importance in relation to the possible precise point of origin of the pial fibres so traced.

Obersteiner thus describes the histological structure of the posterior root where it enters the cord: "At the point where the posterior root pierces the pia mater it is constricted, and sometimes to a marked extent." "This reduction in size takes place entirely at the expense of the myelin sheath. Consequently, when stained by Weigert's method, the root at this point remains colourless, and a bright band, usually convex on the outer side, is seen traversing the root at the point of constriction." LEVI has shown that the posterior root fibres lose their neurilemma sheaths and become imbedded in neuroglia within the spinal cord in the cervical segments, just as they enter the cord in the dorsal segments, but outside the cord in the lumbo-sacral segments. He has further shown that the *Aufhellungzone* or *Ablassungzone*—the zone which stains so palely with the Weigert method—coincides with this transition line, and that here the fibres become narrowed to form the so-called "constriction zone" or ring of Obersteiner. LEVI, ORR and ROWS, and others have looked upon this point as the "locus minoris resistentiæ" of the fibre, and have ascribed to it considerable importance in the pathogenesis of tabes.

A similar *Ablassungzone* has been scarcely recognised for the anterior nerve roots, but ORZECHOWSKI in a case of tabes, with the development of numerous pial neuromata, found that the abnormal pial fibres were present only in the lumbo-sacral segments and almost exclusively in the neighbourhood of the anterior roots. He noted that the position of the *Ablassungzone* in the anterior roots changed in different segments, even of the lumbar and sacral cord, and that all the abnormal pial fibres could be traced to arise from that point of the anterior root fibres peripheral to the *Ablassungzone*, wherever it might be situated. As a rule, it was in the deeper layers of the pia or just at the boundary of pia and the glia border layer.

A very prolonged study of our preparations at all the levels of the cord was carried out with the view of tracing, if possible, the point of connection of the fibres, the intimate association of which with the anterior roots at once suggested their origin from them.

In numerous segments in which the secondary fibrosis had not too greatly involved the intra-medullary course of the fibres, it was found that the emerging anterior nerves, before reaching the pia, show at a definite point of their course a faintly-staining zone (fig. 48). At this point there is a considerable attenuation, possibly even an interruption, of the myelin sheath. That this is not due to overdifferentiation is proved by the staining of the fine abnormal fibres gathered together in the pia. This transition zone differs from that in the posterior roots (fig. 47) in that it is not a constriction zone, for the fibres of each group pass parallel through the *Ablassungzone* before they radiate into the root bundle. Further, the point where the myelin sheath becomes attenuated is not the same for each group of fibres, so that a line passing through the *Ablassungzone* of the anterior roots in any one section is a widely-extended and undulating one.

In the upper cervical segments this *Ablassungzone* was almost invariably found entirely within the glia border layer, or just on its intra-medullary border. In the dorsal cord, in those segments sufficiently healthy to allow it to be traced, it was found just on the borders of glia border layer and pia. In the lumbo-sacral cord the increasing fibrosis in the emerging root zone made it difficult to determine with certainty any regularity in its position. But it could be proved to be an irregular line sometimes within and sometimes without the outer border of the glial border layer.

In consequence of the existence of this *Ablassungzone* the intra-medullary part of some anterior nerve roots is divided into a central and peripheral part. The root bundles outside the pia are cut transversely, so that the emerging roots would seem to take very rapidly a course in the longitudinal direction of the cord. The anterior nerve bundles have thus a central part, an *Ablassungzone*, and a peripheral part. By the varying position of the *Ablassungzone* the length of these portions of the nerve is altered. If it lies within the glia border layer, then the peripheral part is lengthened, and if it lies in the pia the peripheral part is very short.

In Weigert-stained preparations, amongst the thick root fibres—those immediately peripheral to the *Ablassungzone*—small bundles of fine fibres could be traced, either free or disposed around the vessels. The anterior root artery, cut transversely immediately lateral to the nerve root, was almost invariably in the lumbar cord surrounded by a reticulum of fine fibres (fig. 13). A passage of fibres from anterior roots to this vessel could never be traced, for an anterior root bundle seemed to divide and enclose the vessel. In other preparations the *Ablassungzone* of one bundle was unrecognisable and its place was taken by a fibrosis, within which could be traced an interlacing of fibres which were finer than the intra-medullary fibres with which they appeared to be continuous. From this interlacing, in which fibres were cut transversely and longitudinally, there seemed to be a definite gathering up of fine fibres to pass into the pia. A very clear picture of such a group of fibres passing laterally is seen in fig. 39. A careful comparison of numerous such pictures made it not unreasonable to assume that here the *Ablassungzone* had been intra-medullary, and that from the point immediately peripheral to it the pial fibres had arisen, the secondary fibrosis involving the intra-medullary course of the fibres.

The direct association of the abnormal pial fibres with the anterior nerve bundles immediately peripheral to the *Ablassungzone* seemed to be confirmed by further study of the preparations. The connections were often very few, but they must often have been removed by the increasing fibrosis.

It must further be noted that the fibres of several nodules, situated midway between the grey matter and the periphery of the cord, seemed as if they unwound into strands directly continuous both centrally and peripherally with anterior root bundles. A careful examination, however, of serial sections made it evident that such nodules also had formed in relation to vessels passing into the cord alongside the emerging nerve bundles, and that the nodule formation took place just as in relation to other lateral vessels. The close proximity of the emerging fibres to the nodule made it appear as if they entered into and emerged from the nodule. On several occasions, however, the emerging strands showed a definite tortuosity in their course.

According to NAGEOTTE (p. 726), the *Ausgangspunkt* of tabes is formed by an area of transverse neuritis, situated near the point where the roots penetrate the dura. It has already been pointed out that a retrograde degeneration may occur in the anterior roots and that from the point where this may be arrested the anterior roots may regenerate new fibres. If this degeneration ascend to the point where the neurilemma sheath is lost, the new fibres tend to stray into the pial spaces and vessels and to form neuromata, instead of passing onwards in the old sheaths of Schwann to form leashes of young fibres in the degenerated tube.

A careful examination of the cord throughout its whole extent has proved the almost entire absence of any degeneration in the extra-medullary portions of the anterior nerve roots. The nerve roots were retained in most of the segments, especially in those in which the nodules were most numerous, and the pial fibres emerging laterally and medially from the vicinity of the emerging zone were in no way associated with an extra-medullary retrograde degeneration arrested at the point peripheral to the *Ablassungzone.* A regenerative process, in the sense of NAGEOTTE's findings in tabes, can, therefore, not be assumed as an explanation of the pial fibres.

In only one funiculus of the extra-medullary anterior roots was an appearance noted which might be interpreted as a regeneration of new fibres within the old sheaths of Schwann: this passed through several successive sections. It must, however, be stated that the radicular portion of the root was not examined, but, were a retrograde degeneration to be accepted as an explanation of the new pial fibres, it must of necessity have extended to the *Ablassungzone* and been evident in the retained roots. It must further be mentioned, ere leaving this question of the relation of the precise point of origin of the abnormal pial fibres, that the intra-medullary portion of the anterior roots frequently showed a myelin degeneration. This process was secondary to the fibrosis accompanying the nodule formation and will be referred to in a later section.

(d) *Distribution of the Neuromata.*

It has already been noted that with the exception of the upper five cervical and the 2nd and 3rd dorsal segments, no part of the cord was free from nodule formation. The first indication of such in the 6th cervical segment occurred as a very small nodule in relation to a vessel of the anterior roots. The few fibres composing this nodule could be traced in serial sections to fibres passing in from the periphery along this vessel, and in subsequent sections the nodule broke up into fibres within the general substance of the grey matter. The normal structure of the white and grey matter was retained, but at the postero-lateral angle of the anterior horn a slight amount of fibrosis indicated that nerve fibres had been present: under high power this was confirmed, as ghost-tubes could be distinctly recognised as nerve fibres. In the opposite horn, at each angle, antero-mesial, antero-lateral, and postero-lateral, a similar change had evidently occurred, and the vessels leading to these points from the periphery showed a commencing fibrosis. It was evident that fine fibres had passed, in the adventitia of these vessels, to the angles of the grey matter and had there broken up, to disappear finally with the onset of the fibrosis. With the exception of this very minute nodule and the indications that other abnormal fibres had been present, this segment was quite normal. The pia showed a few fibres cut transversely and obliquely, and there was a certain amount of infiltration of the pia and of the vessels of the cord, especially of the grey matter, with lymphocytic-like cells.

In the upper part of the 7th cervical segment the nodule formation had already become much more evident. A large pear-shaped nodule was present in the centre of the anterior horn on one side: this extended through nearly twenty paraffin sections, and several of the vessels distributed in the grey matter show leashes of fine fibrils in their walls. Throughout both this and the next segment, almost every section showed beautifully that most of the vessels in the grey matter contained these delicate fibres. Figs. 10–12 and 29–33 are all taken from these two segments, in which the nodule formation had taken place more in relation to the central than to the peripheral vessels. In the adventitia of the vessels, silver preparations revealed a fine plexus of fibres with numerous lateral branches and fine terminal bulbs or clubs (figs. 10, 12): only a few ring-forms could be traced. These appearances must be looked upon as equivalent to Cajal's *cônes* and *anneaux*. When a vessel bends or divides, the leash of fibrils in its walls curves round or branches off along the two divisions (fig. 33). In relation to many of these nodules, the secondary fibrosis had involved specially that part of the anterior horn bordering the white matter. Weigert-stained preparations also showed that there was an involvement of the myelin of the intra-medullary anterior roots, but silver preparations brought out the integrity of the axis-cylinder (fig. 34).

In the 1st dorsal segment, there was a return to the more normal architecture of the cord, with a few more or less isolated nodules and a commencing fibrosis involving the terminal ramifications of the fibres of the nodules. The 2nd and 3rd dorsal segments were practically normal with the exception of the slight sclerosis to be noted later.

The segments from the 4th dorsal to the 1st lumbar inclusive showed a very uniform change, uniform in character though not in degree. At numerous levels the only nodules present were found in the centre of the grey matter in the form of an extensive plexus round a vessel as its centre. In other sections, leashes of fibres could be traced from such nodules along all the vessels to the circumference of the grey matter—passing to anterior and lateral horns and to Clarke's column. Even where the structure of the cord was retained, there was an indication of fibrosis in relation to the nodules, and as this advanced the nodule gradually disappeared, leaving only a few fine fibres around a vessel. Pial fibres are present, in limited numbers, around the whole lateral cord: and a few nodules could be traced in the pial septa.

The lumbo-sacral cord proved to be a perfect store-house of neuromata. Nodules could be traced in every preparation without exception, and the histological picture, formed by the combined nodule formation, the accompanying fibrosis, the sclerosis, and the fibrosis of the intra-medullary course of the anterior and posterior roots, changes not only in every segment but in every section. Throughout this region the pia also was perfectly black, in Weigert-stained sections, with fibres cut longitudinally, obliquely, and transversely, and with almost every vessel there was a radiation inwards of fibres and more or less marked nodule formation or indications that such had existed. The anterior fissure showed numerous strands of fibres, which were continued in the walls of the commissural vessels to the base of the anterior horn, where they formed a very large nodule from which several smaller nodules branched off along the different vessels. There was frequently, too, a coalescence, at the junction of white and grey matter, of fibres of the nodules in relation to central and peripheral vessels.

In the 2nd sacral segment, the region of the central canal was occupied by a large nodule composed of closely-disposed fibres with numerous nuclei (fig. 44), and on either side the central vessels showed small nodules in the connective tissue surrounding them. The grey matter of the antero-mesial and antero-lateral groups of cells on one side was also occupied by a dense, compact nodule, from which fibres radiated to intermingle with fibres formed in relation to the peripheral vessels. The nodule in the region of the obliterated central canal passed through the whole of the remaining sacral cord; from it fibres radiated in all directions into the grey matter. In the pia were numerous strands of very delicate fibres, but no further nodules could be traced.

(2) Fibrosis associated with the Nodules.

The neuroma formation was not the only pathological process present in the cord, nor was it the most dominant feature. Throughout the pia it has been noted that there was a definite thickening and at numerous levels a marked cell-infiltration, the whole suggesting that at one period there had existed meningitic processes. This process had spread along the adventitia of nearly all the vessels of the antero-lateral cord, and was specially marked at the base of the anterior fissure. The posterior roots were similarly involved in the posterior root-entry zone throughout almost the whole extent of the cord, and the anterior nerves in the intra-medullary root-emergent zone at numerous levels. The upper five cervical and 2nd and 3rd dorsal segments were alone free from this change, and even they, in the 5th cervical and the dorsal segments, showed the change in the posterior root-entry zone to a slight extent.

The question of the sequence of the pathological processes naturally at once arises in the mind. Schlesinger related the neuromata in his cases to a proliferative process, the result of a long-continued chronic irritation. There is abundant evidence of such a chronic irritation in this case, but a prolonged study of individual segments confirmed the first impression that the fibrosis was secondary to the nodule formation. Every nodule, almost without exception, could, by means of serial sections, be definitely related to a vessel. In segments such as the 6th cervical and 1st dorsal, where individual isolated nodules were present and the normal structure of the cord was otherwise retained, the nodule formation was the only abnormal appearance. Such isolated nodules were lying within the adventitia of medium-sized vessels, the walls of which were scarcely altered in structure (fig. 6). Other sections showed similar nodules, with a commencing thickening of the vessel-wall, not only of the vessel in which the nodule was present, but to a lesser extent of all the vessels of the cord. The lower part of the 6th cervical segment in Weigert-fuchsin preparations gives the appearance, under low power, of a normal cord with the vessels, even the capillaries, markedly prominent, owing to the slight thickening of their walls. At a slightly lower level, where a small nodule is evident on one side and a few abnormal strands on the other, the angles of the grey matter are picked out by a commencing fibrosis.

When we pass to the 7th and 8th cervical segments, where the nodule formation in the anterior white matter is marked, this stain shows diffuse pink areas, within which are strands of myelinated fibres, many of which are on the point of disappearance even with the most careful differentiation. A comparison of numerous sections shows that these areas of fibrosis are associated with the breaking up of nodules, and that these have been first involved in, or have at least first yielded to, the compression of the increasing fibrosis and the influence, toxic or otherwise, which first called it into play.

In such sections, when the fibrosis is not sufficiently dense to have involved all the structural elements, there is present a meshwork of fine fibres which suggests the presence of capillaries running in all directions. These are, however, finely-calibred bands, recognised as nerve fibres by the yellowish staining of their protoplasm, the occasional faint trace of axis-cylinder, and the fact that they never contain any red blood cells.

With the increasing fibrosis the pia, pial septa, and grey matter all show an intense perivascular infiltration with cells, whilst in the areas of fibrosis such cells form small accumulations and extend into the surrounding nerve tissue. Most of these cells are of the lymphocyte type, with a darkly-staining nucleus in which no definite structure can be recognised, and with a very narrow zone of protoplasm. Some cells, slightly larger than these, are also present, with an oval nucleus, placed to one side, in which the chromatin network can be recognised, especially with polychrome methylene-blue staining. A few plasma cells, with characteristic *radkern* nucleus and metachromatic-staining protoplasm, are scattered amongst the other cells.

Glia Cells.—In the zone of extension of the fibrosis, an intense glia-cell proliferation and hyperplasia have occurred (figs. 7 and 49). The cells contain oval or irregular nuclei, which are much larger than those in normal glia cells and are situated at the periphery of the cell. The nucleus stains darkly but the chromatin network is distinct, with large nodule points, often a distinct nucleolus, and always a sharply contoured membrane. The protoplasm varies in amount: in the smaller cells it is homogeneous, of very varied shape, and with very fine processes; in the larger cells it assumes an angular or star-like form, and from the angles pass thick ramifying processes which form a network enclosing in its meshes numerous lymphocyte cells. Many of the glia cells are in close relation to vessel walls, especially capillaries. It is in this zone of advancing fibrosis that there are found elements the interpretation of which tends to cause considerable confusion (fig. 7). The young fibroblasts are in appearance very similar to the fusiform cells which arise from the terminal ramifications of the nucleated tubes, especially as the latter undergo a fibrous transformation.

Ganglion Cells.—To a remarkable extent the ganglion cells were preserved in the grey matter, which had not been encroached upon by the fibrosis advancing from centre and periphery. The majority of the cells were altered in character, but many apparently healthy cells were present. In other sections few of the cells failed to show changes: chromatolysis in all stages, from a slight central or peripheral removal of Nissl's granules to their entire absence, vacuolation of the cytoplasm (fig. 50), eccentric position of the nucleus, and all stages of atrophy of the cells. A few cells were found which, even with very complete differentiation, showed a diffuse staining and fusion of the granules.

Throughout the whole dorsal cord below the 3rd dorsal segment, this fibrosis is present to a greater or less extent. Sections at various levels show that the central canal is involved and that the change has extended to the commissural vessels on either side, thence to the centre of each grey matter, from there has passed forwards to the anterior horn, outwards to the lateral horn, and backwards to the posterior. When this fibrosis was very marked the grey matter in Weigert-fuchsin sections was picked out in pink. In the adjoining lateral and in the posterior columns there was a varying degree of sclerosis with markedly fibrosed vessels. The posterior columns showed also a striking degree of fibrosis in the posterior root-entry zones. From this severe degree of involvement of the grey matter there were all transitions to the sections which showed only a slight nodule formation and only a trace of commencing fibrosis.

It is when we reach the second lumbar segment that the probable sequence of the processes becomes evident. Weigert-fuchsin sections at this level (figs. 51 and 52) show on both sides finer or thicker fibrous strands passing from the periphery of the cord to the borders of the grey matter, there to expand into a loose meshwork of pink-stained fibres and not involving to any marked extent the grey matter, the cells of which stand out clearly. In the formatio reticularis, on one side, there is a very evident area of fibrosis, with the remains of a nodule, the connections of which with the periphery can be traced even in the thickened lateral vessel. On the opposite side (fig. 52), a dense area of fibrosis occupies the base of the anterior horn, stretches amongst the antero-mesial group of cells and laterally to the postero-lateral group, where the remains of a whorl of fine fibres may still be recognised. Pial septa and vessels throughout the segment show a very marked thickening.

Similar changes are present in relation to all the nodules throughout the lumbosacral cord, the variations depending on the extent and distribution of the fibrosis. A symmetrical involvement of the grey matter on opposite sides is frequent, and a similar symmetry has been noted in relation to the lateral columns, which were often mapped out by fibrous strands. In the 3rd lumbar segment, the markedly thickened vessel represented in fig. 16 can be traced throughout its whole extent from the anterior fissure, curving into the grey matter, and passing to the neck of the posterior horn. In its course it is surrounded by dense masses of deeply-staining round cells, and a small area of calcification was associated with this accumulation. Below the 5th lumbar segment, the secondary involvement of the strands and nodules was very much less marked.

(3) Fibrosis of the Intra-medullary Portions of the Anterior and Posterior Nerve Roots.

This change in relation to the anterior nerve roots was constant throughout the lumbo-sacral cord, was very irregular in the dorsal cord, and was again present in the 7th and 8th cervical segments. In the anterior root-emergent zone the divergence peripheralwards of the bundles of fibres was much wider than the normal: definite bundles seemed to pass to the antero-mesial angle of the anterior columns and even posterior to this angle, and emerging bundles radiated outwards to a point considerably more than half way to the ligamentum denticulatum. The whole of this root-emergent zone was involved at certain levels in a fibrosis which gave to longitudinal fibres a deeply-staining pink outline, and to transverse fibres just within the pia a sharp pink contour, for each individual fibre was separately enclosed. The myelin sheath of such fibres was frequently degenerated as far as the fibrosis extended, but silver preparations showed that the axis-cylinders were preserved. This accounts for the absence of degeneration in the extra-medullary portion of the anterior roots in spite of the degeneration within the cord. Sometimes the whole anterior root-emergent zone showed this change; at other times only individual bundles of fibres (fig. 54), along each of which it seemed as if the neurilemma, together with a layer of the pia, had been continued inwards. The extra-medullary portion of the root did not share in this fibrosis.

The change in the posterior roots was even more striking and constant. Fig. 53, taken from the 7th cervical segment, shows that the fibres forming the compact bundle of the posterior nerve root give no indication of a constriction zone, but are continued within the cord for a considerable distance, retaining their neurilemma sheath and nucleus and, as in the anterior roots, carrying in, as it were, round each fibre a layer of the pia, with which the neurilemma sheath usually blends at the ring of Obersteiner. Individual fibres can be traced through the posterior root-entry zone almost to the edge of the posterior horn, and reflex collaterals, with this structure, as far as the base of the anterior horn. The extra-medullary root gives the impression of having been carried right into the cord substance and, intra-medullary, differs only in showing an increased interfibrillar tissue with more numerous nuclei. Between, and on either side of, the longitudinal entering strands cross-sections of fibres show an involvement in the fibrosis, as if fine fibrils of connective tissue had enclosed them in a reticulum. An area of the posterior columns, with nucleated fibres mostly cut transversely, is situated almost invariably just to the inner side of the fibrosed root-entry zone.

In longitudinal sections of the cord, the entering posterior root fibres can be traced for fully one centimetre: the fibres show neurilemma sheath and nucleus and an increased interfibrillar tissue. The nuclei in relation to the fibres tend to assume a position actually within the contour of the nerve fibre, and the nucleated fibres end in direct continuity with normal non-nucleated fibres of the posterior columns. No definite fusiform elements could be traced in relation to the terminations of these nucleated fibres.

Weigert-fuchsin preparations show that very many of the fibres in the posterior root-entry zone and in the areas mesial to it are degenerated; in some nerve fibres only a faint shadow of myelin is present. That this again was not due to over-differentiation was proved by the presence of the very fine fibres in the pia immediately anterior to the posterior roots. Under low power, the posterior root-entry zone stood out clearly as an area of diffuse fibrosis, continuous with an oval area immediately internal to it, which was probably the continuation upwards of the root-entry zone of lower levels.

The 5th cervical segment showed only a slight trace of this fibrosis in the posterior root-entry zone, but in the area internal to it were numerous nucleated fibres, each with a delicate pink zone. In these nucleated patches the normally situated glia cells were very much enlarged, and the thickened, ramifying processes formed a fine network around the fibres, the nuclei of which could be distinguished from glia nuclei by their intimate relation to the axis-cylinder.

It is important to note that though so many of the fibres in the intra-medullary portion of the posterior roots showed degeneration, there was no attempt at a regeneration from the healthy extra-medullary portion. None of the fibres in the lateral pia could be traced directly to posterior roots, nor could any definite connection be established between posterior roots and the few pial fibres in the posterior pia and pial septa. NAGEOTTE, as we have seen, has described in tabes a collateral regeneration from the preserved end of the posterior roots, and RAYMOND traced the fibres of the neuromata, found by him in the posterior pia, to a regeneration of posterior root fibres interrupted in their intra-medullary course. An explanation of this absence of regeneration may be found in the integrity of the axis-cylinder as revealed by the silver method.

(4) SCLEROSIS.

Areas of sclerosis are here distinguished from areas of fibrosis, though the latter frequently extended so as to involve the former. We may here confine ourselves to a reference to those areas in which no marked fibrosis accounted for the change, *i.e.* areas in which the normal framework of the cord structure was retained. Such areas of sclerosis had many of the characters of areas of degeneration in disseminated sclerosis. Though the same columns were affected in nearly all the levels of the cord, this was in such varying proportions, and separated by intervals in which no transition could be traced, that the significance of ascending and descending degeneration could not be ascribed to the degeneration. A further similarity to disseminated sclerosis existed in the presence of the thickened vessels on transverse and longitudinal sections, and further, in the presence, in varying proportions, of naked axis-cylinders. No compound granular cells were found in the sclerosed areas, an indication that the process of sclerosis had run its course some time previously.

In the upper cervical segments there was slight degeneration of the column of Burdach near the median septum—frequently lozenge or spindle-shaped; the tracts of Gowers and of Flechsig were also slightly sclerosed to an extent coinciding with the posterior column degeneration, and there was distinct degeneration in the tract of Helweg on one side. In the lower cervical segments there was a slight tendency to degeneration in the direct pyramidal tract on one side, and the crossed pyramidal on the other, and again slight degeneration in postero-mesial columns, tracts of Gowers and of Flechsig. Throughout the various levels of the dorsal cord, there was a very definite area of sclerosis between the tract of Gowers and that of Flechsig on both sides, together with a slight degree of degeneration in the columns of Burdach adjoining the median septum. Throughout the lumbo-sacral region, the fibrosis was so extensive in the white matter that it was impossible to distinguish areas in which sclerosis may have been present independent of the fibrosis, except in the postero-mesial columns, which again showed slight degeneration near the median septum.

In some parts of the cord in the posterior columns there was a remarkable twisting of the fibres. The fibres seemed to twine round upon themselves and to run, as it were, around an irregular axis parallel to the longitudinal axis of the cord, and then in successive serial sections the normal orientation of the fibres was re-assumed. Such appearances were accompanied by a rarefaction of the tissue, not amounting to even slight sclerosis. Similar appearances have frequently been noted in the posterior columns in cases of disseminated sclerosis.

II.—Medulla Oblongata and Pons.

As a preliminary to a description of the nodules in the medulla oblongata and pons, it is necessary to state that they were definitely distinguished from the nodules in the spinal cord in that the fibres composing them stained specifically neither with silver nor with the Weigert method, and, further, that only in one or two isolated instances did the fibres assume a whorl-arrangement. So different were the nodules that for a time it was assumed that a pathological process was in operation essentially distinct from that in the spinal cord. The finding, however, of one or two nodules with definite whorl disposition of the fibres, presenting, as it were, a transition to the more fully developed nodules in the cord, led to the possibility being entertained that these formations were early stages in the development of one process. Later findings also emphasised the nervous nature of the constituent elements of the early nodules.

The examination under low power of Weigert-fuchsin and iron-hæmatoxylin-fuchsin preparations at different levels of the medulla and pons showed that the fibre-tracts were here and there interrupted and replaced by small patches which took a diffuse faint connective-tissue stain to a greater or less extent; in these areas, under a higher magnification, faint lines could be recognised taking the myelin stain. In similar sections stained with the Bielschowsky-Williamson silver method, the fibres were again interrupted by faintly-staining areas in which were found diffusely-staining fragments of axis-cylinders, and in adjoining sections stained with Van Gieson's method it was demonstrated that these areas which had stood out so clearly under a low power as patches of degeneration were in reality patches of nucleated fibres and nucleated elements cut transversely, obliquely, or longitudinally. The fibres, in many instances, seemed to retain the normal arrangement of the fibre strands of the part involved (figs. 57 and 58). In other parts the fibres terminated in a loose meshwork of interlacing, nucleated fibres, or strands of such nucleated fibres ended in a vortex of elongated nucleated elements which diverged from each other to interlace with similar elements from adjoining strands (figs. 59–62). Such areas showing this loose structure were in all instances closely related to the tissue around blood-vessels. The iron-hæmatoxylin stain very readily revealed the existence of even the smallest nucleated patches, as it showed the break in the continuity of the normal fibres, and, further, the minute nuclear structure of the elements replacing them could be ascertained in one and the same section.

In the pia a few fully-stained medullated fibres around vessels were found, but in no case did these form strands or nodules in the vessels or pial spaces. OBERSTEINER has observed that the cranial pial vessels usually contain such fibres, while the spinal pial vessels rarely do so.

From this brief description it is seen that there are present in the medulla and pons abnormal formations which bear a certain structural resemblance to one another. For purposes of description we distinguish between the following:—

(1) The simplest nucleated patches with the retention of the normal framework of the tissue;
(2) The patches in relation to sensory nerve paths;
(3) The patches which consist of a loose meshwork of interlacing nucleated fibres and spindle-shaped elements;
(4) The definite nodule formation;
(5) The areas in relation to the superficial origin of motor nerve roots;
(6) The areas of pure fibrosis.

DISTRIBUTION OF THE PATCHES AND NODULES.

It will be convenient at this point to indicate the general distribution of the patches and nodules at different levels. Only these have been represented in the figures that were readily recognisable under a low magnification in Weigert-fuchsin or iron-hæmatoxylin sections.

LOWER PART OF MEDULLA OBLONGATA—"A."

Four well-marked patches are to be found on examining sections at this level. The smallest of these is situated in the mesial line in the centre of the space bounded posteriorly by the two nuclei of the hypoglossal nerves and anteriorly by the two posterior longitudinal fasciculi, between which it extends for a short space. A second patch is situated at the lateral surface of the medulla, just anterior to the descending root of the 5th nerve, and appears to involve some of the fibres of the direct cerebellar tract which pass backwards into the restiform body at this level. This patch is triangular in outline, the apex being directed inwards. The remaining two patches lie between the pyramids and the lower end of the inferior olivary nucleus, one lying close to the surface of the medulla, the other about the middle of the posterior surface of the pyramid. These two patches thus involve the fibres of the hypoglossal nerve as they pass between the inferior olive and the pyramids on their way to the surface of the medulla.

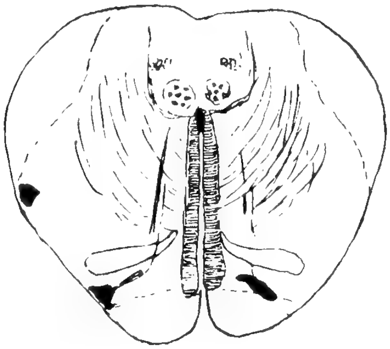

FIG. A.

MIDDLE OF THE MEDULLA OBLONGATA—"B."

The number of patches has greatly increased at this level. Two well-marked examples are to be found in each restiform body, all being quite superficial in position. The remaining patches may be considered in relation to the inferior olivary nucleus. A narrow elongated mass is to be seen between each olive and the corresponding pyramid, the strands of the hypoglossal nerve on each side being thus involved, and appearing to pass through these patches. Other two are situated at the postero-lateral angle of the inferior olive, touching the grey matter itself, while two further patches lie between the two arms of one olive just at the hilum and directly intercepting the strands of the hypoglossal nerve, where they pass between the mesial fillet and the olive, the hypoglossal nerve on one side, therefore, being interrupted by three such patches.

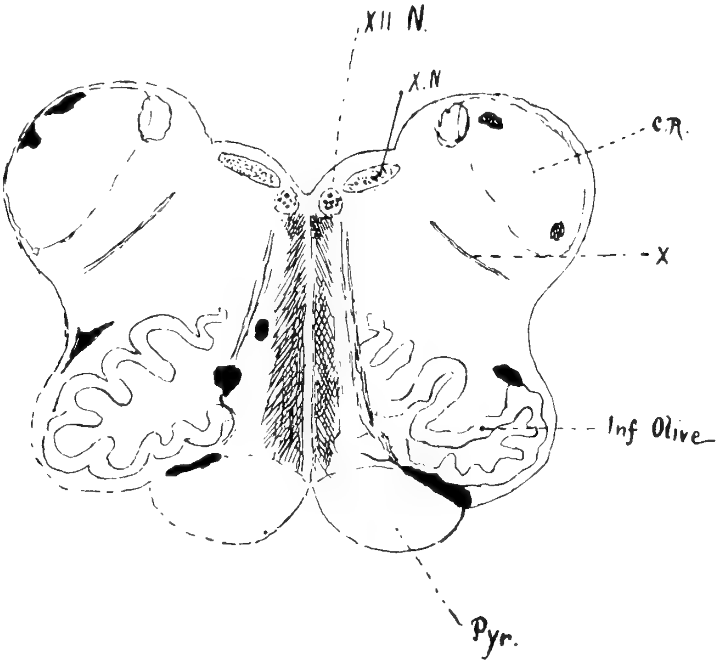

Fig. B.

Middle of Pons Varolii—"C."

The most important patches at this level lie in relation to the fibres of the 5th nerve at their point of entry, both nerves being approximately equally affected. The

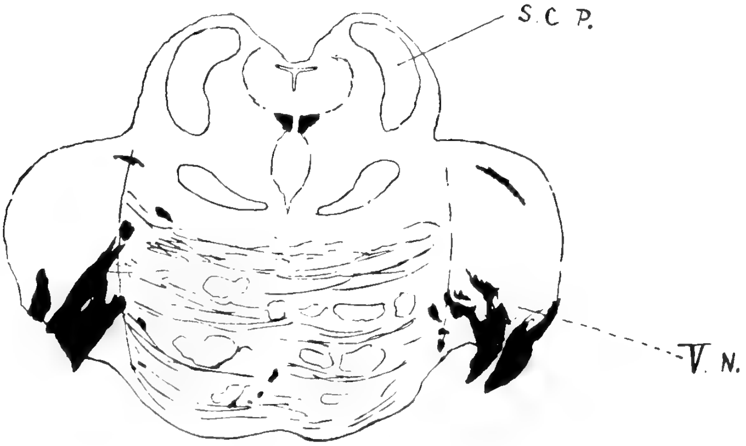

Fig. C.

smaller patches are also visible in the neighbourhood of the lateral fillet upon one side, and a number of smaller ones may be detected amongst the transverse fibres of the pons towards their more superficial bundles. A narrow elongated patch is also to be seen amongst the deeper part of the fibres on one of the 5th nerves.

Upper Part of Pons Varolii—"D."

The number of patches has increased very greatly at this level, no fewer than twenty-one being found in one section. The largest of these is lozenge-shaped and is situated in the middle line anterior to the posterior longitudinal fasciculus, and midway between it and the trapezium. Within the fibres of the trapezium itself, three smaller patches may be detected, and still other three, also small in size, lie in the reticular formation, just posterior to the trapezoid fibres. Another is found at the cerebello-pontine angle. The remainder are scattered throughout the transverse fibres of the pons, mostly amongst the more superficial of these fibres, but not limited to them. Their exact positions may best be seen from the accompanying figure.

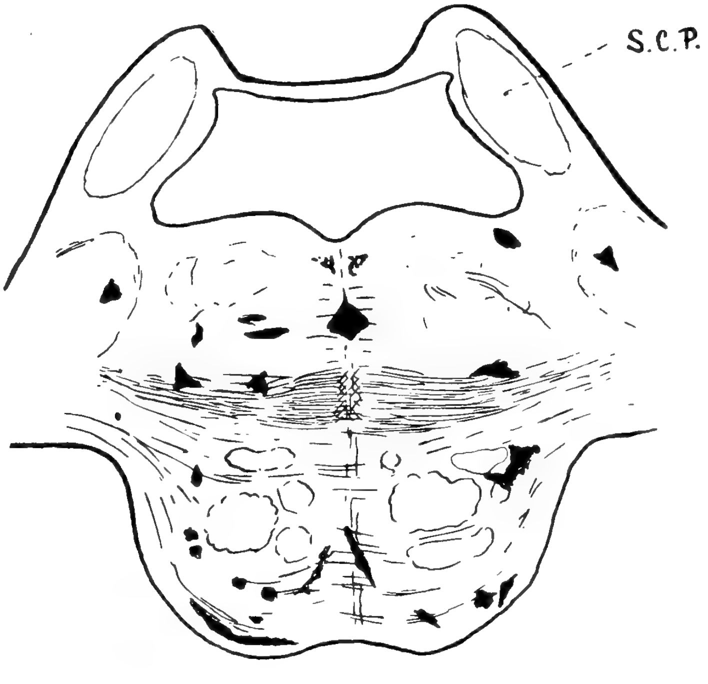

Fig. D.

Upper Level of Mesencephalon—"E."

The patches at this level are very few in number, and are limited to the region of the crus cerebri, only one of which is affected. The largest patch implicates the fibres of the 3rd nerve just at their point of emergence, the area affected being, however, slight in comparison with the corresponding involvement of the 5th nerve as already described. Several smaller and superficial patches are situated towards the inner part of the crus, while a single isolated one, also small in size, is to be seen at a little depth from the surface, and probably implicating pyramidal fibres.

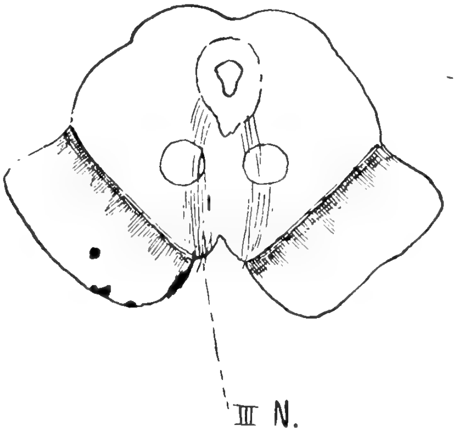

FIG. E.

(1) ISOLATED NUCLEATED PATCHES.

It is necessary again to emphasise that it is such patches which show a break in the continuity of the myelin-staining fibres. They are of two kinds: (*a*) Those of the first are small in size, isolated, few in number, and are in no way related to the paths of cranial nerves within the medulla or pons; (*b*) Those of the second are more numerous, often extensive, and definitely on the paths of nerves from or to their superficial and deep origin.

(*a*) In the smallest patches we note that two or three normally-staining longitudinal strands, composed of a very few fibres, *e.g.* in the transverse fibres of the mesial fillet, are interrupted in their course by nucleated fibres which seem to be continuous with them. The nuclei in these fibres are elongated, with their longitudinal axis parallel to the long axis of the tube; they stain darkly, have no nucleoli, and are definitely within the lumen of the tube. The transversely-cut strands, between and immediately in relation to the nucleated fibres, are also nucleated, so that under low power we have the picture of the normal transverse and longitudinal strands of fibres for a short part of their course showing nuclei. Under a higher magnification it is recognised that a distinct break occurs on either side of the nucleated fibres, between them and the normal fibres, and that in this short interval only glia fibrils are present. These can be definitely followed right through the patch, retaining and probably maintaining the longitudinal direction of the fibres. A careful analysis of sections stained with Van Gieson's, iron-hæmatoxylin, and Bielschowsky's methods, when this last method has not stained electively and glia fibrils take the stain, proves conclusively that the glia fibrils in these patches are retained and serve to form channels, as it were, for the nucleated fibres.

The elongated nuclei are definitely within the fibre contour and can be readily distinguished from the rows of small round nuclei so frequently seen in relation to the transverse fibres of the fillet and transverse fibres of the pons. The longitudinal fibres stained yellow-brown with Van Gieson's method and no distinct central filament was recognised. The transversely-cut fibres showed a similar structure, a faintly yellow-brown disc and a reticulum of glia fibres encircling it: the circular nuclei in relation to the fibres showed their identity, in structure and staining, with the elongated nuclei.

Such is the structure of those simplest nucleated patches: they could be recognised as retaining this structure through only a few serial sections, and almost without exception they were in relation to the transverse fibres of the mesial fillet or transverse fibres of the pons near the median raphe.

(*b*) The nucleated patches next to be described with fibres cut transversely (fig. 58) and longitudinally (fig. 57) are of an entirely different nature. They were all found in relation to strands of the sensory cranial nerves, and it will be convenient to describe them with the next group of changes.

(2) Changes in Relation to the Intra-medullary Course of Sensory Roots.

A reference to fig. 56 shows that the entering strands of the 5th nerve are, for a considerable part of their course within the pons, nucleated. Symmetrical changes were found in the 5th nerve on the opposite side and in relation to strands of the 8th and 9th nerves, though to a less extent. A comparison with fig. 53, showing the posterior root-entry zone in the 7th cervical segment, reveals the similarity of the process. The whole extra-medullary nerve root seems carried into the pons with the fibres retaining their neurilemma sheath and nucleus. Different strands showed this to a varying extent of their course, and individual fibres, with the structure of the peripheral nerve, became directly continuous with the normal non-nucleated and sheathless medullated fibres, the nuclei in the tube becoming more and more isolated and the transition occurring almost imperceptibly.

This nucleation of the fibres could be traced far into the pons, and even the deep strands of the 5th nerve showed that one third or one half, or even more, of the fibres composing them were nucleated. In these deep sensory strands the neurilemma sheath was absent, and the nuclei were more definitely within the fibre contour than in the more superficial fibres. If such strands were cut transversely we get the appearance shown in fig. 58, and, if cut longitudinally, that in fig. 57. This seems to us to be the meaning of many of the nucleated patches. An explanation would thus also be found for the fact that such transversely-cut fibres could often be followed for a considerable distance in successive sections with only a slightly varying position, and with no very defined relation to any vessels, while the longitudinally-cut fibres soon become oblique. In all of these patches the normal framework of the tissues was preserved, with an enlargement of the glia cells in relation to the fibres: a change similar to that noted in relation to the nucleated patches internal to the posterior root-entry zone in the cord. Here, also, as in the cord, the nucleated fibres could never be, beyond doubt, found to end loosely in the tissue or break up into fusiform elements. Weigert preparations proved a degeneration of the fibres coincident with the nucleation, but adjoining Bielschowsky preparations proved the integrity of the axis-cylinders.

Before leaving these changes in relation to sensory nerve paths, which we consider quite analogous to the changes in the posterior root-entry zone, it is necessary to add that a very exhaustive examination of serial sections of medulla and pons was made before the conclusion was arrived at that this change was limited to sensory strands. The only motor nerve root which showed changes at all comparable was the 3rd. The fibres of the oculo-motor nerve seemed to have a very extensive zone of exit—passing out from the surface in several widely separated strands, the outermost of which adjoined the crus. Several of these strands were nucleated, but only for a short distance, and the greater part of the change was analogous to that, to be described under (5), in connection with the motor nerve roots.

(3) PATCHES COMPOSED OF INTERLACING NUCLEATED FIBRES AND FUSIFORM NUCLEATED ELEMENTS.

The first impression received from a low power view of such a patch, if the attention be confined to the loose meshwork, is that we have a proliferation of young connective tissue cells, for this loose tissue is in intimate relation to dilated capillaries, which, with their walls composed of a single layer of endothelium, are very similar to new-formed vessels (59 and 61). A closer examination, however, shows that these cells differ in many respects from young fibroblasts, and that they bear a close resemblance to the spindle-shaped elements, derived from the proliferation of the sarcolemma nuclei and the increase of the sarcoplasm—young myoblasts—in the young granulation tissue between the two ends of a muscle wound, before the increasing condensation of the scar tissue has caused their atrophy and their transformation into connective-tissue-like elements. Such cells stain more homogeneously than fibroblasts, have not the same branching processes, and can for a time be readily distinguished from connective tissue cells and endothelial cells.

Further, it is noted that these spindle-shaped nucleated elements link themselves on to one another in the most definite way (figs. 59 and 60), again just as endothelial cells in granulation tissue align themselves to form young capillaries. There is this difference, however, that this alignment is seldom in two parallel rows with a lumen between, but is an interlacing in very varied directions of linked elements, which only later converge, as it were, into strands composed of several nucleated cell-chains. From figs. 59 and 60 it can be seen that as these fusiform nucleated elements link themselves to one another, end to end, their processes fuse in an imbricated manner, and that by the time the cell-chain thus formed is extricating itself, as it were, from the maze of cells and passing out from them, it has assumed an uneven cylindrical appearance, the points of fusion being still narrower in calibre than the parts of the cylinder which contain the nuclei. Such nucleated, protoplasmic cylinders are, in future, indicated when the term "nucleated tube" is used.

Several of these chains of linked cells give the appearance of a dichotomous division (figs. 59 and 60). This forking in some instances clearly reveals the mode of origin of the two first components of the branches, for the first links in the respective new chains lie very close and almost parallel to one another. The impression is received that a longitudinal cleavage of a terminal cell had occurred, that the proximal portions of each resultant cell had remained attached to the common stem, and that growth in length had continued in each new branch till, further on, a new longitudinal cleavage had taken place when a new dichotomous division resulted. No mitosis could anywhere be noted.

The convergence of the nucleated tubes forms bundles which run as parallel strands for a varying distance (fig. 62), and then assume a more convoluted course. Such convoluted nucleated tubes (fig. 63) form the transition to the definite nodules to be described below (4).

Between the parallel strands formed by the convergence of the cell-chains are found cells and tubes cut transversely, which show clearly their identity with the longitudinal elements.

Structure of the fusiform cells and nucleated tubes.—The earliest stage of the cell is a very thin spindle, with an elongated nucleus and a slight amount of protoplasm extending from its poles. As the cell increases in size the protoplasm extends, and with Van Gieson's stain is homogeneous and faintly tinged pink. Larger cells, under oil immersion, reveal the presence of a more deeply staining filament in the protoplasm just on one side of the cell; this filament extends, with the growth of the cell, beyond the poles of the nucleus and becomes more evident. In cells which show a central nucleus, their filament can often be recognised through it and extending on either side for a short distance. The nucleus stains always deeply, but shows a chromatin network and membrane and fine nodal points, one or two of which are always larger than the others. The transverse section of such fusiform cells shows the nucleus at first occupying almost the whole disc; later it leaves a portion of protoplasm on one side, in which is again recognised the deeply-staining point (fig. 1).

As the cells become linked to form chains, the central filament becomes more evident in each cell element, and as the fusion of the imbricating processes becomes complete and the cell borders disappear, the discontinuous filaments form a continuous line which may be traced passing two, or three, and even more nuclei. The surrounding protoplasm in these tubes is homogeneous, yellow tinged with faint pink, and its outer border is often denser and deeper pink. The nucleus tends to be peripheral, but is still large, and surface views especially give the impression of its being still central or bulging into the lumen. The examination of cross sections gives the true relation of the nucleus to the protoplasmic tube (fig. 2).

A further stage in the evolution of these nucleated tubes, which have resulted definitely from the fusion of the fusiform cells, is reached as the contours become cylindrical and parallel, and most of the nuclei have taken a peripheral position and flattened appearance. The protoplasm still stains homogeneously, but the condensed outer border and the sinuously-winding filament become more marked (fig. 3).

In the loose meshwork there is present only a slight amount of intercellular tissue derived from the adventitia of the neighbouring blood-vessels: between the tubes, however, distinct glia fibrils, very evident with iron-hæmatoxylin, run parallel to them. Very enlarged glia cells, with thick branching processes, are found in close relation to the meshwork.

Preparations, stained with polychrome methylene-blue, reveal the presence in numerous cells of very fine granules, accumulated chiefly at the poles: similar granules are found here and there in the protoplasm around the nuclei of the tubes. The metachromatic staining of these granules indicates their relation to the granules described by REICH and ALZHEIMER.

Preparations, stained with iron-hæmatoxylin-fuchsin, show that these nucleated tubes or bands are in various stages of commencing myelination (figs. 14 and 66): some tubes show only the pink tinge of the fuchsin (fig. 14*a*), but all indicate the segmental character of the tube in which this differentiation is taking place. The first evidence of this is noted in a darkening just within the outer border of the segment (fig. 14*b*); this then shows a fine granularity (fig. 14*c*) and, later, a commencing lattice-work appearance (fig. 14*d*): on cross-section of such tubes, this transition from a homogeneous, dark ring or shadow, through the granular stage, to the appearance of dark radial peripheral points is also seen, and also the relation of the nucleus to the forming myelin (fig. 14*f*).

These appearances are undoubtedly those of a commencing myelination of these tubes, formed by the alignment and fusion of the fusiform elements. In one strand may be recognised tubes which show varying stages in its development (fig. 66). Several writers have pointed out that in its first development in the peripheral nerve the myelin is deposited in imbricated, closely applied rings, the spaces between the rings representing the future Lantermann incisures. On cross-section such fibres would show radial points of myelin at the periphery, and, on longitudinal section, the myelin would take the form of a lattice with elongated spaces.

The appearance of the nucleated tube at this stage, in Van Gieson preparations, is not indicative of the structure of a peripheral nerve: the nuclei are much larger and more numerous, and the neurilemma sheath is absent. In the stage to be next described, where the tubes assume a convoluted disposition, they become more like the peripheral nerve fibre in character.

We desire to draw special attention to the photographs (figs. 59–66) which show beautifully the fusiform nucleated elements (figs. 59 and 60), their linking into cell-chains and the fusion of imbricated ends (figs. 60 and 65), the transition of the chains into nucleated bands (fig. 61), and the convergence of the bands into longitudinal strands (figs. 62 and 66), between which are found tubes cut transversely.

(4) Nodule Formation with Convoluted Arrangement of the Fibres.

Such nodules were found in very few and isolated positions. The largest, composed of tortuous fibres with numerous nuclei, is represented in fig. 64, and was situated laterally and posteriorly to the strands of the 7th nerve and close to the floor of the 4th ventricle. It had developed in relation to one side of a medium-sized vessel, and when traced upwards divided into strands which passed along the two divisions of this vessel to form more or less large nodules in relation to each branch. In serial sections both the original nodule and the two smaller ones could be followed till the fibres unwound themselves from their compact disposition both at the upper and lower limits into tortuous but parallel fibres, which resolve into nucleated tubes, and then finally break up into interlacing fusiform nucleated elements. Within the fibres of the nodule, in iron-hæmatoxylin-fuchsin sections there is present a distinct central filament—the axis-cylinder, a continuous but faintly-staining myelin sheath, and, where the fibres can be isolated, a distinct outer membrane staining pink. A small amount of interfibrillar connective tissue is also present, derived probably from the adventitia of the vessel. Fig. 5 shows the fibres of this nodule cut longitudinally for a short part of their course, with a structure very similar to that of a peripheral nerve: the nuclei, however, are larger and more numerous.

If a dissociation of the fibres by an increase of the interfibrillar tissue takes place, as was found in a nodule lying near one inferior olivary nucleus, the fibres assume more the appearance of those of a peripheral nerve. In such fibres the fact that the nucleus —though peripheral—is still definitely within the lumen of the tube and is not applied to it from the outside as a connective-tissue nucleus, can be very beautifully recognised. In relation to all the nodules, similar in structure to that just described, there were found, in the immediately surrounding tissue, radiating lines, the structure of which was resolved into cell-chains and isolated fusiform cells which were undergoing a fibrous transformation.

(5) Areas in Relation to the Superficial Origin of Motor Cranial Nerves.

The earliest indication of such change was in the form of a proliferation of cells just within the pia, accompanied by a certain amount of fibrosis and degeneration of emerging fibres. This change was most marked in the emerging roots of the hypoglossal on both sides. These strands, with Weigert's stain, show along their course a degeneration which must be compared and related to the degeneration of the intra-medullary anterior nerve bundles in the cord. In addition to this, however, there was a definite proliferation of cells, many of which are spindle-shaped elements, which again fuse to form nucleated tubes, closely applied to one another and intertwining. Further, the fibrosis extended to involve these new-formed elements. Such a picture required very careful examination under oil-immersion and the use of several staining methods to interpret its constituent elements. Weigert and Bielschowsky preparations showed a disappearance of the myelin and a diffuse staining of the axis-cylinder of the emerging fibres, while control preparations, stained with Van Gieson's method, proved that there is a dense network of new nucleated tubes and fusiform cells, and an advancing fibrosis which is causing their atrophy and disappearance. The appearance of some of these nucleated tubes is very similar to that which we have seen in stump-neuromata, where the increasing condensation of the scar-tissue causes compression of many of the new nerve tubes—the myelin of which does not yet take the specific myelin stain and shows as a homogeneous yellow zone with central axis-cylinder. Radiating from such areas may be found the nucleated tubes and spindle-shaped elements undergoing a fibrous transformation.

(6) Patches of Pure Fibrosis.

This again must be brought into relation to a similar change in the spinal cord. It has already been stated that small areas may be recognised which, under low power, stain diffusely pink, and, under high power, reveal few or no structural elements. These areas are related to a thickened vessel, and in the extension of the fibrosis the new-formed nucleated tubes are involved. Within those areas, showing no recognisable cell elements with other stains, there may frequently be found in Bielschowsky preparations diffusely-stained axis-cylinders which we have taken to represent the remains of axis-cylinders of the fibres displaced by the new-formed nucleated tubes.

It is thus seen that the histological picture is an extremely complex and varied one, that at first sight the recognition of any relation between the different appearances is difficult, and that a prolonged investigation of serial sections and comparison of adjoining differently stained sections is necessary before any satisfactory conclusion as to the nature of these nucleated patches and nodules and their relation to one another can be reached.

We look upon the patches showing a meshwork of interlacing fusiform cells, described in (3), as the first stage in a process which in the medulla and pons evolves as far as the nodule formations described in (4). Cells, the genesis of which cannot be traced, have proliferated, and the proliferated cells link on to one another and form chains of cells which converge to form parallel strands. The simpler strands, owing to the retained glia framework, may for a time conform to the plan of the normal strands of the part involved, but, in their further evolution, they became tortuous and intertwined and convoluted, and form the nodules described in (4). The simplest patches described in (1) (*a*), we regard as sections of the margins of a patch of nucleated strands similar to those in (3). The nodules described in (5), in relation to the superficial origin of the motor nerves, we also take to owe their origin to the proliferation of spindle-shaped cells, which form nucleated tubes and nodules. The nodules have then undergone a fibrosis, which involves the emerging roots. The small areas of fibrosis in (6) are areas of a fibrous transformation affecting blood-vessels, nucleated tubes, and spindle-shaped cells.

Finally, the nucleated patches described in (1) (*b*), cut transversely and longitudinally, we relate to transverse and longitudinal strands of sensory nerves in their path to their nuclei of origin. An explanation of the areas described in (2) in relation to the sensory nerves is extremely difficult. A comparison of their extra-medullary and intra-medullary course shows that within the brain the interstitial tissue and nucleation is more evident, and the impression is confirmed that here also not only had the neurilemma sheath been carried inwards, but pial fibrous tissue also, and that within the brain this connective tissue element in relation to the fibres had increased. The change must be related to, and have the same explanation as, the fibrosis affecting the posterior roots of the cord; but further than this it is impossible to go.

To complete this histological study it is necessary to refer briefly to the presence of several abnormalities which can here be grouped together.

At the level of the point of emergence of the 7th nerve, a curious condition is to

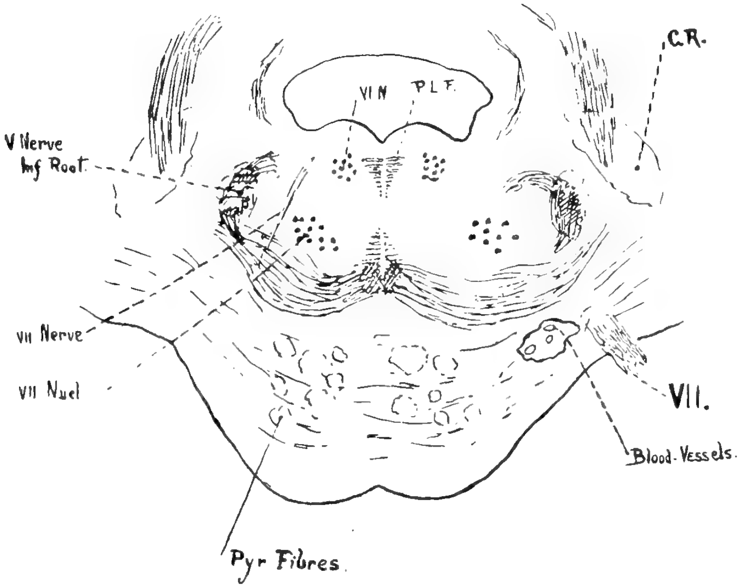

FIG. F.

be found, possibly of the nature of a malformation. The tissue immediately to the mesial side of the facial nerve appears to be unusually vascular, and a cavity—small in size and with irregular walls—is developed in relation to the vessels. This cavity increases in size as it is traced upwards, and involves the fibres of the trapezium. Higher still, it opens out directly on to the surface of the pons and a large irregularly-shaped depression results, which does not involve either the facial nucleus or the descending root of the 5th nerve, but does destroy part of the transverse fibres of the pons and trapezium (figs. F., G., H., I.).

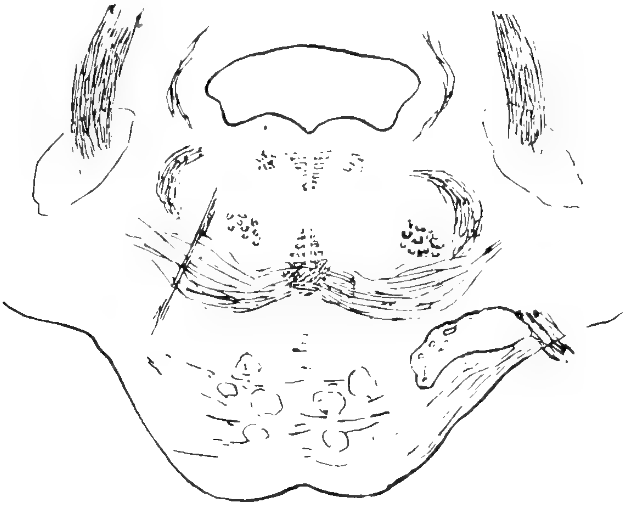

Fig. G.

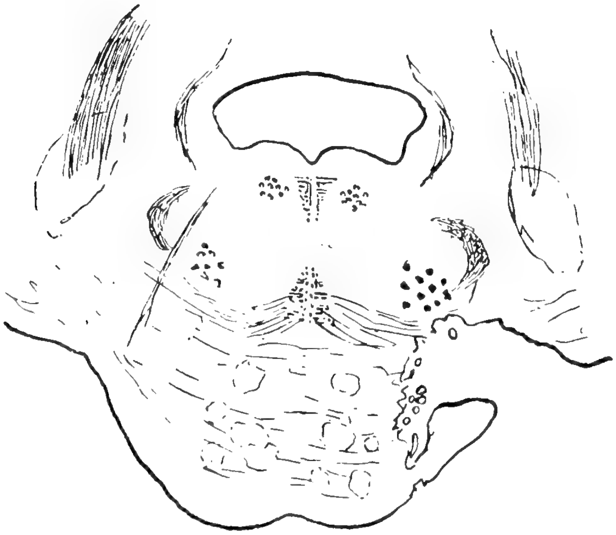

Fig. H.

Round the vessels, especially the smaller vessels, of the tissue in close relation to this malformation, a granular deposit was found: the dust-like particles were arranged usually in a row in the adventitial spaces and frequently fused to assume irregularly-rounded forms. If these further coalesced, they formed wide layers in the hyaline adventitia of the vessel. These concretions stained with the hæmatoxylin very like calcareous particles, and with polychrome methylene-blue were a diffuse green (fig. 55).

In the lumbar cord, the pia structure was interrupted at one or two levels and replaced by small nodules, staining homogeneously yellow with Van Gieson's method in contrast to the pink connective tissue of the pia. These nodules were immediately anterior to the posterior roots, and the staining gave the impression of glia islets which had undergone a homogeneous transformation.

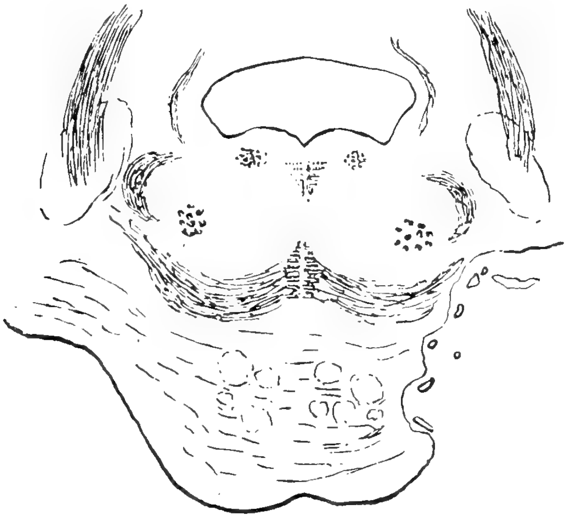

Fig. I.

Finally, in a very few sections, well-stained and well-developed ganglion cells—of the type of those in the spinal ganglia—were found amongst the extra-medullary anterior roots immediately outside the pia.

III.—INTERPRETATION AND CONCLUSION.

In trying to answer the question, What conclusions may be drawn from our observations? or, in other words, What is their explanation? we are met at the outset by the necessity of bringing, if possible, the various formations described into a genetic relation to one another. In the attempt to correlate the appearances in the cord with those in the medulla oblongata and pons the problem in the cord is, obviously, the genesis of the nerve fibres, for these elements are the essential constituent of the nodules, while the problem in the medulla and pons is the genesis of the fusiform cells, for the various formations can be related to them.

In the cord the fibres were disposed, more or less, in the form of strands or nodules in numerous positions. They were found always in relation to pia, pial septa, or the adventitia of vessels, and only in their terminal ramifications did the individual fibres come into direct contact with the actual nerve tissue. The fibres of the nodules could in all instances be traced to strands passing laterally or ventrally from the immediate vicinity of the emerging anterior roots. Those passing laterally in the pia entered inwards by all the peripheral vessels of the lateral region of the cord; they formed nodules in the vessel-walls and at the junction of white and grey matter, where their fibres terminated by gradually unweaving themselves from the nodule into the general texture of the grey matter. The fibres passing ventrally curved round into the anterior fissure, as a rule to its base, forming a large nodule in the region of the central canal, passed along the commissural vessels to form nodules in the centre of each grey matter, and often leashes of fibres passed along in the vessel-walls anteriorly, laterally, and posteriorly. The terminal fibres of these nodules again gradually unwound into the general meshwork of the grey matter, interlacing with fibres from the nodules which had formed in relation to peripheral vessels.

With Weigert's medullated sheath stain these fibres are found to have a specifically but faintly-staining myelin sheath with short and bulging interannular segments; with Cajal's silver method for medullated nerves the axis-cylinder stained specifically; and with nuclear stains the fibres gave the appearance of peripheral nerves with, however, a finer general structure, and more numerous and larger nuclei. The nuclear stains revealed also—what the myelin sheath and axis-cylinder stains had only slightly indicated—that the fibres in their terminal ramifications were continuous with nucleated protoplasmic tubes in which a central filament and a homogeneous outer zone could be recognised, corresponding to the axis-cylinder and myelin sheath, and, further, that these nucleated tubes could be traced frequently to terminate in fusiform, nucleated elements. Some of these were simply the sections of the nucleated tubes cut in various directions, but others could be satisfactorily and definitely proved to be individualised fusiform cells. In some of these cells could be traced a fine continuous deeply-staining filament in the protoplasm on one side of the nucleus.

In the medulla and pons the most distinctive feature of the formations was an interlacing meshwork. When this was analysed it was found to consist of fusiform elements and again nucleated tubes cut in various directions. In the protoplasm of many of the cells there was present on one side of the nucleus, or projecting beyond its poles, a deeply-staining filament which increased in size with the size of the cell. Further, many of these fusiform cells were found linked together by their adjoining processes which had fused, and stages could be followed in the transition to cylindrical tubes in which the fusion had become complete and the cell-boundaries had disappeared, and protoplasmic bands or tubes had resulted. In these nucleated tubes or protoplasmic bands there was present a deeply-staining central filament, winding in and out amongst the nuclei, and around it a homogeneous zone, with very numerous nuclei definitely within or projecting into the lumen of the tube. Further, it was noted that a cell-chain, thus formed, frequently divided into two, the first components of the chain lying very close, almost parallel to one another. The linked cells as they formed nucleated tubes tended to converge together to form strands, and in these strands of nucleated tubes running parallel to one another the central filament became gradually more distinct, the nuclei more flattened and peripheral and with an alternating position. Further, in such strands evidence was found of an undoubted commencing myelination, the tubes showing this all having a very definite segmental structure. Further, these parallel strands of nucleated tubes assumed a tortuous or twining character to form nodules, and during this further evolution the nuclei took a still more peripheral position and the whole tube more the character of a peripheral nerve. This was the furthest stage in the evolution of the nodules in the medulla and pons : the tubes had thus three phases in their evolution—firstly, a cellular one ; secondly, that of protoplasmic bands or tubes ; and thirdly, one showing the division into interannular segments and a commencing myelination.

In the cord, therefore, we have well-stained nerve fibres, apparently terminating in nucleated tubes and fusiform cells ; in the medulla and pons we have fusiform cells and nucleated tubes apparently forming strands of nucleated fibres which have many of the characters of the fibres forming the more fully evolved nodules in the cord but without their specific staining ; while the constituents common to the formations in both regions are the nucleated tubes and the fusiform cells. The position stated thus, it is not difficult to correlate the appearances, and the conclusion might at once be reached that in the cord we have simply a further stage in the evolution and differentiation of the fibres.

Before, however, accepting this conclusion, it is necessary to ascertain if no other explanation can be found. If we limit ourselves to the cord and recall the fact that the nerve fibres composing the nodules could in all instances be traced to the immediate vicinity of the anterior roots, two possible explanations at once present themselves, both of which are in agreement with the old-established outgrowth theory. The one is, that the fibres represent aberrant anterior nerve roots in the sense of ORZECHOWSKI

(p. 742), and the other, that these are new-formed fibres of regeneration from the anterior roots, in the sense of the collateral regeneration of NAGEOTTE (p. 726) in tabes.

For the first we must assume that in early fœtal life a meningeal lymphangitis had caused a diversion of the growing axons, so that instead of passing into the spinal nerves a certain number of them had become side-tracked into the meninges, and thence made their way along the vessels of the cord and in the pial spaces ventrally and laterally. The fact that in the immediate neighbourhood of the anterior roots the fibres composing the strands were few in number compared to the great mass of the fibres composing the nodules, in no way tells against this view, for the importance does not depend upon the number of the axis-cylinders. It is well known that one axis-cylinder can furnish a large number of fibres by breaking up into its constituent fibrils: these, according to accessory circumstances, can twist up into whorls and form nodules when they come even from an extremely restricted number of fibres. Such neuromata would be analogous to stump-neuromata. But while it is possible in Weigert- and silver-stained preparations to explain the fibres as outgrowths from the axis-cylinders and their divisions, it is impossible to account for the nucleated tubes and fusiform cells with which the nerve fibres were continuous as outgrowths from axis-cylinders.

For the second possibility it is necessary to pre-suppose a degeneration, in order that a regeneration might occur from the preserved end. Such neuromata would again be analogous to stump-neuromata. NAGEOTTE'S position has been already stated, and it has also been pointed out that such an explanation cannot be accepted for the fibres forming the neuroma, for no degeneration of extra-medullary anterior root could be traced. Further, if evidence of such regeneration had been present, the explanation is still awanting of the presence of the nucleated tubes and fusiform cells with which the nerve fibres are continuous.

If, now, we turn to the medulla and pons, it is clear that neither of the two possibilities that at first presented themselves as accounting for the cord nodules need be considered. There is no question of tracing the fibres composing even the most fully formed nodules to aberrant nerve fibres nor to a regeneration of fibres. Further, if such connections existed it would be the connection between fully differentiated fibres and immature fibres—a connection inconsistent with the explanation of the axis-cylinder as an outgrowth.

We have still to consider one further possible explanation for the cord neuromata before we have cleared the way for attempting a unification of the processes at work. This explanation is related to the multicellular structure of the peripheral nerves. In stump-neuroma, KENNEDY has found that the new-formed fibres terminate in protoplasmic tubes and fusiform cells within which axis-cylinder and myelin-sheath differentiation is taking place. The new-formed fibres are in direct continuity with a nerve which preserves its connection with the centre, and, according to the cell-chain theory, the new fibres have arisen within the proliferated cells of the sheath of Schwann, and only later become continuous with the fibres of the preserved end.

The possibility here also is that these are aberrant anterior nerve roots which in early fœtal life have taken this aberrant course, and that later some influence has caused a proliferation of the sheath of Schwann cells at the growing tips of the fibres with the formation of nucleated tubes and fusiform cells: these would therefore retain their connection with the centre just as the new fibres in the stump-neuroma. This explanation, while satisfactory for the cord, from the point of view of the cell-chain structure of the nerves, prevents the unification of the processes, for there can be no such analogous explanation of the nucleated tubes and fusiform cells in the medulla and pons. If, now, in our endeavour to correlate the changes, we pass from our observations to the conceptions which they justify, it is essential to admit that the question of the genesis of the nerve fibres is the same as the question of the genesis of the fusiform cells.

Before entering upon the consideration of the origin and nature of the fusiform cells, it is necessary to ask what collateral evidence we have that such fusiform cells can thus form nerve fibres, and we find that along three pathways research has led to the conclusion that the peripheral nerve fibre arises as a multicellular structure.

It is beyond the scope of this paper to deal with the general evidence for and against the different views relating to the development of the nerve fibre in the embryo, in regeneration, and in tumour formation, but from this evidence we wish to take such observations as throw light on our own.

(*a*) In embryonal development.—The works of BALFOUR, DOHRN, BEARD, HOFFMAN, and others have demonstrated that, in Elasmobranchs and Selachians, cells, migrated from the embryonic medullary tube, form cell-chains, and that each nerve fibre proceeds out of any single chain by a differentiation within the protoplasm. In the higher vertebrates the conditions seem not quite so simple. Numerous recent observations, especially those of BETHE, have shown that the first evidence of nerves consists of a characteristic series of cells which form a syncytial cell-chain, and that the first fibres lie within the protoplasm of this syncytium. KOHN, too, in rabbits, has demonstrated the gradual transformation of the indifferent cells of the spinal ganglionic *anlage* into ganglion cells and nerve fibre cells, and the development of the latter into nucleated tubes, and finally into the fibres of the sensory nerves, the nuclei becoming ultimately the nuclei of the sheath of Schwann. KOHN, further, has shown that the indifferent cells of the spinal ganglionic *anlage* migrate along developing nerve paths, *e.g.* the visceral branches of the spinal nerves, to form the sympathetic ganglionic *anlage*, that in it the indifferent cells (neurocytes of Kohn) undergo their differentiation into ganglion cells, nerve fibre cells, and chromotrope cells, and that only when the nerve fibres are formed does the connection take place with the ganglion cell.

(*b*) In regeneration of nerves.—GALEOTTI and LEVI found in the new-formed tails of lizards that the first evidence of the new nerve fibres between the young muscle fibres was in the form of chains of fusiform cells linked end to end. Within the protoplasm of these cells a central granular filament—corresponding to the future axis-cylinder—

developed, and, ultimately as the processes of the cells fused and the cell boundaries became lost, the central filaments became continuous. In mammals the activity of the neurilemma cells in the regeneration of nerves has never been disputed, only its result has been questioned. According to the supporters of the cell-chain theory, the proliferation of the neurilemma nuclei results in the formation of elongated cells which fuse to form syncytial cell-chains, and in the syncytial protoplasm an axis-cylinder differentiation occurs.

Now, as the proliferation of the neurilemma nuclei indisputably results in the production of a tissue, acknowledged by centralists and peripherists alike to be a specific tissue, in the sense that it is a product of the Schwann cells and differs in structure, staining, and arrangement from ordinary connective tissue; further, as this specific tissue has, with slight unessential differences, the characters of embryonic nerve tissue; and, further, as the works of DURANTE, BALLANCE and STEWART, and BETHE have shown that the production of this tissue from proliferated cells leads to the formation of nucleated tubes and fibres with axis-cylinder and commencing myelinisation, we have distinct evidence in support of our observations of the formation of nucleated tubes and fibres from the alignment and fusion and evolution of fusiform cells.

(*c*) In tumour formation.—WEICHSELBAUM, VEROCAY, FALK, and SCHMINCKE have all described the formation of a neurogenous tissue composed of protoplasmic nucleated tubes or bands in the condition of embryonic, and even more fully differentiated, nerve fibres. They bring this tissue into relation to a proliferation of the cells of Schwann's sheath or the less differentiated precursors of the same—nerve fibre cells. The transition between fusiform cells and nucleated tubes was followed to the increasing development within the latter of the differentiated elements of the nerve fibres. VEROCAY emphasised the statement that a tissue giving the characters of immature or embryonic nerve fibres must in all cases be related to a proliferation of the sheath of Schwann cells or analogous elements.

Having received this collateral evidence that fusiform cells in development, in regeneration, and in tumour formation, may develop a neurogenous tissue composed of nerve fibres in the condition of nucleated tubes with a commencing myelination, we can now pass to consider the source and nature of the fusiform cells.

Origin of the Cells.—Two possibilities alone can account for their genesis. The one, that they are derived from fixed tissue elements of the nervous tissues; the other, that they are derived from abnormal cells enclosed in the tissues in early development —in other words, from embryonal residues. For the first we have no evidence. For the second it may be objected that the terms "embryonal residues," "cell-rests," "cell-inclusions," convey no concrete conception, yet it must be admitted that some such term must be postulated, and the oncology of the cord, in the processes related to the closure of the medullary groove, allows a possible relationship between tumour-growth and disturbances of development to be more clearly perceived than in most tissues.

Obviously, then, to go further in our conclusions than our actual observations justify, we need to start with a good deal assumed. The one conclusion that appeared as a natural consequence of our observations—the multicellular structure of the fibres composing the nodules—leaves much still to be explained, and for this further explanation we must have recourse to deductions from conclusions accepted by other workers.

Nature of the Cells.—The development of the cells thus enclosed in the brain and spinal cord into nucleated tubes and fibres suggests that they were destined to form such structures in the ordinary course of development. For collateral evidence on this point we refer again to the development of nerve fibres in the embryo and in tumour formation.

(*a*) In embryonal development.—Numerous observations point to the possibility that the cells of the early medullary tube differentiate along three lines to form ganglion cells, glia cells, and nerve fibre cells—cells which migrate and form cell-chains and are therefore peripheral neuroblasts. Other observations point to the possibility that the indifferent cells of the spinal ganglionic *anlage* differentiate into ganglion cells, capsule cells, and nerve fibre cells. In each case the nerve fibres are only secondarily brought into connection with the process of the ganglion cell. The prototype of the ganglion cell (central neuroblast), glia cell, and nerve fibre cell (peripheral neuroblast), is the same mother-cell. Similarly, in the sympathetic ganglionic *anlage*, indifferent cells differentiate into ganglion cells, nerve fibre cells, and chromotrope cells.

(*b*) In tumour formation.—In the ganglio-neuroma, described by Falk and Verocay, the origin of the ganglion cells and nerve fibres has been traced to a common parent cell—the early indifferent cell, which has remained undeveloped. The nerve fibres found in these tumours in varying stages of development are ascribed to these cells as nerve builders and not to the ganglion cells, which were too immature—in many cases quite a-polar—to have formed them. The importance of Kohn's researches on the development of the sympathetic is of special significance in relation to the development of ganglio-neuroma. These tumours are traced to indifferent cells which have not achieved their differentiation and evolution, and, later, fulfil their destiny in an exaggerated degree. The presence of ganglion cells, nerve fibre cells, and chromotrope cells has been described by numerous writers in such tumours, especially those developing in relation to the medulla of the adrenal.

In some of the tumours of the cranial nerves described by Verocay, and in the tumours of the Gasserian ganglion and intra-cranial portions of the cranial nerves, described by Risel, ganglion cells, glia cells, and nerve fibre cells could be traced in all stages of transition between a common undifferentiated type to mature ganglion and glia cells and nerve fibres in different stages of development. Such observations are obviously difficult of objective proof, but their importance lies in the conception of the authors that the tumour formations must be traced to an undifferentiated cell which realised to differing degrees the differentiating possibilities present in it in the form of all three components of the nerve tissue. Verocay has suggested the term "neurinoma" for tumours of nervous nature derived from the proliferation of nerve fibre cells or their precursors. In neuro-glioma the ganglion cells and glia cells are both traced to the proliferation of an undifferentiated cell common to both forms, and in a case of a neuro-glioma of the temporal lobe Schmincke traced the nucleated protoplasmic tubes present also to a common parent cell. He suggests that the production of such neuroblast chains in a tumour of the central nervous system may throw some light on the development of the central nerve fibres from cells. Glioma also are to be traced back to the development of embryonic indifferent cells, without excluding the possibility of glioma-formations in later life from already differentiated glia tissue.

Circumscribed neuromata, including amputation neuromata, are ascribed to the proliferation of the sheath of Schwann cells, which thus reassume their primitive neuroblastic function and may develop into a-myelinated or myelinated fibres or remain at a less differentiated cellular stage.

From these observations we conclude that there is evidence for the view that undifferentiated nerve fibre cells, arisen either from the early medullary tube or neural crest and remaining undeveloped in the tissues, may develop into nerve fibres through stages which include the fusion of the adjoining ends of linked cells, the formation of nucleated plasmodial bands or tubes, and the differentiation of these into segmented nerve fibres. Further, that peripheral neuroblasts (nerve fibre cells), from the point at which they emerge from the medullary tube, or from the point of the medullary tube which they reach from the neural crest, migrate outwards and proliferate to form a cell-chain, the proximal link of which becomes connected with the process of a central neuroblast. For the sensory cerebro-spinal nerves we would substitute the ganglionic *anlage*, derived from the neural crest, as the centre for the centripetal and centrifugal growth of the cell-chains, and for the motor cranial nerves their superficial origin instead of the line formed by the anterior spinal roots. Indifferent cells (neurocytes) would thus lie in immediate relation to the mesodermic tissue which would form the *anlage* of the connective tissue elements of the cord and brain, and in this mesodermic tissue the indifferent cells might remain undeveloped. When the invagination of the early medullary tube takes place by the entering vessels, some of these indifferent cells would be carried in with the pia and, especially in the medulla and pons, where the distribution of the nerve fibres is not so uniform as in the cord where the anterior columns run in straight lines, would be carried inwards in the walls of the vessels to numerous and widely distributed areas.

The question of the unification of the processes in the cord with those in the medulla and pons here again arises. The analogy with the growing terminal ramifications of the new nerve fibres in amputation neuroma, and in the regeneration of nerve fibres in the tail of lizards where the new fibres terminate in a brush of fusiform cells, and the knowledge that the growing axon of a nerve is surrounded by a capsule of such cells, would lead us to assume that the terminal ramifications of the fibres, which break up into these fusiform cells, are the growing points of the fibres, and that the most fully evolved and differentiated part is the oldest part of the fibres. In the cord this part of the fibres is in the pia, in the immediate vicinity of the anterior roots; in the medulla and pons the most fully-differentiated fibres are in the more central parts of the nodule, and the winding of the fibres, as it were, has taken place around the first-formed elements. The fibres in these positions are derived, therefore, from "rests" of undifferentiated cells of the value of peripheral neuroblasts, which have been carried in to the tissue in the walls of the ingrowing vessels, and which go on to the production of a neurogenous tissue which reaches the stage of embryonic fibres—the protoplasmic bands of Durante. The fibres in the cord have arisen from "rests" of undifferentiated cells left in the immediate vicinity of the part where in normal development the fibres are first laid down. As the spaces in the pia and pial septa give them a free path of growth, they develop in parallel and intertwining strands, and only later, when possibly they meet with some difficulty in their path, do they assume a twisted and nodular form. The precise origin of the fibres from the point immediately peripheral to the *Ablassungzone* of the anterior nerve roots is explained by the fact that here probably the nerve fibre cells, according to this view of their development, are first likely to be deposited.

Still assuming the peripherist view of the origin of the nerve fibre from a cell-chain, the question arises: Is it possible for such indifferent cells of the value of peripheral neuroblasts, independent of any central influence and function, to differentiate to the stage of the most fully evolved fibres in the cord? An answer to this question would be rendered easier if we could indicate the period at which these nodules have arisen. Is it that in a very early stage of development, *pari passu* with the development of the blood-vessels, indifferent cells have laid down embryonic nerve fibres? In such a case we find it easy to understand that this abnormal cell-chain might become linked on to the process of a central neuroblast just as the normal anterior roots become connected. If these, then, were such aberrant nerve roots, the incompleteness of their differentiation would be sufficiently accounted for by the sterility of their function. In such a case, however, we would have to admit that nodules with fibres having no function have persisted through life in spite of the supposed inherent weak vitality of such fibres. On the other hand, is it possible that undifferentiated potential peripheral neuroblasts have remained undeveloped at the point of their first deposition, and in later life have taken on a proliferative activity which has resulted in the formation of nerve fibres? The most fully evolved portions of such fibres have remained as parallel strands near the point of their formation, because the free lymph space in the pia and pial vessels has allowed the progression, laterally and ventrally, of the fibres.

Returning now to our question regarding the stage to which peripheral neuroblasts alone may achieve the differentiation of the nerve fibre, we must refer to evidence obtained from the regeneration of nerves and from tumour formation.

(*a*) In regeneration.—It has frequently been pointed out that a neurogenous tissue, with many of the characters of embryonic nerve tissue, arises in the distal end of a severed nerve as a result of the activity of the cells of Schwann's sheath. DURANTE, BALLANCE and STEWART, and BETHE have shown that in the specific tissue a differentiation to axis-cylinder and incomplete myelination may take place even when the distal end is not united to the central end. For a complete differentiation of axial fibrils and myelin, all admit that the influence of the central neuroblast is essential.

(*b*) In tumour formation.—The generalisation that the genesis of nerve fibres in regeneration recapitulates the stages of its first development has necessarily its limitations, and one of these may be the modifications imposed on the cells derived from the proliferation of the sheath of Schwann nuclei. It is not necessary, then, to deny the possibility that in tumour formation peripheral neuroblasts can form completely differentiated fibres, for here we are dealing with cells left undeveloped in the tissue. The evidence from the cases of ganglio-neuroma already mentioned leads us to suppose that the nerve fibre cells or their precursors differentiate to the development of nerve fibres which show many of the characters of fully formed nerves, stopping short again of the stage of complete axial fibril and myelin differentiation.

From this evidence, therefore, we gather that it is quite conceivable that the fusiform cells in our preparations have evolved to the formation of nucleated tubes in the condition of the protoplasmic bands of Durante in the medulla and pons, and in the cord to a yet completer stage of differentiation. LENHOSSEK, a convinced centralist, states in his latest paper that he cannot deny the evidence that the sheath of Schwann cells (lemnoblasts) may in pathological conditions, in virtue of their origin from the neural crest, produce true nerve fibres. To LENHOSSEK the sheath of Schwann cells are the glia elements of the peripheral nervous system, but he thinks that, in the uncertainty of our conception of the actual manner of cell differentiation, it is possible that a mother cell which should have differentiated along one line may in pathological conditions differentiate along another which had the same histogenesis.

This attempt at a possible interpretation and correlation of our observations is not regarded as in any sense a logical proof. It is not contended that the facts prove the truth of this conception, but it is maintained that this view, though based only on deductions, gives clearness to an otherwise quite unintelligible process.

It is convenient at this stage to consider one or two criticisms of the peripherist standpoint with special references to appearances in our preparations.

The necessity of the influence of the central ganglion cell to complete the differentiation of the new nerve fibre, arisen from the proliferation of the sheath of Schwann cells, in regeneration has seemed an unassailable argument in favour of the centralists' view. To this criticism the reply has been made that if it is true that every cell differentiates in view of a function, it is necessary to remember that it is the functioning which determines and perfects the cell differentiation. The nerve paths in the embryo remain as embryonic nerves till the function of the tract is called into play; influences which accelerate or retard the period at which nerve fibres are brought into functional activity have also an effect in determining the date of complete axial fibril and myelin differentiation. **Margulies** has pointed out that in the newly-born kitten, if the eyelids on one side are carefully opened, the optic nerve on that side myelinates before that of the opposite side excluded from the light, and numerous other instances might be given where the completion of differentiation is related to the completion of function. The fibres in the distal end of a non-united nerve remain for a very considerable time as embryonic nerve fibres, but when secondary suture is carried out they very rapidly effect a complete differentiation—in a period of time in which it would have been impossible for axis-cylinders to grow out from the central to the distal end.

The differentiation proceeds, therefore, *pari passu* with the functioning which is its determining cause. **Ballance** and **Stewart** think that some stimulus, afforded by the conducting of impulses, is necessary in order to admit of the full development of the nerve fibres, and **Graham-Kerr** relates the differentiation of the neurofibrils to the repeated passage of impulses along them. To attain its perfect structure, therefore, a nerve must be brought into relation to its functional *Inanspruchnahme*. **Bethe**, at present the most prominent supporter of the peripherist view, claims that it is not necessary to have complete differentiation to have an autogenous regeneration. Regeneration in the distal end of a non-united nerve is not due to the ingrowing of axis-cylinders from the central end, but the autogenous regeneration of the sheath of Schwann cells forms a neurogenous tissue to which complete differentiation comes when the nerve is brought into its *Funktionskreis*. This neurogenous tissue is the maximum of what could be expected for the regenerative powers inherent in cells which have been derived from highly differentiated elements, while the first development is carried out in definite correlation with tissues all in the act of development. **Bethe** in some of his interpretations may have overstepped the mark, and some of his experiments may not be unequivocal, yet his basal contention, maintained after long research and in face of the severest criticism, that the new fibres arise within the proliferated cells of the sheath of Schwann and not as outgrowths of the central axis-cylinder, is supported by the results of the most recent embryological researches, by a very large number of workers on the regeneration of nerves, and by numerous observations on the genesis of nerve fibres in tumours.

A further criticism has been raised by **Cajal** and **Perroncito** in regard to the division of the fibres and the leashes of fine fibrils found in the old neurilemma sheaths of a regenerated nerve. Those writers think that it is impossible to explain such findings except by the dissociation of the old axis-cylinder into its constituent fibrils and the terminal or collateral branching-off of these primitive fibrils. **Ballance** and **Stewart** have noted that the proliferated sheath of Schwann cells divide in an obliquely longitudinal plane so that the resulting daughter cells somewhat overlap one another, and by successive divisions closely-set longitudinal columns or chains are formed. The first threads of axis-cylinders appear in close relation to the elongated nuclei, and each cell is potentially capable of forming a segment of a complete nerve fibre, so that within an old neurilemma sheath may be found parallel axis-cylinder filaments which ultimately join with the poles of adjoining filaments to form a leash of fibrils. FRANCINI and DURANTE have observed that in the proliferation of the sheath of Schwann nuclei the division may take place in two directions, *i.e.* transversely to the longitudinal axis of the cell, and parallel to it. In our preparations we have drawn attention to the evidence of the longitudinal cleavage of nucleus and cell which results in the formation of the first links of two new chains, which thus give the appearance of a dichotomous division and have suggested that a further elongation of the cell-chain takes place by transverse cleavage of nucleus and cell.

Again, regarding the chemiotropic influence attributed by the centralists to the sheath of Schwann cells, it is not easy to understand what attracting or directing or orienting influence these cell-chains could have in the development of a nodule whose fibres cross each other in such varying directions. There is much to indicate that the nerve fibres take the path of least resistance, and are guided by the more fixed structures in the line of their general growth.

We have noted these criticisms of the peripherist view in relation to points bearing on our preparations, and we close with a brief statement of three criticisms of the outgrowth theory. The supporters of the cell-chain structure of the peripheral nerves, firstly, find it difficult to conceive of a prolongation of a cell so disproportionate to the element which gave it birth; secondly, believe it impossible that a differentiated substance like the axis-cylinder can bud, as such a procedure is against the *data* of general cytology which attributes to differentiated substances only a functional rôle; and finally, they attribute the absence of any satisfactory demonstration of regeneration of fibres in the central nervous system to the absence of the activity of the neurilemma cells.

Conclusion.—FRANCINI states that in the histological study of a neuroma an intuition came to him of the constitution of the peripheral nerves. We think it right to emphasise that we began this investigation with no preconceptions in favour of the multicellular structure of the peripheral nerve. We accepted the classical teaching of HIS and CAJAL that the axis-cylinder is an outgrowth from the central cell and that its free end terminates in an incremental cone of growth. A prolonged study of our preparations and the further light shed upon them by research into the literature of the genesis of the nerve fibres in the embryo, in regeneration, and in tumour formation, led us, however, to the following conclusions :—that fusiform nucleated cells linked on to one another have formed embryonic nerve fibres; that in these nucleated fibres, which show very distinctly in their segmental structure their origin from individual cells, have differentiated to a greater (in the cord) or lesser (in the medulla oblongata and pons) degree the specific nervous elements—axis-cylinder and myelin sheath; and that function is essential to the complete differentiation of the nerve fibre. As the genesis of these cells cannot be traced to any of the specific elements of the tissue, we suggest that the fusiform nucleated cells which build up the nucleated tubes and nerve fibres are indifferent cells of the value of peripheral neuroblasts—according to the cell-chain conception—which have wandered into the mesodermic tissue forming the *anlage* of the vessels and of the connective tissue constituents of the cord, and that, later, they develop their latent activity.

The multiplicity of the nodules favours this mode of origin, and the presence of several anomalies—the malformation in the pons, the glia islets in the spinal pia, and the heterotopia of ganglion cells—lends countenance to the correctness of the assumption that these, together with the neuromata, must be regarded as developmental anomalies.

Our study, then, is a confirmation, from the aspect of a pathological new formation, of the multicellular structure of the peripheral nerve fibre.

The supporters of this view claim that the neurone conception is thus placed in its true light without necessarily destroying it: "Elle réduit la doctrine des neurones à sa véritable valeur sans l'ébranler." The neurone would therefore no longer be looked upon as a structural unit but its trophic autonomy is retained. Two of our predecessors in the study of this difficult and complex problem have taken as the motto of their work, "To travel hopefully is a better thing than to arrive," and, in concluding, as we recognise the conscientiousness of the research which has led equally able workers to take views that seem so fundamentally opposed to one another, we must admit that there are no sufficient grounds for stating that the old neurone theory has had its day, nor, on the other hand, that the cell-chain theory has no foundation.

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DESCRIPTION OF PLATES.

(Figs. 1–14 are from drawings: figs. 15–66 are micro-photographs.)

PLATE I.

Figs. 1–5. Stages in the evolution of the nucleated nerve fibre from individualised fusiform cells. *Cf.* figs. 59–66. Van Gieson's stain. × 1000.

Fig. 1. Earliest stage—a thin spindle with elongated nucleus and a slight amount of protoplasm: gradual increase in the size of the cell with a more deeply-staining filament in the protoplasm on one side of the nucleus. Transverse sections of such cells show at first the nucleus occupying almost the whole of the disc.

Fig. 2. Uneven cylindrical appearance of the nucleated "tube": the cell processes have joined in an imbricated manner and fused, and, with the fusion, the cell outlines have become lost. The discontinuous filament in each cell may now be traced as a continuous line. Cross-sections of such cylinders through nucleated and non-nucleated portions.

Fig. 3. Contours of nucleated "tubes" have now become parallel, the sinuously-winding filament more marked, and the nucleus has become slightly peripheral and flattened, though still large and bulging into the "lumen" of the "tube." Cross-sections of such "tubes."

Figs. 4 and 5. Nucleated "tube" gradually assuming the characters of the fibres of a peripheral nerve with central filament very distinct, nucleus flattened and peripheral, condensed outer layer of myelin, and the appearance of a slight amount of interfibrillar tissue.

Fig. 6. Isolated neuroma nodule, within the adventitia of a medium-sized vessel, lying in the anterior column of white matter (1st dorsal segment). The nodule is composed of interlacing fibres with neurilemma nuclei and the fibres are cut transversely, obliquely, and longitudinally. Note the central vessel and the outer thickened wall of the adventitia completely cutting off the nodule from the surrounding healthy white matter. *Cf.* fig. 19. Van Gieson's stain. × 250.

Fig. 7. Glia cell proliferation and hyperplasia in an area of commencing fibrosis in the cord. Note infiltration of lymphocyte-like cells, also the presence of spindle-shaped elements. Van Gieson's stain. × 350.

PLATE II.

Figs. 8–12. Cajal's reduced silver method for myelinated axis cylinders. × 250.

Fig. 8. Neuroma nodule. Whorl-arrangement of the fibres giving the typical ball-of-wool appearance; some of the fibres interlacing in all directions and others passing parallel for a time.

Fig. 9. Transverse section of normal small vessel in the white matter of the cord from neuroma case.

Fig. 10. Similar vessel with delicate fibres in the adventitia.

Figs. 11 and 12. Vessels in the grey matter of the 7th and 8th cervical segments showing within the adventitia a plexus of fine fibres, with branchings ending in homogeneous bulbs.

Fig. 13. Anterior spinal root vessel within the pia (lumbar cord); showing very numerous newly-formed medullated fibres within the adventitia. Note the vesicular appearance and intertwining of the new fibres, that the internodal segments are short and irregular, the fibres being made up of elongated, often bulging, cylinders with narrow connecting bridges, and that the myelin stains specifically yet not so intensively as that of fully formed fibres. Kulschitzky-Pal and picro-fuchsin. × 350.

Fig. 14. *Cf.* figs. 65, 66. Stages in the myelination of the nucleated "tube." Note the segmental character of the tube in which the differentiation is taking place (*a*), the darkening (*b*), and the granularity (*c*) within the outer border of each segment; and the commencing lattice-work appearance given by the newly-formed myelin (*d*, *e*). Cross-sections of fibres in the above stages (*f*). Heidenhain's iron-hæmatoxylin stain. × 700.

PLATE III.

Figs. 15–18. Transverse sections at different levels of the lumbo-sacral cord. Note (1) numerous nodules both in the grey and white matter, (2) the unravelling of the fibres composing the nodules into the general texture of the tissue, (3) the radiating lines of fibrosis passing inwards along pial septa and lateral vessels, also (4) the marked fibrosis of the posterior root-entry zones. Paraffin sections. Van Gieson's stain. Figs. 15 and 16, × 20. Figs. 17 and 18, × 10.

Figs. 19–22. Different varieties of nodules to show the intertwining of the fibres and the varying amount of neurilemma nuclei. Van Gieson's stain.

Fig. 19. Isolated nodule in the white matter of the anterior column of the 1st dorsal segment. *Cf.* fig. 6. × 180.

Fig. 20. High-power view of the nodule in fig. 15 seen passing inwards from the pia in region of ligamentum denticulatum. × 200.

Fig. 21. Nodule in relation to a commissural vessel. × 200.

Fig. 22. Nodules in the pia of the lateral region of the cord and passing inwards from the periphery. *Cf.* fig. 35. × 150.

Plate IV.

Figs. 23–28. Kulschitzky-Pal modification of Weigert's medullated sheath stain. Different levels of the lumbo-sacral cord: to show the medullated character of the fibres composing the nodules.

Fig. 23. Large nodule, with very fine intertwining fibres, at anterior mesial angle of grey matter. × 15.

Fig. 24. Similar nodule, with slightly coarser fibres, within the mesial margin of anterior grey matter. × 20.

Fig. 25. Nodule within a glial septum, together with a vessel in the pia showing numerous fibres within the adventitia. *Cf.* fig. 13. In successive serial sections a connection could be traced between the fibres in the vessel-wall and the fibres composing the nodule. × 35.

Fig. 26 (× 100), fig. 27 (× 160), and fig. 28 (× 160) show high-power views of the nodules in figs. 23, 24, and 25 respectively.

Figs. 29–34. Cajal's reduced silver method for axis-cylinders. Different levels of lower cervical cord: to show the presence of axis-cylinders in the fibres composing the nodules.

Fig. 29. The nodule drawn in fig. 8. This nodule had its long axis parallel to the long axis of the cord. × 200.

Fig. 30. Nodule, of more cylindrical shape, with its long axis at right angles to the long axis of the cord. Note the very fine character and intricate intertwining of the fibres composing the nodule. × 160.

Fig. 31. Nerve fibres in the adventitial lymph spaces of the vessels at the base of the anterior median fissure and of the commissural vessels. These fibres in successive sections were traced to the nodule in fig. 29. × 75.

Fig. 32. Vessels passing to the anterior horn showing numerous fine fibres in the adventitia. × 200.

Fig. 33. Similar vessel within the grey matter showing the fibres in the adventitia following the bending and the division of the vessel. × 160.

Fig. 34. Intra-medullary course of the anterior root artery showing very fine fibres in the adventitia. × 250.

Plate V.

Figs. 35–39. Sections chosen from 3rd lumbar segment (cut serially) to trace the mode of formation of the nodules. Kulschitzky-Pal and picro-fuchsin.

Fig. 35. Wedge-shaped nodule lying in the pia, opposite the ligamentum denticulatum, and extending inwards from the periphery. × 70.

Fig. 36. Shows the fibres passing from this nodule in the adventitia of the lateral vessel to a nodule at the margin of the grey and white matter. × 50.

Fig. 37. Nodule of fig. 36 showing the unravelling of the fibres into the general texture of the grey matter. × 180.

Fig. 38. Fibres of nodule in fig. 35 passing inwards from the periphery, forming tuft-like nodule, and fibres in a vessel-wall in the pia. × 180.

Fig. 39. Fibres passing from nodule of fig. 35 in parallel strands towards the region of anterior roots. × 35.

Fig. 40. Wedge-shaped nodule, at anterior mesial angle of anterior column, formed by fibres which have passed mesially from the anterior roots. Kulschitzky-Pal and picro-fuchsin. × 20.

Figs. 41–43. Sections from 2nd sacral segment. Kulschitzky-Pal and picro-fuchsin.

Fig. 41. Fibres passing in commissural vessel to anterior horn. × 50.

Fig. 42. Very fine fibres, contorted irregularly, in the adventitial lymph spaces of the anterior central vessels at base of anterior fissure. Vessel dividing: one branch seen in fig. 41, another in fig. 43. × 50.

Fig. 43. Branch of the anterior central vessel seen in fig. 42, passing to lateral grey matter with leashes of fine fibrils in its adventitia. × 50.

Figs. 44–46. Paraffin sections from 3rd sacral segment, Van Gieson's stain, showing nodule in region of central canal (fig. 44, × 160), and in successive serial sections the unravelling of the nodule into nucleated fibres (fig. 45, × 160), and a meshwork of individualised nucleated elements (fig. 46, × 160).

PLATE VI.

Fig. 47. Posterior root-entry zone (3rd lumbar segment), to show the *Ablassungzone*, or constriction zone, or ring of Obersteiner. Kulschitzky-Pal. × 50.

Fig. 48. Anterior root-emergent zone (7th cervical segment), to show similar *Ablassungzone* in relation to the anterior roots. Kulschitzky-Pal. × 70.

Fig. 49. Glia cell proliferation and hyperplasia. *Cf.* fig. 7. Van Gieson's stain. × 180.

Fig. 50. Anterior horn cells, showing only slight changes. Note well-marked vacuolation in a cell at lower border of figure. Unna's polychrome methylene blue stain. × 100.

Fig. 51. Transverse section of cord at level of 2nd lumbar segment: areas of marked fibrosis, often almost symmetrical in the anterior horns. Kulschitzky-Pal and picro-fuchsin. × 10.

Fig. 52. Dense area of fibrosis at base of anterior horn, and stretching amongst the antero-mesial and postero-lateral groups of cells. Kulschitzky-Pal and picro-fuchsin. × 20.

Fig. 53. Fibrosis of posterior root. Extra-medullary root gives the impression of having been carried right into the cord substance with its extra-medullary structure. Van Gieson's stain. × 35.

Fig. 54. Fibrosis of intra-medullary course of anterior root. The neurilemma, together with a layer of the pia, seems as if carried inwards along individual bundles of fibres. Van Gieson's stain. × 160.

Fig. 55. Granular deposit, often coalescing to form concretions, found in the adventitial spaces of the smaller vessels of the tissue, in close relation to the malformation described on page 778. Van Gieson's stain. × 250.

Fig. 56. Fibrosis of intra-medullary course of 5th nerve. *Cf.* fig. 53. Van Gieson's stain. × 24.

Fig. 57. Isolated nucleated patch (cut longitudinally) on the course of deep strands of 5th nerve. The affected fibres retain the normal arrangement of the fibre strands of the part involved. Van Gieson's stain. × 60.

Fig. 58. Isolated nucleated patch, similar to above, but cut transversely. Van Gieson's stain. × 60.

PLATES VII. AND VIII.

Figs. 59–66. Paraffin sections from medulla oblongata. *Cf.* figs. 1–5 and fig. 14.

Figs. 59 and 60. Loose meshwork of interlacing nucleated fibres and elongated nucleated elements. Fusiform cells (*cf.* fig. 1) are seen linked together, by their processes, to form cell chains, and by the fusion of the imbricated ends there is a transition into nucleated plasmodial bands or "tubes" (*cf.* fig. 2). Note appearances as of dichotomous division, and that the nucleus lies definitely within the cell outline or within the "lumen" of the "tube." Fig. 59 (× 200), fig. 60 (× 400). Van Gieson's stain.

Figs. 61 and 62. Convergence of nucleated "tubes" to form more or less parallel bundles or strands, between which similar elements are found cut transversely. Presence of small amount of interfibrillar connective tissue and delicate capillaries. Fig. 61 (× 160), fig. 62 (× 160.) Van Gieson's stain.

Fig. 63. Commencing intertwining of the parallel strands. Such intertwining forms the transition to the definite nodule in fig. 64. Van Gieson's stain. × 200.

Fig. 64. Nodule on floor of 4th ventricle, situated laterally and posteriorly to the strands of the 7th nerve—a further stage of the intertwining in fig. 63. Van Gieson's stain. × 25.

Figs. 65 and 66. Commencing myelination of the nucleated "tubes." Note the lattice-work appearance of the newly-formed myelin. Heidenhain's iron-hæmatoxylin stain. Fig. 65 (× 450), *cf.* fig. 14, *a*, *b*, *c*. Fig. 66 (× 450), *cf.* fig. 14, *d*, *e*, *f*.

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BRITISH MUSEUM NATURAL HISTORY

BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.

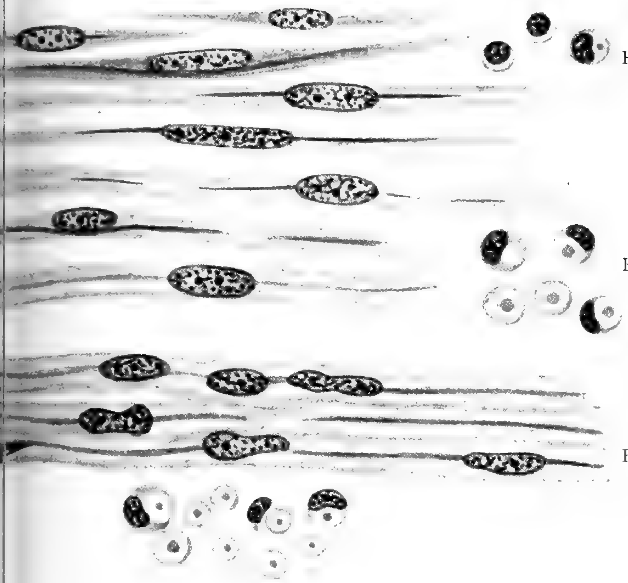
FIG. 1.

FIG. 2.

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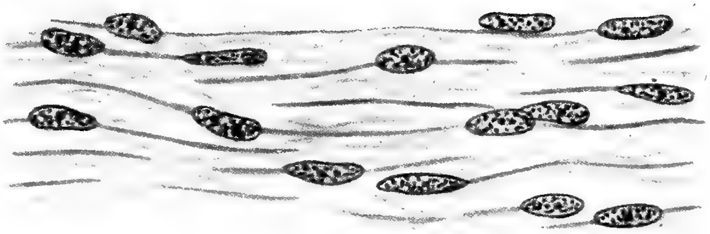
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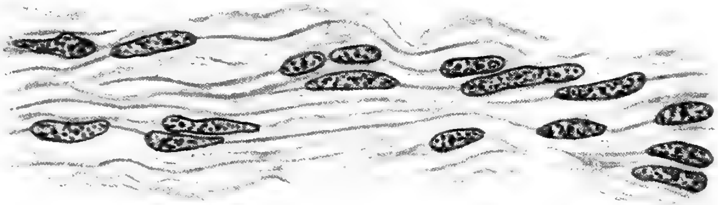
FIG. 5.


FIG. 6.

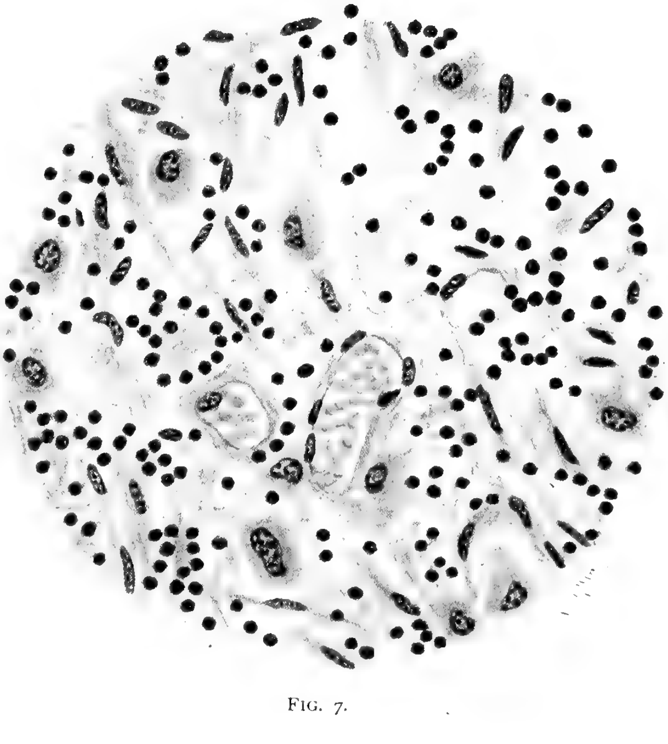
FIG. 7.

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BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.

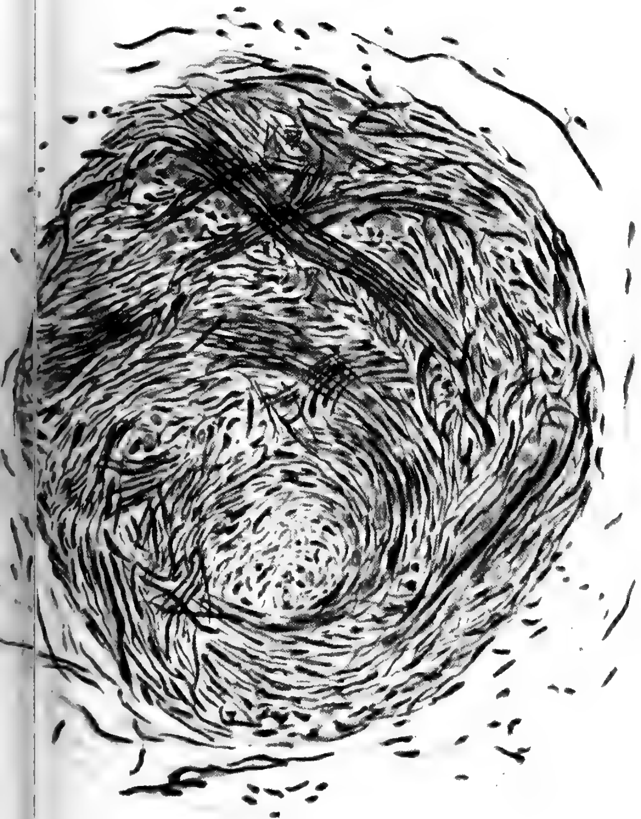

FIG. 8.

FIG. 9.

FIG. 10.

FIG. 11.

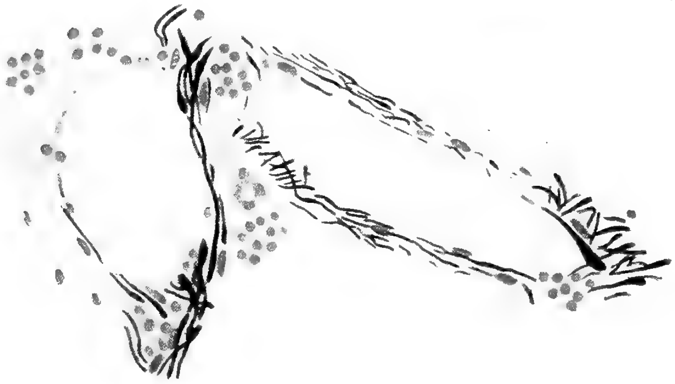

FIG. 12.

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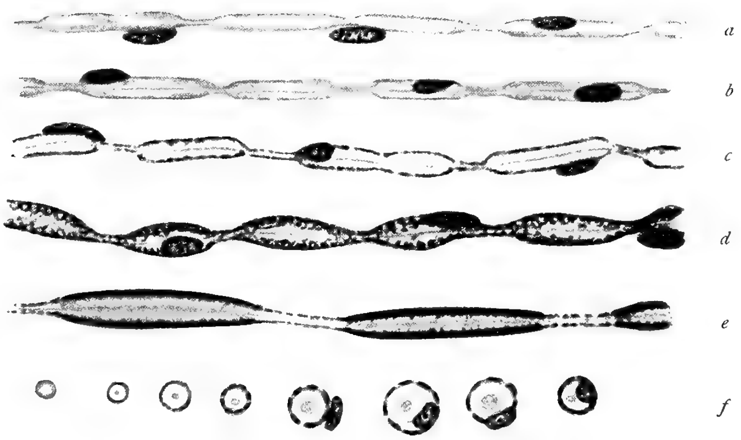

FIG. 14.

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BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.

FIG. 15.

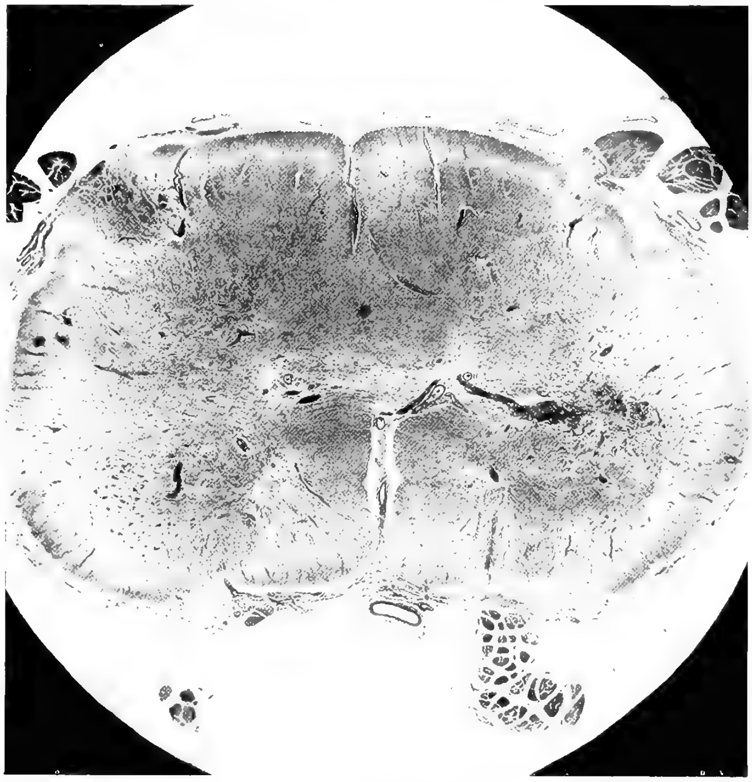

FIG. 16.

FIG. 17.

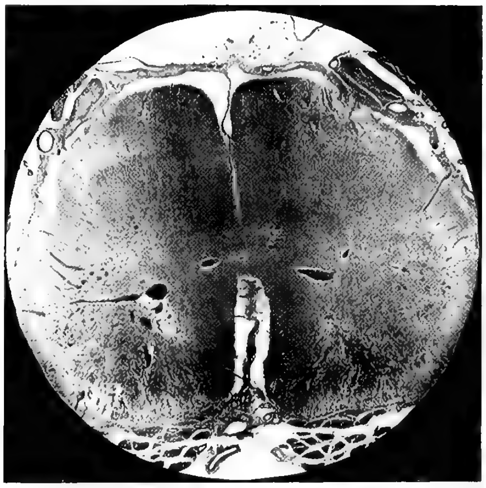

FIG. 18.

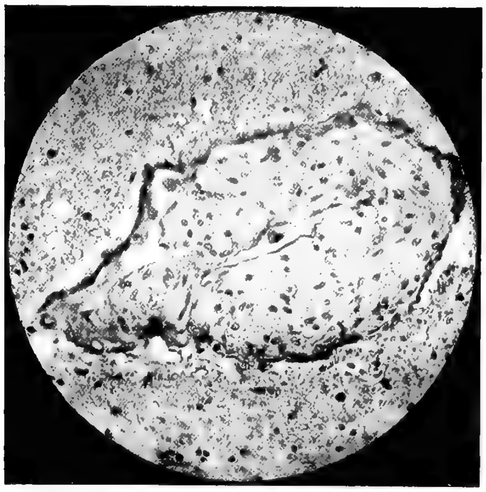

FIG. 19.

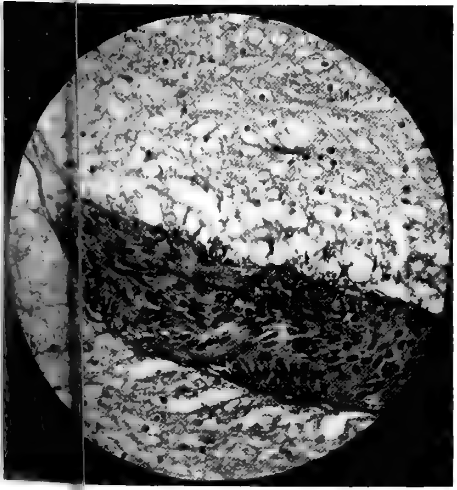

FIG. 20.

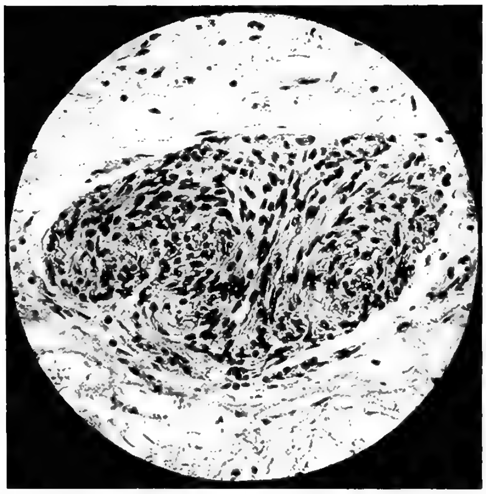

FIG. 21.

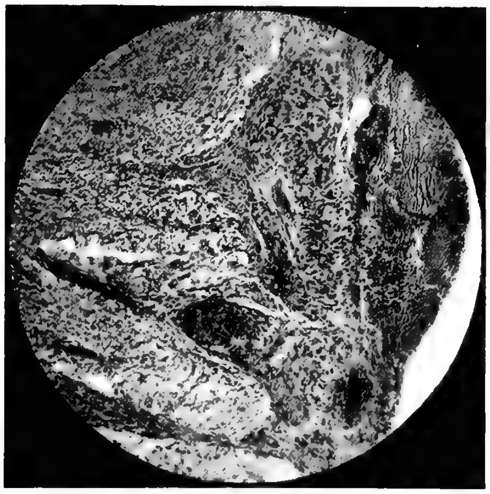

FIG. 22.

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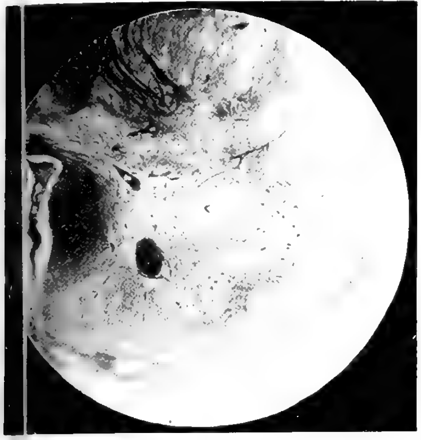

FIG. 23.

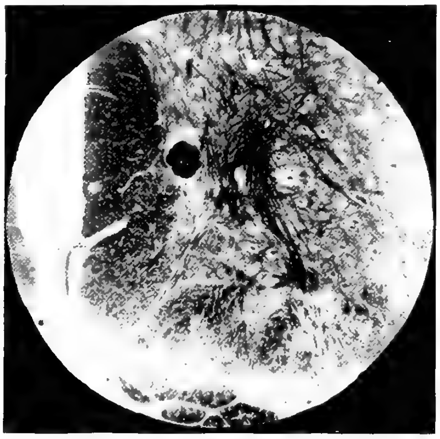

FIG. 24.

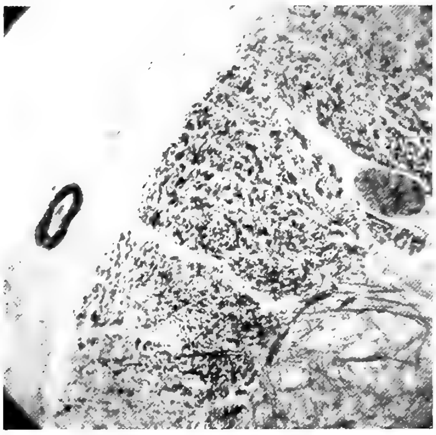

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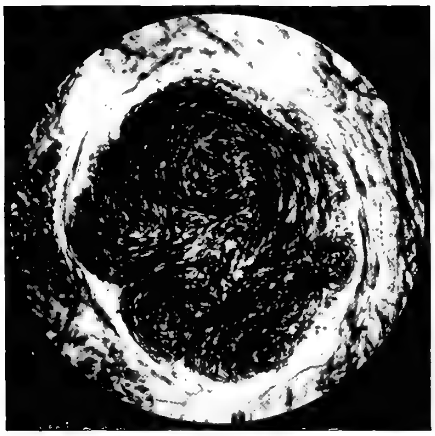
FIG. 26.



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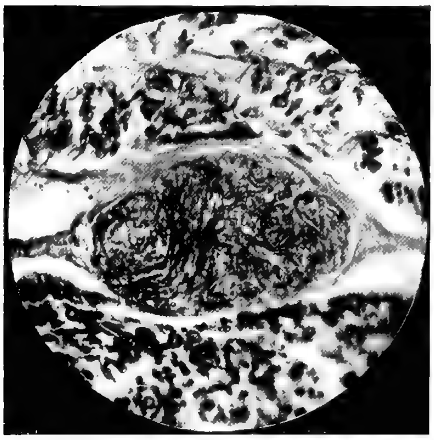

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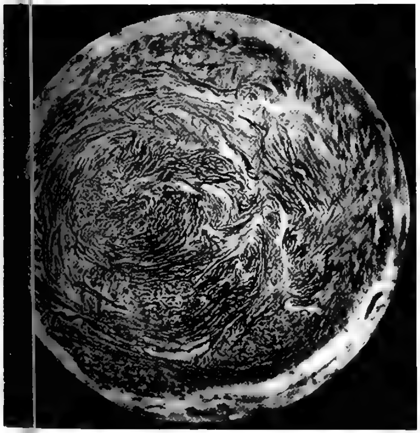

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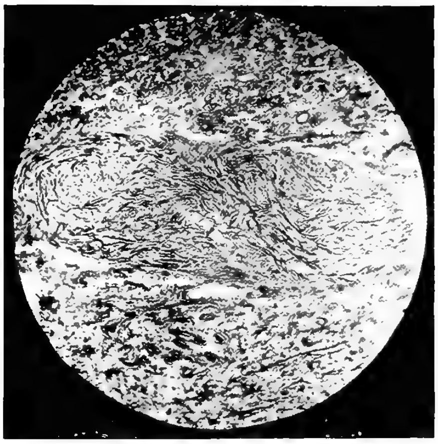

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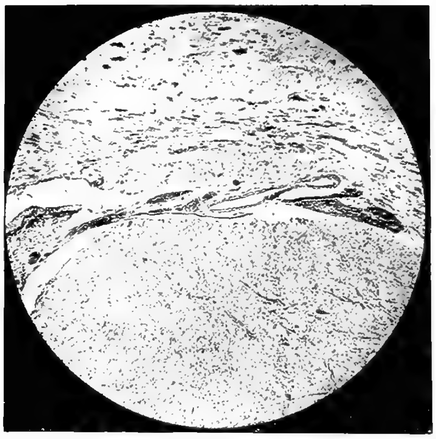

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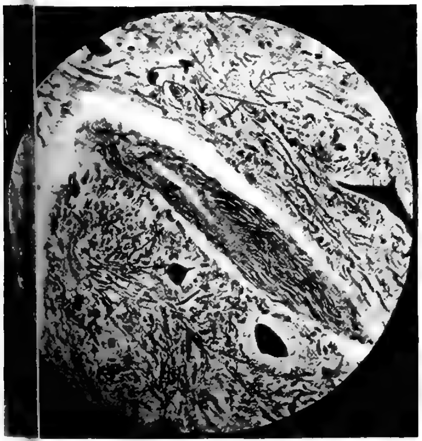

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FIG. 33.

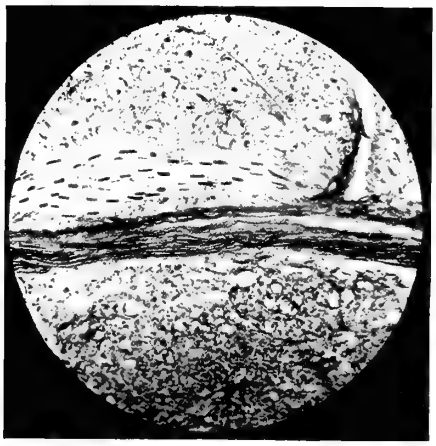

FIG. 34.

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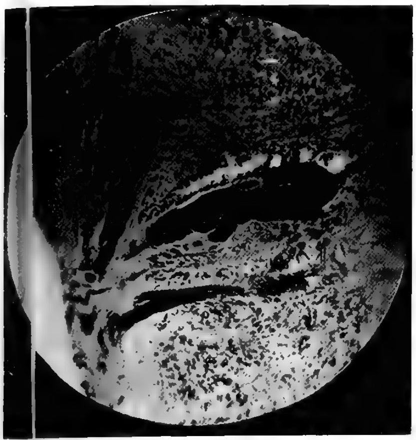
BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.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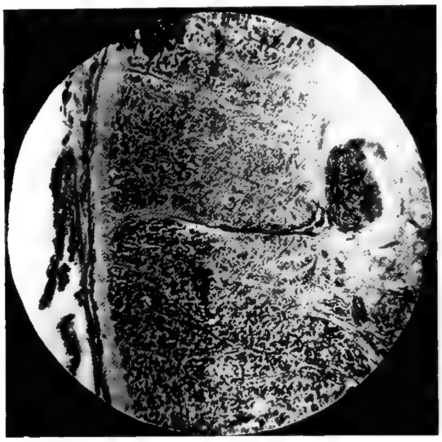
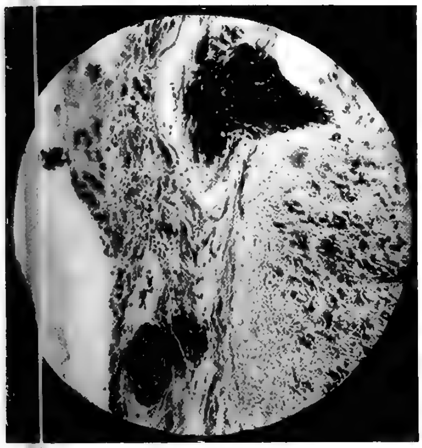


Fig. 36.


Fig. 37.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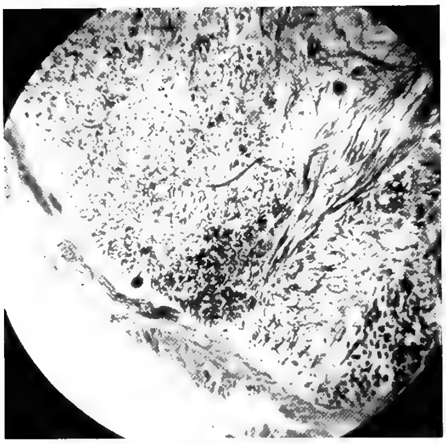


Fig. 39.


Fig. 40.

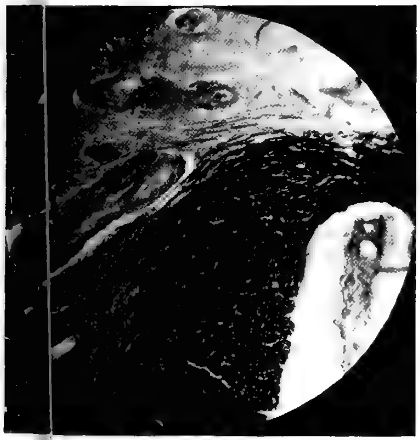
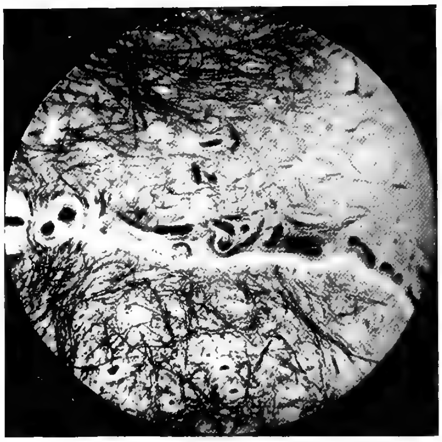


Fig. 41.


Fig. 42.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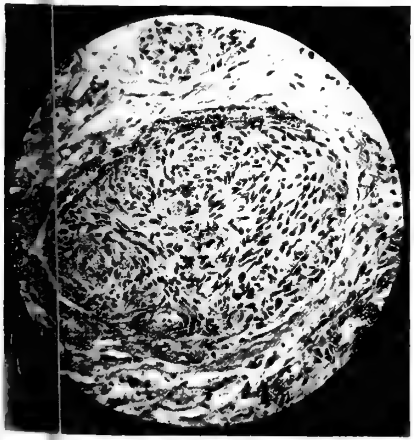
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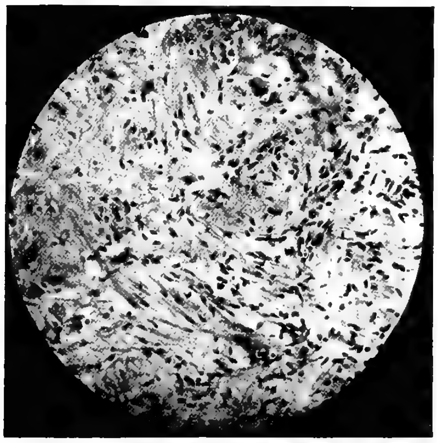
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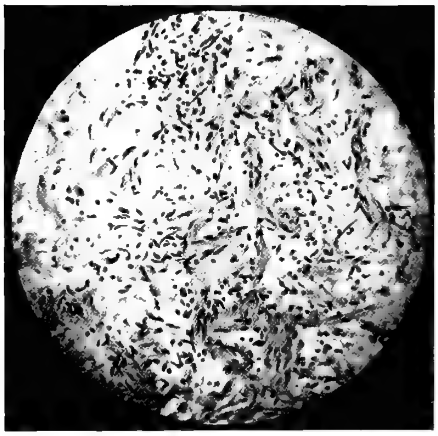
Fig. 46.

BRITISH MUSEUM NATURAL HISTORY

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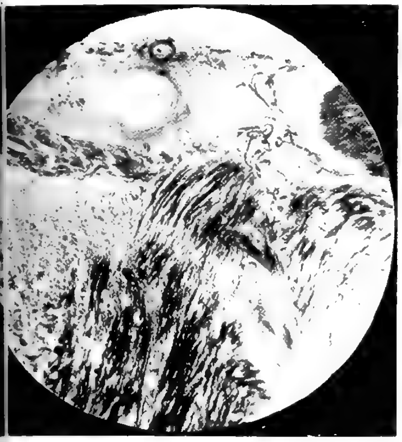
BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.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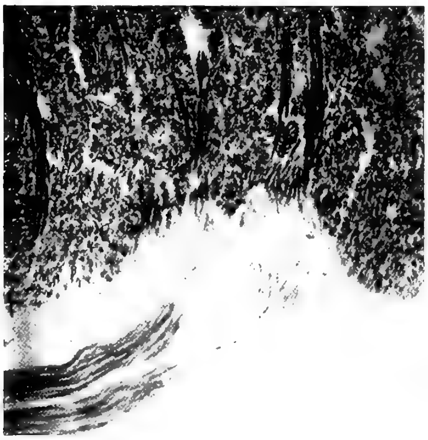
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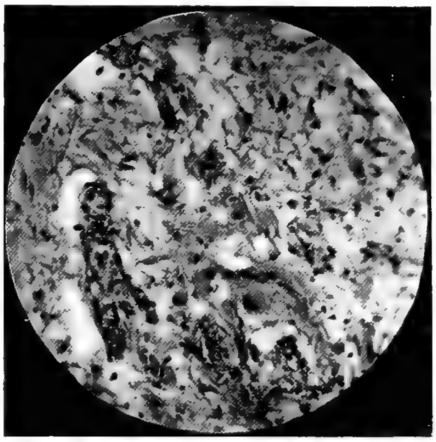
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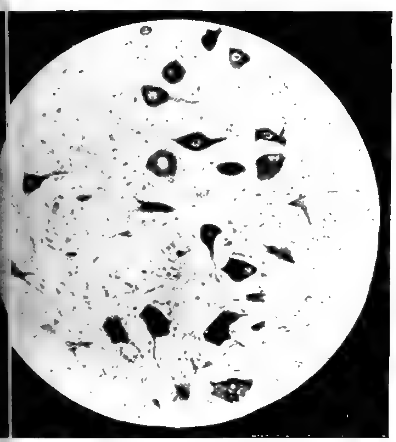
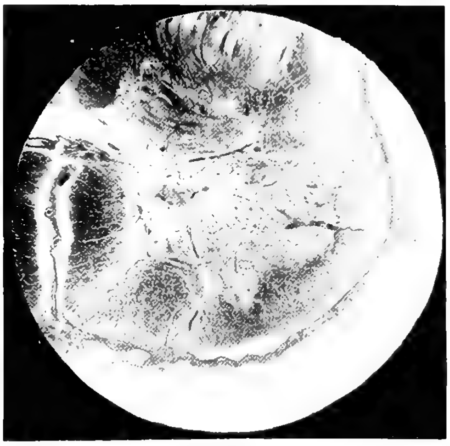


FIG. 50.


FIG. 51.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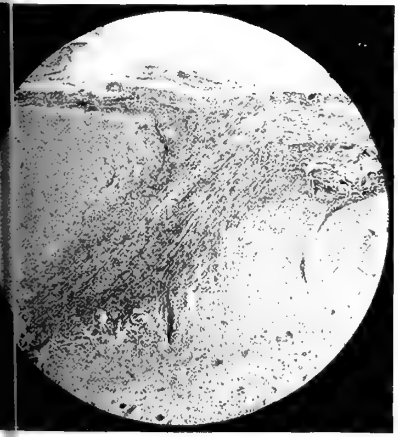
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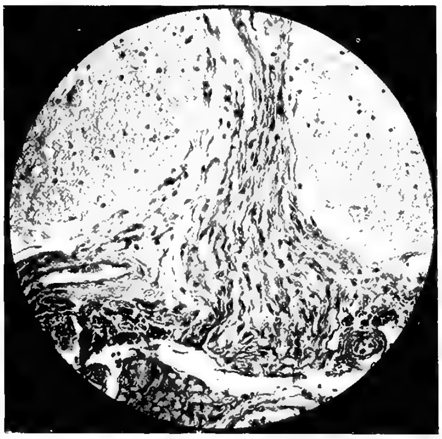
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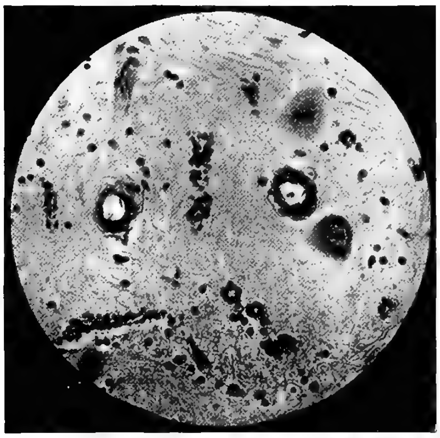
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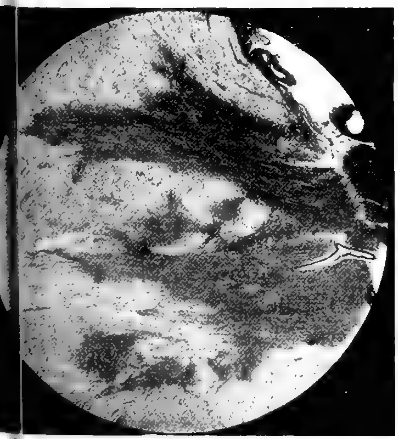
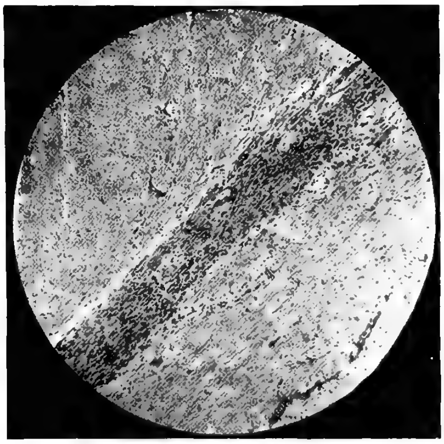


FIG. 56.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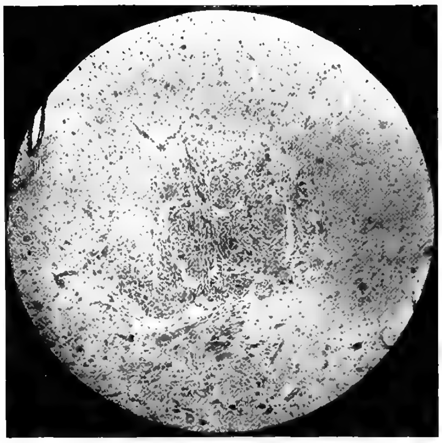
FIG. 58.

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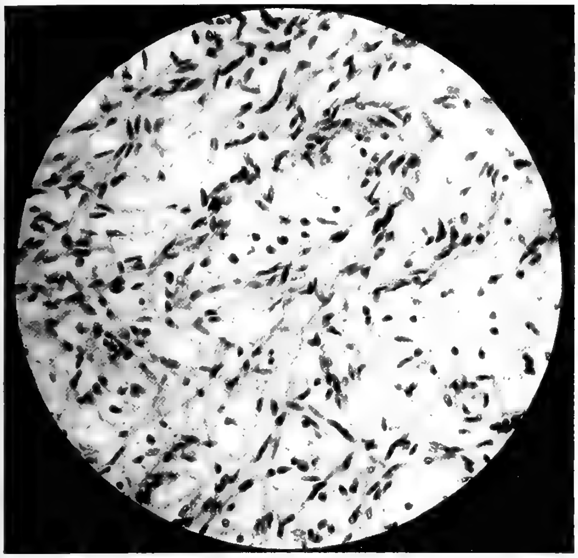
BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.



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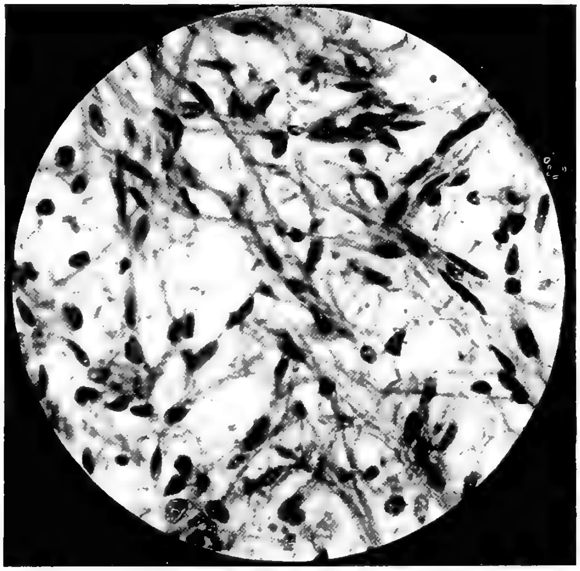

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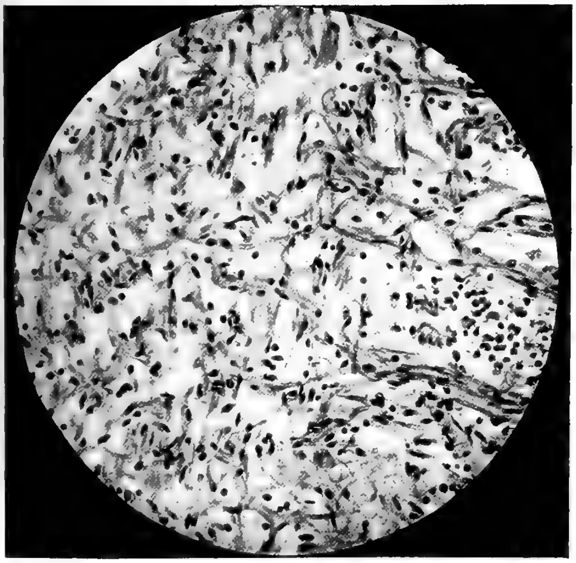

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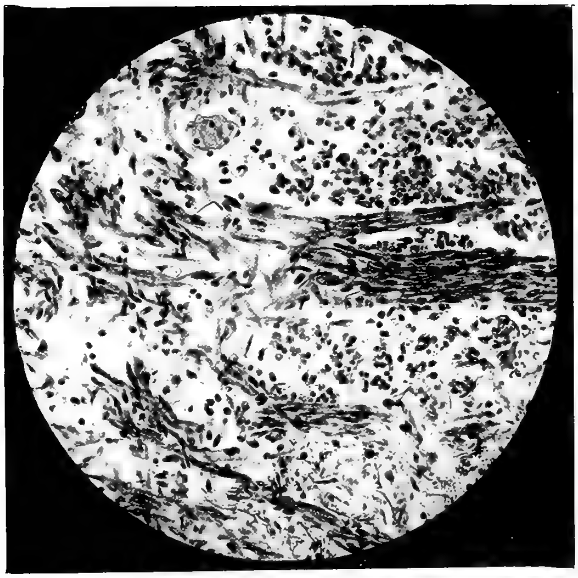

FIG. 62.

BRITISH MUSEUM
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BRUCE AND DAWSON.—MULTIPLE NEUROMATA OF THE CENTRAL NERVOUS SYSTEM.

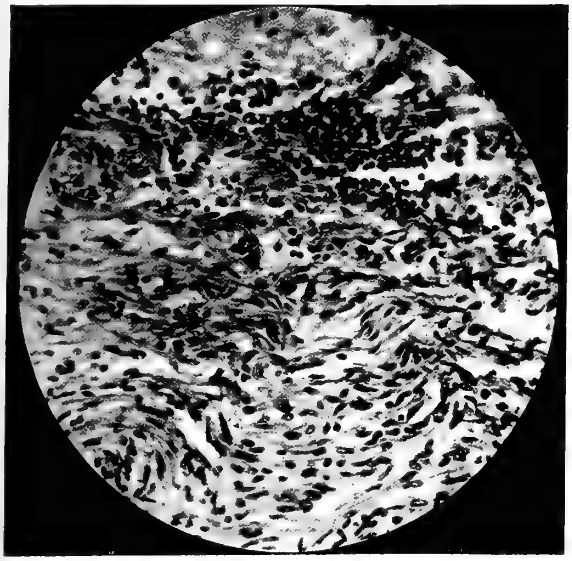

FIG. 63.

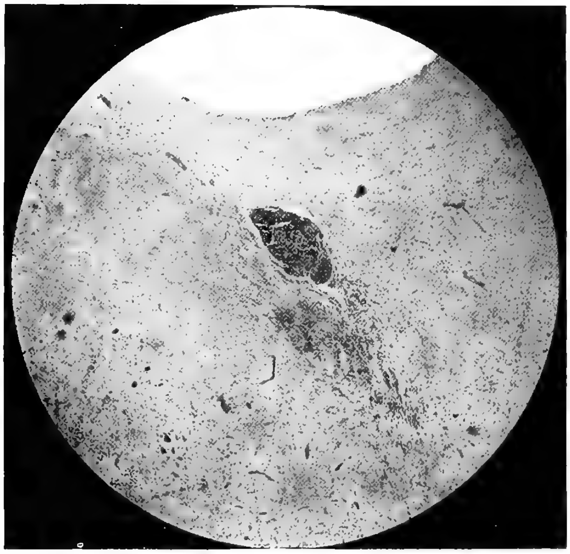

FIG. 64.

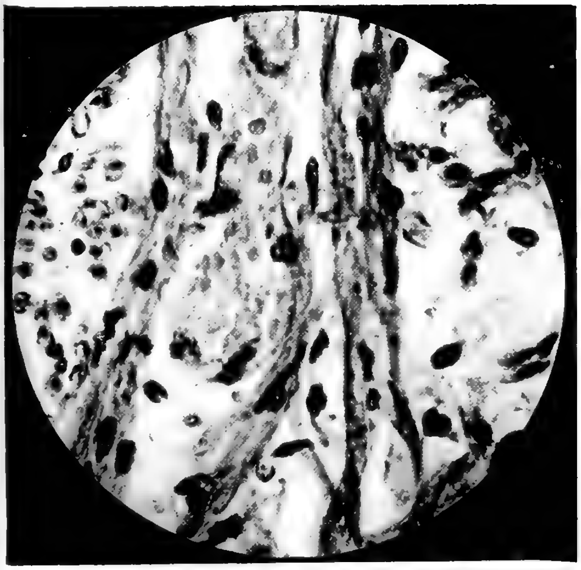

FIG. 65.

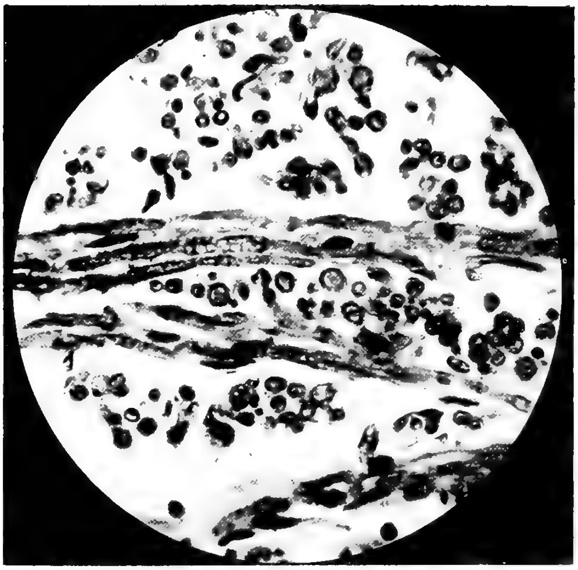

FIG. 66.

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XXXV.*	Pt. 1	2	2	0	1	11	0
,,	Pt. 2	1	11	0	1	3	6
,,	Pt. 3	2	2	0	1	11	0
,,	Pt. 4	1	1	0	0	16	0
XXXVI.	Pt. 1	1	1	0	0	16	0
,,	Pt. 2	1	16	6	1	7	6
,,	Pt. 3	1	0	0	0	16	0
XXXVII.	Pt. 1	1	14	6	1	5	6
,,	Pt. 2	1	1	0	0	16	0
,,	Pt. 3	0	16	0	0	12	0
,,	Pt. 4	0	7	6	0	5	8
XXXVIII.	Pt. 1	2	0	0	1	10	0
,,	Pt. 2	1	5	0	0	19	0
,,	Pt. 3	1	10	0	1	3	0
,,	Pt. 4	0	7	6	0	5	8
XXXIX.	Pt. 1	1	10	0	1	3	0
,,	Pt. 2	0	19	0	0	14	6
,,	Pt. 3	2	3	0	1	11	0
,,	Pt. 4	0	9	0	0	7	0
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	,,	Pt. 2	1	7	0	1	0	0
	,,	Pt. 3	1	13	9	1	5	3
	,,	Pt. 4	0	4	6	0	3	6
	XLVI.	Pt. 1	1	1	10	0	16	6
	,,	Pt. 2	1	5	8	0	19	4
	,,	Pt. 3	1	7	3	1	0	11
	XLVII.	Pt. 1	0	19	9	0	15	0
	,,	Pt. 2	1	3	0	0	17	4
	,,	Pt. 3	1	0	10	0	15	8
	,,	Pt. 4	1	7	7	1	0	9
	XLVIII.	Pt. 1	1	2	9	0	17	2
	,,	Pt. 2	1	9	6	1	2	5
	,,	Pt. 3	1	11	0	1	3	3
	,,	Pt. 4		—			—	
	XLIX.	Pt. 1	0	7	6	0	7	6

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BRITISH MUSEUM

XXVIII.—The Loss of Energy at Oblique Impact of Two Confined Streams of Water. By Professor A. H. Gibson, D.Sc., University College, Dundee. (With Five Diagrams.)

(MS. received June 26, 1912. Read December 2, 1912. Issued separately January 10, 1913.)

CONTENTS.

1. INTRODUCTION.

When two jets or streams of water moving with equal or unequal velocities meet at an angle and combine to form one common stream, the impact is usually accompanied by loss of energy, which may be large if the velocities are high. If the jets are free (exposed to air on every side), the pressures are unaltered by impact, and the loss may be readily calculated in terms of the initial velocities and angle of inclination, by an application of the equations of energy and of momentum. Where the streams are confined before and after impact—as, for example, where the streams outflowing from the impeller of a centrifugal pump impinge on the more slowly moving body of water in the volute, or where the two streams combine in the mixing chamber of a jet pump or injector,—both pressures and velocities are altered by the impact, and the available data are insufficient to enable the magnitude of the losses to be predetermined from *a priori* reasoning.

Where an attempt has been made to calculate such losses it has been usual to assume that the kinetic energy possessed by the impinging stream, in virtue of its motion normal to the primary, or undeflected, stream, is entirely dissipated by the shock of impact, and that, if θ be the angle of incidence and if v_1 and v_2 be the velocities of the primary and impinging streams, the loss due to the parallel component ($v_2 \cos \theta$) of the velocity is given by $(v_2 \cos \theta - v_1)^2 \div 2g$ foot-lbs. per lb. of the impinging jet. The total loss per lb. of this jet is then

$$\frac{(v_2 \sin \theta)^2 + (v_2 \cos \theta - v_1)^2}{2g} \text{ foot-lbs.} = \frac{v_2{}^2 + v_1{}^2 - 2v_1v_2 \cos \theta}{2g} \text{ foot-lbs.}$$

This assumes that the loss accompanying admixture of two such streams at different velocities is the same as occurs at a sudden change of velocity between the same limits in a circular pipe suffering an enlargement of section. In view of the very different conditions obtaining in the two cases, there would appear to be as little theoretical as experimental justification for this assumption, and the present experimental investigation was projected with a view of determining the magnitude of the loss and its variation with the angle of impact, with the velocities of the streams, and with their relative cross-sectional areas.

2. Description of Apparatus and Method of Experimenting.

The pipes used in the investigation were rectangular in section, being made of wood and varnished. The following table shows the range of sizes and of angles examined:—

Series.	Sections of		Ratio of Areas.	Values of θ.
	Impinging Stream.	Primary and Final Streams.		
I.	½″ wide × 1″ deep	½″ wide × 1″ deep	1 : 1	5°, 15°, 30°, 45°, 60°, 90°.
II.	½″ ,, × 1″ ,,	1″ ,, × 1″ ,,	2 : 1	15°, 30°, 45°, 60°, 90°.
III.	½″ ,, × 1″ ,,	1½″ ,, × 1″ ,,	3 : 1	15°, 30°, 45°, 60°, 90°.
IV.	½″ ,, × 1″ ,,	2″ ,, × 1″ ,,	4 : 1	45°.
V.	½″ ,, × 1″ ,,	2½″ ,, × 1″ ,,	5 : 1	60°, 90°.

Fig. 1 shows a sectional plan of one of the channels. Pressures were measured at points (1), (2), and (3), by water piezometers at low velocities, and by differential water and mercury piezometers at high velocities. Point (3) is distant 12 inches down-stream, and points (1) and (2) each 1·5 inches upstream from the junction. The piezometer openings in the walls of the passages were formed as shown in fig. 1, *a*. The pressure

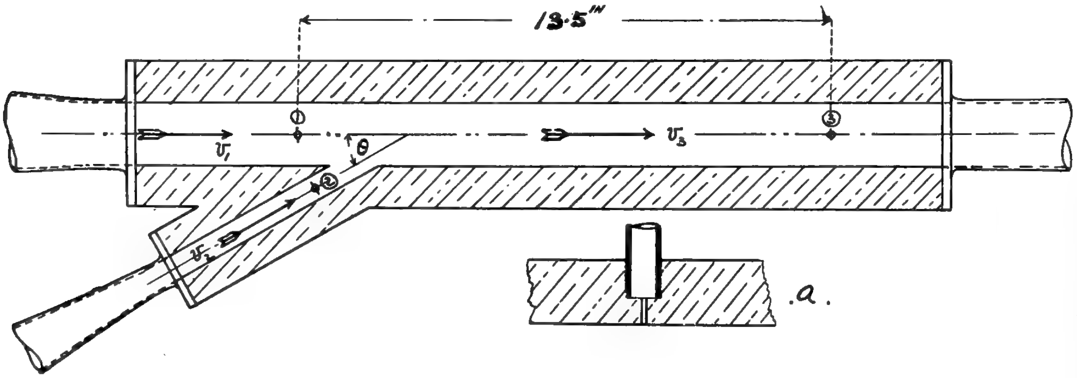

Fig. 1.

opening through the wall ($\frac{1}{16}$-inch diameter) was bored with a hot wire, and all roughness at its junction with the interior surface of the passage was afterwards carefully removed. Brass nozzles gradually changing in section from a circular to rectangular form were fitted to the two inlets and to the outlet. The primary stream (1) was supplied through a Venturi meter having a 3-inch body and a 1-inch throat. This was calibrated immediately before, and checked at intervals during, the experiments. The total discharge was caught and measured in a calibrated tank, and the volume and velocity of the impinging stream (2) were then computed by differences. The velocities adopted in the experiments ranged from 6 f.s. to 22 f.s.

Friction Loss.—The friction loss in each pipe was measured after carrying out the impact tests, by blocking up the side opening with plasticine carefully trimmed off to shape, and by measuring the drop in pressure between points (1) and (3) at different velocities. As the surface area of this plasticine is comparatively small, and as its roughness does not differ appreciably from that of the varnished surface of the wood, no special allowance has been made for its presence. From these results a friction-velocity curve was plotted showing the friction loss per foot run of the pipe, and the loss between each piezometer opening and the junction was then calculated for each experiment and deducted from the total loss to give the impact loss.

The friction loss varied slightly in different channels of the same cross-section; but the mean of the experiments gives the result, for all sizes of channel :—

$$h = \frac{flv^{1 \cdot 83}}{2gm^{1 \cdot 20}} \text{ feet of water,}$$

where h is the friction loss.

l ,, length of channel in feet.

m ,, hydraulic mean depth in feet.

v ,, velocity in feet per second.

$f = \cdot 0036$.

3. Loss at Elbows.

A general expression for the loss at impact in terms of the two velocities must be true when v_1 is zero. This corresponds to flow round an elbow having a dead end in the line of the final direction of flow, and preliminary experiments were carried out to determine the losses in such cases. Within the range of velocities adopted (6 f.s. to 22 f.s.), the excess loss of head over that in the same length of straight pipe is sensibly proportional to the square of the velocity of the initial jet (2), and is given by $F \frac{v_2^2}{2g}$ feet of water, where F has the mean values given in the following table :—

TABLE I.

θ.	Ratio of Areas of Outlet and Inlet Legs.				
	1	2	3	4	5
90°	1·53	·97	·915	·921	·925
60°	·71	·59	·70	·75	·79
45°	·44	·45	·60	·68	·73*
30°	·22	·35	·53	·62*	·68*
15°	·060	·28	·48	·58*	·652*
5°	·0084	·254	·447	·566*	·642*
0°	·0	·250	·444	·563	·64

* Obtained by extrapolation.

The values of F corresponding to $\theta = 0°$ are calculated on the assumption that the loss is then due to a sudden enlargement of section from initial to final area.

After trying various systems of graphical representation it was found that for any pipe, on plotting the logarithms of the excess of the loss occurring with any angle θ over the loss when $\theta = 0$, on a base representing the logarithms of θ, the plotted points lie sensibly on straight lines similar to A A′ (fig. 2), from which the following values of F are deduced:—

Ratio of Areas of Outlet and Inlet Legs.	Value of F.
1 : 1	$\cdot 000460\theta^{1\cdot 8}$
2 : 1	$\cdot 25 + \cdot 000228\theta^{1\cdot 8}$
3 : 1	$\cdot 444 + \cdot 000154\theta^{1\cdot 8}$
4 : 1	$\cdot 563 + \cdot 000115\theta^{1\cdot 8}$
5 : 1	$\cdot 64 + \cdot 00092\theta^{1\cdot 8}$

Here θ is measured in degrees.

Calling m the ratio of areas of outlet and inlet legs, the loss of head when $\theta = 0$ is given by $\left(\frac{m-1}{m}\right)^2 \frac{v_2^2}{2g}$ feet. Furthermore, the numerical coefficients of $\theta^{1\cdot 8}$ in the above formulæ vary almost exactly as the reciprocal of m, so that these are particular cases of the general formula—

$$\text{loss of head} = \left\{\left(\frac{m-1}{m}\right)^2 + \frac{\cdot 000460}{m}\,\theta^{1\cdot 8}\right\}\frac{v_2^{\,2}}{2g}\text{ feet.}$$

Within this range of area ratios this formula gives the loss at an elbow in such pipes, having a dead end, within about 2 per cent.

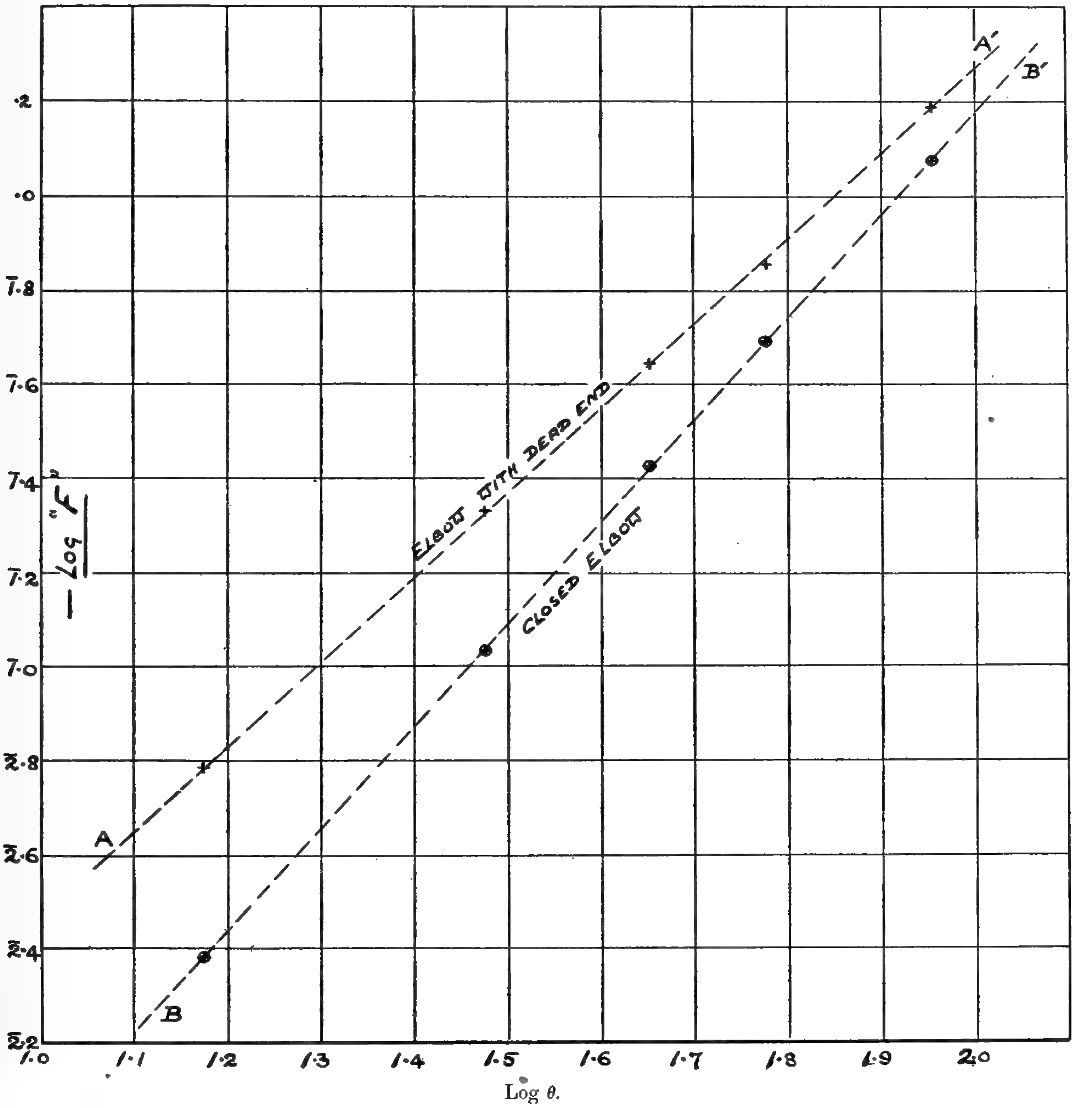

FIG. 2.—Logarithms of loss at elbows having an area ratio of 1 to 1.

Loss at Plain Elbows.—In the dead end of the elbow in the preceding examples a certain amount of energy is of necessity dissipated in eddy formation ; and with a view of investigating the effect of this, and of determining the loss in a plain elbow of uniform section throughout, and without such a dead end, these branches were closed up with plasticine, trimmed off to follow the line of the approach channel, the surface thus formed being comparable as regards smoothness with the rest of the pipe. Under these circumstances the losses were considerably reduced. The plots of the logarithms of the loss on a base of logarithms of θ (B B′, fig. 2) now lie on a straight line representing the formula—

$$\text{loss} = F \frac{v^2}{2g} \text{ feet,}$$

where $F = \cdot 0000676\theta^{2\cdot 17}$.

The mean experimental values of F are given in the following table against those calculated from this formula :—

	θ	90°	60°	45°	30°	15°	5°
F	calculated	1·20	·495	·264	·109	·0241	·0023
	experimental	1·20	·492	·263	·111	·0240	—

WEISBACH,* from experiments on a series of elbows of circular cross-section 1·2 inches in diameter, obtained values of F corresponding to

$$F = \cdot 9457 \sin^2 \frac{\theta}{2} + 2\cdot 047 \sin^4 \frac{\theta}{2}.$$

This gives the following values—

θ	90°	60°	45°	30°	15°
F	·987	·365	·183	·0728	·0222

It will be noted that these are considerably less than the author's values. The difference may be due to some extent to the difference in the shapes of the passages, although a few more recent experiments by BRIGHTMORE † and by DALEY ‡ on elbows and tees of circular cross-section give results in close agreement with those of the author. Thus BRIGHTMORE found F equal to 1·19 for right-angled elbows in 3-inch and in 4-inch pipes, while DALEY, using a 4-inch right-angled tee filled in to make a square elbow, found F equal to 1·10, and equal to 1·50 when the idle branch formed a dead end full of water.

4. LOSS AT IMPACT OF TWO CONFINED STREAMS.

In determining the loss due to the impact of two streams, experiments were carried out on each pipe (*a*) with v_1 constant, v_2 varying; (*b*) with v_2 constant, and v_1 varying. The loss per lb. of the impinging stream (2) was then calculated. An examination of the results shows that on plotting the loss with v_1 constant on a base of $v_2^2 \div 2g$ the

---

* *Mechanics of Machinery.*

† *Proc. Inst. Civil Engineers*, vol. clxix., 1906–7, p. 326.

‡ *Cornell Civil Engineer*, Dec. 1911, p. 107.

points lie on a straight line, while on plotting the loss with v_2 constant on a base of $v_1^2 \div 2g$ the points also lie on a straight line. These lines are so related that the tangent of the inclination of the one is equal to the intercept on the axis of zero velocity of the other. Fig. 3 shows the plotting of typical results, these being obtained from the pipe having $\theta = 60°$, and having the areas of passages (1) and (3) twice that of passage (2). In this figure two sets of experiments having v_1 constant are plotted on a $\frac{v_2^2}{2g}$ base.

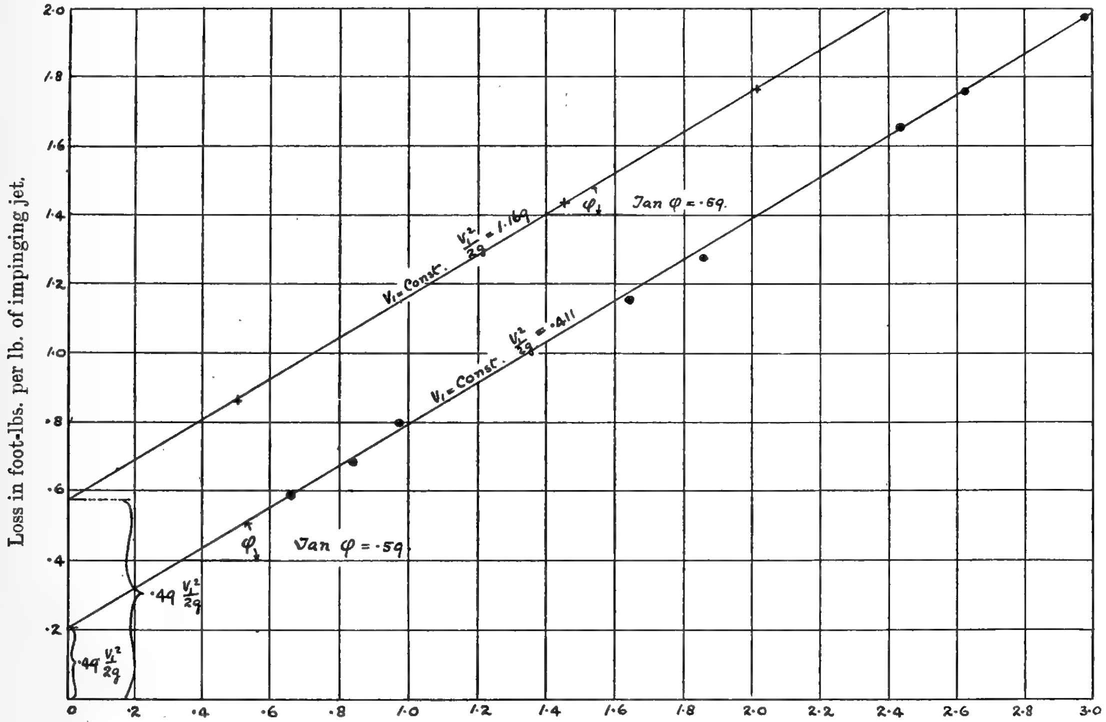

FIG. 3.—Values of $\frac{v_2^2}{2g}$.

From this relationship it follows that the loss is equal to—

$$a \frac{v_1^2}{2g} + b \frac{v_2^2}{2g} \text{ foot-lbs. per lb. of impinging jet,}$$

where a and b are coefficients obtained from the plotted lines.

When v_1 is zero the loss $= b \frac{v_2^2}{2g}$ feet, and since this is the state of flow round an elbow with a dead end, b is the same constant as the "F" of Table I., § 3.

The following table shows the mean experimental values of a, while the curves of figs. 4 and 5 show graphically the relationship between a, b, θ, and the ratio of enlargement of area.

TABLE II.

θ	Ratio of Areas of Streams (1) and (3) to Area of Impinging Stream (2).				
	1	2	3	4	5
90°	3·0	1·85	1·57	1·42	1·33
60°	2·0	·49	·38	·335	·31
45°	1·5	·32	·22	·19	·17*
30°	1·0	·20	·12	·10*	·083*
15°	·50	·090	·049	·040*	·034*
5°	·167	·030	·0135	·011*	·009*
0°	·00	·00	·00	·00	·000

* By extrapolation.

Except when m (the ratio of areas) is unity there would appear to be no simple expression connecting a and θ over the whole range from 0° to 90°.

When this ratio is unity, $a = \frac{\theta}{30}$. For greater values of the ratio, and for values of θ between 0° and 60°, the relationship

$$a = \frac{\cdot 0052}{m}\,\theta^{1\cdot 28}$$

gives the value of a within about 5 per cent., for all values of m between 2 and 6.

It will be noted that when θ is large, and particularly when m is small, the v_1^2 term is all-important. As m increases, the relative value of this term at first falls off very rapidly, the relative diminution being greatest with small values of θ. As the area of the primary stream is increased, the v_2^2 term at first diminishes to a minimum, afterwards increasing with an increase in the area. With large values of m the value of b approximates, as would be anticipated, to unity, for all values of θ.

Where θ and the volumes of the streams (1) and (2) are known, the data of Tables I. and II. or the curves of figs. 4 and 5 enable the ratio of areas of primary and impinging stream for minimum loss of energy to be calculated. Thus, if $Q_1 = nQ_2$, $v_1 = \frac{n}{m} v_2$, and the loss is given by

$$\text{loss} = \left\{ a\left(\frac{n}{m}\right)^2 + b \right\} \frac{v_2^2}{2g} \text{ foot-lbs. per lb. of (2).}$$

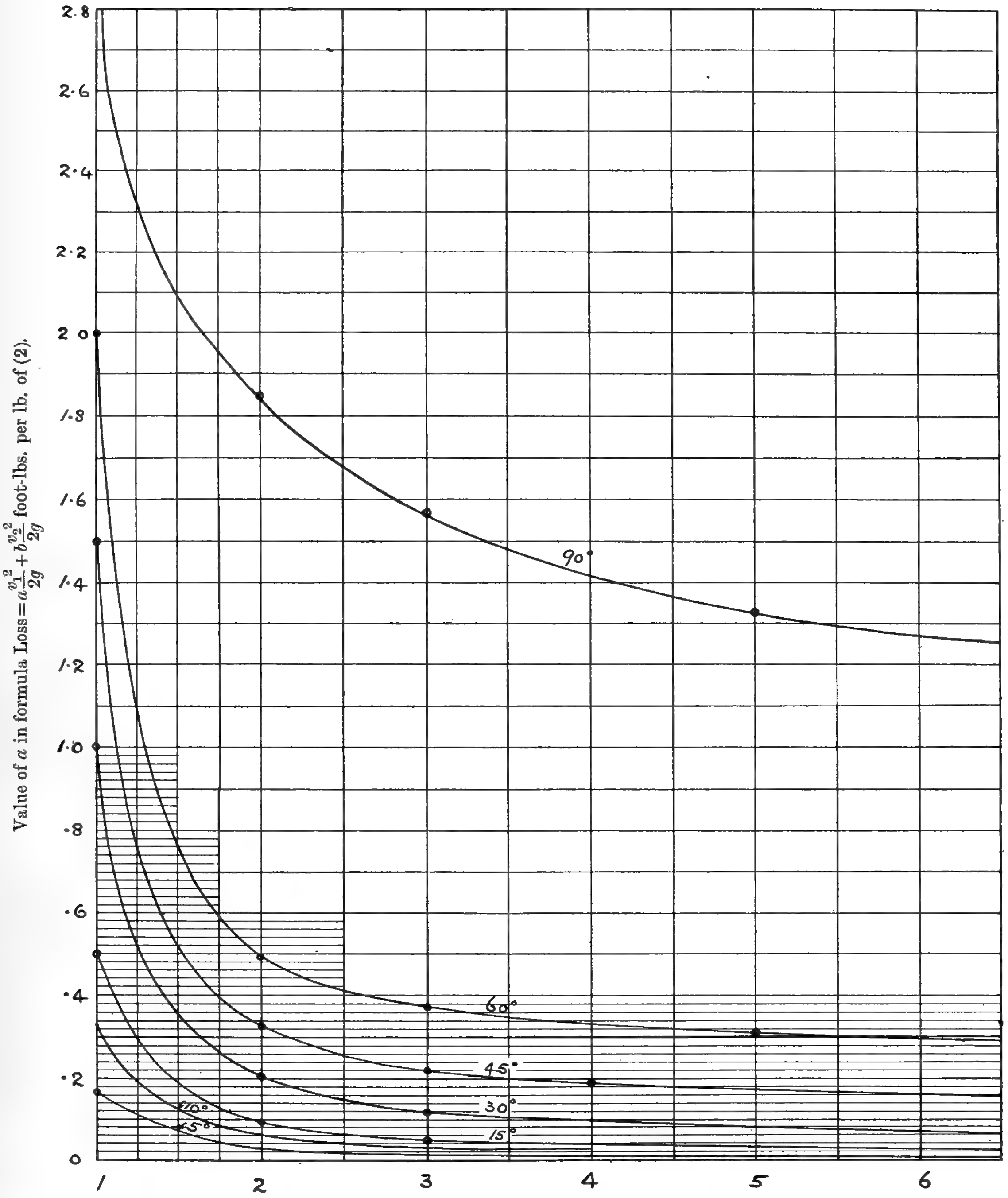

FIG. 4.—Ratio of areas of Primary and Impinging Streams.

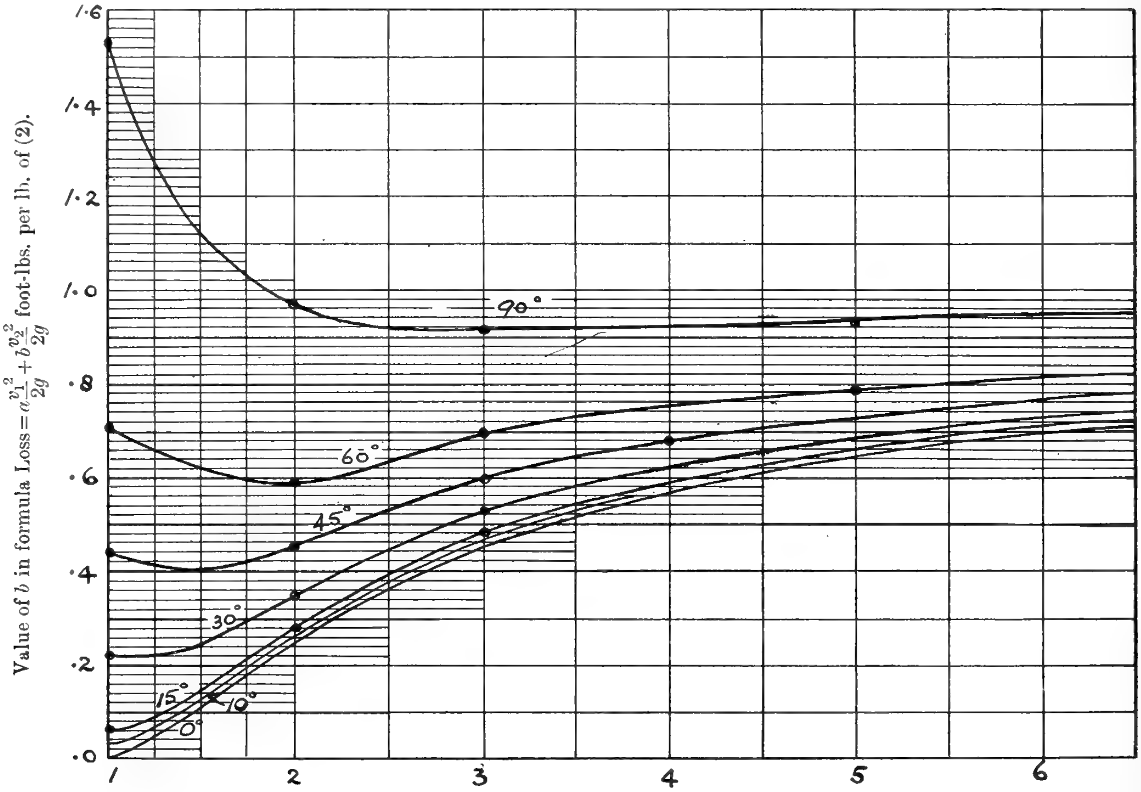

FIG. 5.—Ratio of Areas of Primary and Impinging Streams.

E.g., if $\theta = 30°$ and $Q_1 = 2Q_2$, *i.e.* $n = 2$,

$$\left\{\begin{array}{lll}
\text{If } m = 1{\cdot}5, & a = {\cdot}34,\ b = {\cdot}24, & \text{loss} = ({\cdot}603 + {\cdot}24)\frac{v_2^2}{2g} = {\cdot}843\,\frac{v_2^2}{2g} \\
\text{If } m = 1{\cdot}75, & a = {\cdot}25,\ b = {\cdot}30, & \text{loss} = ({\cdot}326 + {\cdot}30)\frac{v_2^2}{2g} = {\cdot}626\,\frac{v_2^2}{2g} \\
\text{If } m = 2{\cdot}0, & a = {\cdot}20,\ b = {\cdot}35, & \text{loss} = ({\cdot}200 + {\cdot}35)\frac{v_2^2}{2g} = {\cdot}550\,\frac{v_2^2}{2g} \\
\text{If } m = 2{\cdot}25, & a = {\cdot}17,\ b = {\cdot}40, & \text{loss} = ({\cdot}135 + {\cdot}40)\frac{v_2^2}{2g} = {\cdot}535\,\frac{v_2^2}{2g} \\
\text{If } m = 2{\cdot}5, & a = {\cdot}15,\ b = {\cdot}44, & \text{loss} = ({\cdot}096 + {\cdot}44)\frac{v_2^2}{2g} = {\cdot}536\,\frac{v_2^2}{2g} \\
\text{If } m = 3{\cdot}0, & a = {\cdot}12,\ b = {\cdot}52, & \text{loss} = ({\cdot}053 + {\cdot}52)\frac{v_2^2}{2g} = {\cdot}573\,\frac{v_2^2}{2g}
\end{array}\right.$$

On plotting these values of m against the loss, it appears that the minimum loss occurs when $m = 2{\cdot}3$, and amounts to ${\cdot}532\frac{v_2^2}{2g}$ foot-lbs. per lb. of stream (2).

To facilitate the solution of practical problems the range of values of θ from 0° to 45°, and of m from 1 to 6 has been examined in this way. As a result it appears that the value of m for minimum loss is given with a close degree of accuracy by the relationship

$$m = \left\{1 + \frac{2\theta}{100} + \frac{\sqrt{\theta}}{11{\cdot}4} \cdot \frac{Q_1}{Q_2}\right\}.$$

The following table indicates how this best value of m varies with θ and with the ratio of Q_1 to Q_2:—

θ.	Value of $Q_1 \div Q_2$.						
	1	2	4	6	8	10	12
5°	1·31	1·50	1·85	2·25	2·65	3·05	3·45
10°	1·50	1·80	2·35	2·90	3·40	4·00	4·60
15°	1·65	1·95	2·65	3·45	4·05	4·75	5·35
20°	1·80	2·20	3 00	3·80	4·50	5·30	6·10*
30°	2·10	2·60	3·50	4·50	5·40	6 40*	7·30*
45°	2·55	3·15	4·25	5·50	6·70*	7·80*	8·90*

* Obtained by extrapolation.

while the loss of energy, expressed as a fraction of $\frac{v_2^2}{2g}$, with the best value of m is given in the following table:—

θ.	Value of $Q_1 \div Q_2$.						
	1	2	4	6	8	10	12
5°	·13	·18	·27	·35	·42	·47	·51
10°	·22	·29	·43	·53	·60	·67	·71
15°	·28	·36	·53	·64	·71	·78	·83
20°	·33	·43	·60	·71	·79	·85	·91*
30°	·41	·53	·72	·82	·91	·97*	1·02*
45°	·53	·68	·88	·97	1·04*	1·10*	1·14*

* Obtained by extrapolation.

A comparison of these results with those obtained by an application of the formula

$$\text{loss} = \frac{(v_2 \sin \theta)^2 + (v_2 \cos \theta - v_1)^2}{2g} \text{ foot-lbs. per lb.}$$

shows that over a range of values of m from 1 to 6, of θ from 10° to 30°, and of v_2 from v_1 to $4v_1$, this formula gives results which may be anywhere between twenty times too small and ten times too large. In particular cases the two results may be approximately the same, but for general application this formula is quite valueless.

5. Loss at Impact of Two Similar Streams, both of which undergo the same Deviation of Direction.

The experiments were extended to cover the case of two equal streams impinging at an angle θ, forming a single stream of twice the area and the same mean velocity as each of the single streams, and having a direction making an angle $\frac{\theta}{2}$ with each of the latter.

Under these conditions the loss per lb. of each of the impinging streams might be expected to be approximately the same as that experienced in an elbow having uniform area throughout with a deviation equal to $\frac{\theta}{2}$.

The pipes examined had values of θ respectively, equal to 15°, 30°, and 60°, and cross-sectional areas $\frac{1}{2}$ inch × 1 inch, and within the limits of experimental error the above conclusion was found to be justified.

6. CONCLUSIONS.

The following are the conclusions to be drawn from the experimental results of the investigation :—

(*a*) The friction loss per foot run of such rectangular passages as were used, with sections varying from 1 inch × $\frac{1}{2}$ inch to $2\frac{1}{2}$ inches × $\frac{1}{2}$ inch, is given by

$$h = \frac{\cdot 0036 v^{1\cdot 83}}{2gm^{1\cdot 20}} \text{ feet}$$
$$= \frac{\cdot 000056 v^{1\cdot 83}}{m^{1\cdot 20}} \text{ feet,}$$

where $m = \text{area} \div \text{perimeter}$ in foot-units.

(*b*) The loss at plain elbows of uniform rectangular section is given by $\mathrm{F}\frac{v^2}{2g}$ feet, where $\mathrm{F} = \cdot 0000676\theta^{2\cdot 17}$. Here θ is the angle of deviation of the elbow in degrees.

(*c*) Where the elbow is formed by the junction of one pipe with a second, and so has a dead end facing the final direction of flow, the loss is increased. In such a case

$$\mathrm{F} = \left\{ \left(\frac{m-1}{m}\right)^2 + \frac{\cdot 00046}{m}\theta^{1\cdot 8} \right\},$$

where m is the ratio of the areas of the outlet and inlet legs of the elbow.

(*d*) The loss at impact of two confined streams, only one of which suffers deviation, is given by

$$\text{loss} = a\frac{v_1^2}{2g} + b\frac{v_2^2}{2g} \text{ foot-lbs. per lb. of the impinging jet (2).}$$

By the impinging jet is meant that which is deviated on impact. The velocity of this stream is v_2 and that of the primary or undeviated stream is v_1. The values of the coefficients a and b in this formula are given in Tables II. and I., and by the curves of figs. 4 and 5.

(*e*) The formula

$$\text{loss} = \frac{(v_2 \sin \theta)^2 + (v_2 \cos \theta - v_1)^2}{2g} \text{ feet}$$

gives results which, except in one or two particular cases, are totally unreliable.

(*f*) Where the volumes Q_1 and Q_2 to be discharged by the two streams are known, and where the ratio m of their areas may be modified as required, the value of m for minimum loss is given by the relationship

$$m = \left\{ 1 + \frac{2\theta}{100} + \frac{\sqrt{\theta}}{11 \cdot 4} \cdot \frac{Q_1}{Q_2} \right\}.$$

(*g*) Where both streams are similar and each suffers the same deviation θ, the area of the combined streams being equal to the combined areas of the impinging streams, the loss is substantially the same as in an elbow of uniform section and with the same angle of deviation.

The foregoing experimental work has been carried out in the Engineering Department of University College, Dundee, and the author would express his indebtedness to Messrs J. A. Hood and J. Mechie for much valuable assistance in carrying out the experiments.

XXIX.—On Rhetinangium arberi, a new genus of Cycadofilices from the Calciferous Sandstone Series. By W. T. Gordon, M.A., B.A., D.Sc., Lecturer in Palæontology, Edinburgh University. *Communicated by* Professor James Geikie, D.C.L., LL.D., etc. (With Three Plates.)

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During the past few years probably no group of fossil plants has received more attention from palæobotanists than that of the Pteridospermeæ. Many fern-like impressions, derived from Carboniferous rocks, have proved to be members of this division of the vegetable kingdom; while many more may ultimately be removed from the Filicales and included in the Pteridospermeæ. Specimens, however, in which the internal structure is preserved, may, as a rule, be correctly referred to their respective class, but among those included in the latter group there is considerable diversity of organisation, and recently described genera have tended to increase the diversity of type rather than to indicate relationships among the forms already known. In fact we seem so far to have obtained only a very few examples of what must have been an exceedingly diversified plant family in late Palæozoic times.

Yet certain genera—*Sutcliffia*, *Stenomyelon*, etc.—exhibit anatomical characters which place them in an intermediate position between the polystelic *Medulloseæ* and the monostelic *Lyginodendreæ*. These recently discovered forms, while helping to link up the extreme types, cannot be included in the same genus; their anatomy, indeed, seems to indicate several different lines of evolution within the group.

The first petrifaction described from the Calciferous Sandstone rocks of Pettycur, namely, *Heterangium grievii*, was one of the simpler pteridospermous * forms, and the specimens were so abundant and so well preserved that the structure of this species is exceedingly well known. It has marked fern affinities, while cycadean characters are also present in the loose form of the secondary wood. No other Pteridosperm was obtained from the Pettycur rocks until about four years ago, when I collected what appeared to be a new species of *Heterangium*.† Subsequent investigation has shown that it differs markedly from *Heterangium* and also from all known genera of the *Pteridospermeæ*, though it undoubtedly belongs to the *Cycadofilices*. I have been compelled, therefore, to make it the type of a new genus. In the choice of a name I have been guided by a characteristic feature of the anatomy, namely, the great development of what appear to be secretory sacs and ducts. At the same time *Rhetinangium*—the name adopted—suggests affinities with *Heterangium*. The specific name was given in

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* Classed as a Pteridosperm on structural evidence only. Scott, *Studies in Fossil Botany*, 1909.

† *Heterangium arberi*, Gordon: Thesis, *On the Fossil Flora of the Pettycur Limestone*. University Library, Cambridge (1910), Edinburgh (1911).

honour of Dr E. A. Newell Arber, to whom I was much indebted for his kindly criticism and advice while conducting my research work at Cambridge.

Description of the Specimens.

As already stated, the first specimen was obtained about four years ago, and the structure determined as far as possible; but a second example was discovered more recently at the same locality; while a third, which may be specifically identical with these two, was collected by Dr Kidston on the bank of the Whiteadder Water near Edrom, Berwickshire. All three specimens were derived from rocks of Lower Carboniferous age and probably from similar horizons. The Berwickshire stem was obtained several years ago, but was so indifferently petrified that it could not be described. The following description has therefore been based on the remains from Pettycur, which are, on the whole, well preserved, though not uniformly so. This variable preservation is very noticeable in the shorter of the two specimens, and, unfortunately, the best portion lay exposed on the surface of the limestone block, with the result that it had been partially weathered away. When followed further into the mass this stem was poorly petrified and finally disappeared. Its total length did not exceed 5½ inches.

The second example was nearly twice as long (10 inches), and it passed completely through the block in which it was embedded. From both specimens series of transverse and longitudinal sections have been prepared. These number about 120, and a very fair idea of the anatomy of the plant has been obtained from them.

Several petioles were also discovered, either in organic continuity with the stems or closely associated with them, while a root was obtained attached to one of the specimens.

General Structure.

A transverse section of the stem is represented in Pl. I. fig. 1, and, although the central xylem cylinder is not particularly well preserved in this specimen, a good general idea of the anatomy may be obtained by an examination of the figure. The actual measurements of the stem are 2·5 cm. × 1·5 cm., but the flattening is entirely due to compression prior to fossilisation. This is proved by the fact that the cortical tissues at the ends of the longer diameter are crushed together. The stem in the living plant would therefore be circular in section and probably about 2 cm. in diameter.

In the centre of the specimen is the vascular axis, which consists of an internal zone of primary wood (x^1), and an external one of secondary wood (x^2). Surrounding the xylem cylinder is the phloem and inner cortical tissues, while enclosing the whole is a thick layer of outer cortex with a well-marked hypodermal zone of anastomosing sclerotic strands. A general resemblance to the stem of *Heterangium* will at once be noticed, but a more detailed examination will disclose several differences between *Rhetinangium* and that genus.

As the vascular axis is not well petrified in the example figured (Pl. I. fig. 1), we shall turn to the other stem from Pettycur in order to examine that part more closely. In this specimen the xylem cylinder is about ·7 cm. in diameter, and sections of it are represented in Pl. I. figs. 2 and 7. As in the former example, two regions may be noted in the xylem—the inner, primary wood, and the peripheral secondary zone (Pl. I. fig. 2, x_1 and x_2 respectively). The primary wood consists of anastomosing groups of tracheides scattered in a parenchymatous ground tissue (Pl. I. figs. 3 and 5, x^1). In the parenchyma numerous secretory sacs and ducts may be seen, their deeply coloured contents imparting a dark appearance to this central zone (Pl. I. fig. 7, *s.s.*). Surrounding the primary xylem is a zone of secondary wood with its radially distributed elements, and, in both specimens, this tissue attains a fair thickness (Pl. I. figs. 1 and 2, x_2). It is traversed by medullary rays which vary greatly in height and breadth. These rays sometimes spread out when they enter the phloem region as they do in *Heterangium tiliæoides.*

The various tissues which succeed the wood externally are each well preserved at one or other part of the specimen. In one stem the phloem is seen to consist of elongated elements, but sieve plates have not been detected with certainty. No pericycle or endodermis can be separated from the inner cortex, which appears to have been a zone of rather delicate tissue containing numerous resin ducts and cells with dark contents (Pl. II. figs. 10 and 11, *i.c.*). These latter elements may have acted as storage or even mucilage cells, and this would account for their dark colour. No stone cells or other strengthening elements occur in the inner cortex. The outer cortex, on the other hand, contains numerous strengthening fibres, and these give a characteristic appearance to the whole zone. Pl. II. fig. 15 gives an excellent idea of this tissue; in the inner part a rather thick-walled parenchyma is seen, but the hypodermal part contains a reticulum of elongated sclerotic bands or threads. The meshes of the reticulum are narrow but they are exceedingly long. Associated with the fibres themselves are long secretory ducts.

The general outer surface of the stem is rendered irregular by the decurrent petioles. These swell out enormously at their junction with the stem, their outer cortex loses its sclerotic fibres, and so the cortex of the leaf base consists entirely of a mass of uniform small-celled parenchyma through which the petiole-trace passes to join the central axis (Pl. I. fig. 4, *pet. b.*). As a result, the petioles are readily torn from the stem, and this, no doubt, accounts for the fact that the outer cortex often appears broken up into separate segments. Usually three petiole-traces are seen departing from the stem in any transverse section. They show a succession in their development, but the stems are so crushed that the phyllotaxy has not been determined.

When the petiole-trace leaves the xylem axis it is rather peculiar in form and does not resemble the trace in any known genus of the *Pteridospermeæ.* The xylem consists of a more or less continuous, corrugated mass while still in the cortex of the stem. In the free petiole the xylem still appears continuous though the outline is irregular (Pl. III. fig. 19), and even in the smallest divisions of the petiole observed the same irregular outline may be seen in the trace (Pl. III. fig. 20).

One example of an adventitious root has been discovered in organic continuity with the stem, but the preservation leaves much to be desired. The root-trace is represented in transverse section in Pl. II. fig. 12.

HISTOLOGY OF THE STEM.

Although both specimens are to some extent crushed, yet the preservation is sufficiently perfect to allow of a minute examination of the tissues. Starting with the primary wood, we find that there is conjunctive parenchyma between the anastomosing xylem strands, and this ground tissue is interesting on account of the numerous secretory ducts and sacs contained in it (Pl. I. fig. 7, *s.s.*). The ducts may result from the fusion of several sacs or they may be elongated sacs. The former notion seems to be supported by the fact that the dark contents do not occur as continuous masses but are, in every case, broken up into small pieces (Pl. III. fig. 25, *s.s.*). This appearance, however, may be explained otherwise, for the resinous contents may have contracted prior to fossilisation, and the fragments have been subsequently separated by the petrifying medium. The whole duct would thus seem to contain a series of dark coloured bodies in its interior, and appear to result from the fusion of separate cells. In transverse section the ducts may be clearly seen in Pl. I. fig. 7, *s.s*; the dark contents are here seen contracted into the centre of the lumen. Taking all available data into account, however, it seems more probable that these ducts are produced by the elongation of single elements. No epithelium has been noticed surrounding the secretory elements.

The primary wood consists of tracheides, on the walls of which multiseriate pits are arranged in a reticulate manner (Pl. I. fig. 5, x^1). These elements vary in size from 130μ to 150μ in diameter, and are united in groups of from twenty to sixty. The number of tracheides in each group is thus much greater than in the corresponding groups in *Heterangium.* There are, however, fewer xylem groups in the primary wood of *Rhetinangium* than in the former genus.

Round the periphery of the primary wood the xylem groups contain much smaller tracheides. These are the protoxylem elements, and they are seen in longitudinal sections to have scalariform or sub-spiral thickenings on their walls (Pl. I. fig. 6, *prx.*). They are *exarch* in position and not mesarch as in *Heterangium.*

Each peripheral group of the primary xylem is bounded externally by a wedge of secondary wood, and so the principal medullary rays are in direct communication with the ground tissue of the central primary wood. The elements of the secondary zone are much smaller than those of the primary xylem, being from 45μ to 85μ in diameter, and they are arranged, as usual, in radial rows. Secondary medullary rays occur in each wedge, and usually a ray occurs between each two or three rows of xylem, though sometimes they occur between every two rows (Pl. I. fig. 8, *m.r.*). In one specimen, after the development of some fourteen rows of tracheides, there is a sudden change to much smaller elements (Pl. I. figs. 8 and 9, *w.r.*). Just such a change, indeed, as is seen between the spring and autumn wood in living trees. About three rows of small elements are formed and then the larger tracheides are again developed. The change occurs simultaneously all round the stem and not irregularly, as has been occasionally observed in some fossil stems. It is not suggested, however, that this proves seasonal alternation at that early time in the earth's history, though probably some external influence had caused a temporary check to the growth. When, however, the conditions became favourable again, large elements were developed as before.

Immediately beyond the xylem cylinder there occur, in certain places, patches of phloem in a fair state of preservation. The elements comprising this tissue have thin walls and are considerably elongated. No sieve plates were observed on their walls, but the light brown contents of the cells may have obscured them. Secretory sacs and ducts are sometimes seen in this region.

Passing outwards from the phloem the cortical zone is reached, and it can easily be separated into two layers—the inner and outer cortex. No hard and fast line, however, can be drawn between the pericycle and the inner cortex. In transverse section the latter tissue may be seen in Pl. II. fig. 10, *i.c.*, and there the delicate cell walls of the parenchyma may easily be observed. Numerous secretory cells (*s.c.*) and sacs (*s.s.*) are also clearly visible. In longitudinal tangential section a great number of these elongated sacs (*s.s.*) are shown, while the small secretory cells are also very distinct (Pl. II. fig. 11, *s.s.* and *s.c.* respectively). The secretory elements with their dark contents are so numerous that they impart a peculiar appearance to the whole inner cortex. One would almost imagine that the whole tissue was of a mucilaginous nature.

Towards the periphery of this region the cells appear tangentially elongated (Pl. II. fig. 10, *c.p.*), but that is due to the outer cortex being crushed down upon the inner zone. As a result there is a well-defined junction between inner and outer cortex, but the junction is less marked where there has been little crushing (Pl. II. fig. 15, *i.c.*). The great number of secretory elements in the inner cortex at once distinguishes it from the innermost layers of the outer cortex.

The outer cortical region constitutes one of the most distinctive features of the genus, and in both specimens it is very well preserved. Three zones may be noticed. The innermost consists of a thick-walled parenchyma and is free from secretory elements. The second (hypodermal) zone consists of a parenchymatous ground tissue in which anastomosing groups of sclerotic fibres are set. These fibres are closely associated with secretory ducts. The ground tissue of this cortical layer is peculiar. In a transverse section of the stem the parenchyma is seen to contain elements which are elongated radially with respect to the nearest sclerotic group (Pl. II. fig. 15, *e.o.c.*). In any other direction they resemble the rest of the cortical cells in size. The elongation takes place towards the sclerotic groups as centres (Pl. II. fig. 15). In some cases the elongation of the cell has been so great that it divides into two cells (Pl. III. fig. 23, *c.w.*). Although this elongated parenchyma is very marked in some cases, yet it is not always constant over the whole hypodermal region. In Pl. II. fig. 15 it is a marked feature over the whole area, particularly towards the inner part of the hypoderma, but in Pl. II. fig. 14, while present on the right-hand side, it is almost absent on the left-hand side of the figure. A similar phenomenon is shown in longitudinal section in Pl. III. fig. 23 (marked elongation at *a*) and in Pl. II. fig. 13 (no elongated parenchyma).

The sclerotic strands, which are not uninteresting in themselves, consist of groups of vertically elongated elements in which the lumen has been almost entirely closed by deposition of material on the cell walls. The number of these cells in each strand varies greatly. The strands unite tangentially at various levels and hence a reticulum results. They only unite, however, at considerable distances, so that the meshes of the reticulum are long and narrow. Each strand may also divide radially into two or three smaller groups (Pl. II. fig. 15). Between the sclerotic strands the ordinary cortical parenchyma is found, while associated with these fibrous groups, or partly or completely sunk in them, are long secretory ducts (Pl. II., figs. 13, 14, and 15, *s.s.*). These ducts are about 100μ in diameter, and are clearly seen among the smaller-celled cortical parenchyma and sclerotic fibres.

In some cases the hypodermal sclerenchyma abuts directly on the surface of the stem, but, as a rule, there are about three layers of small-celled parenchyma external to the hypoderma. In certain parts, however, there is an enormous development of parenchyma beyond the sclerotic zone (Pl. I. fig. 4, *pet. b.*), and sometimes the fibrous outer cortex disappears entirely at these places. This takes place at the junction of the petiole with the stem, and will be considered later.

Histology of the Petiole.

In the centre of the petiole is the vascular strand, and it is quite unlike the corresponding strand in other *Pteridospermeæ.* In the more complex members of that group a great number of small strands pass into the petiole, while in the *Lyginodendreæ* the trace consists of a single or double bundle. In *Rhetinangium*, however, the petiole-trace appears to consist of several U-shaped xylem groups aggregated into one long corrugated band. Usually three such traces are seen round the stem in any transverse section, and these are in different stages of development. In Pl. I. fig. 2 one trace has just been emitted at A, a second is completely differentiated from the stem at B, while the third is only forming at C. The first thing to be noted about this last trace is that it appears to consist of several peripheral strands of the primary wood. As will also be noted, it has passed about half-way through the zone of secondary wood. The second trace B has emerged from the secondary xylem, and the various groups are more or less U-shaped and connected together either directly or by conjunctive parenchyma. The protoxylem groups are on the external edge and are fairly numerous

(Pl. III. fig. 16, *prx.*). The trace B is shown at a lower level in Pl. III. fig. 17, and at a still earlier stage in Pl. III. fig. 18. In this last figure the trace is just leaving the zone of secondary wood; a few of the elements of the latter tissue still may be seen on the outer margin of the trace (Pl. III. fig. 18, x^2). The peculiar fashion in which the xylem of the petiole strand is connected together is clearly shown in Pl. III. fig. 17. The trace passes slowly outwards as we ascend, but unfortunately the soft nature of the inner cortex of the stem has allowed the latter to be easily crushed, and the petiole-traces have suffered disintegration along with the inner cortex. All that can be said of the petiole-trace in this region is that it certainly does not divide into small strands during its passage through the cortex into the free petiole. The protoxylem elements lie abaxially in the trace (Pl. III. figs. 16 and 17, *prx.*).

Opposite the point of emission of a petiole-trace from the central axis of the stem, the sclerotic hypoderma thins out and finally disappears. Concurrently as the hypoderma dies out, the external part of the cortex becomes enormously developed until it becomes almost as large as the stem itself (Pl. I. fig. 4, *pet. b.*). In the figure shown the petiole base is detached from the stem, and in fact this section is cut some distance above the point where the trace enters the petiole. It indicates, however, the great development of buttressing tissue round the petiole base.

It will also be noticed that at this point the petiole has no sclerotic hypoderma. This fibrous zone, however, again appears higher up the petiole, but at that level the diameter of the whole rachis is much reduced. In other words, the base of the petiole is greatly dilated, and in that region the sclerotic outer cortex disappears. As a result of the soft nature of the petiole base the rachis is almost always torn from the stem or laterally displaced. The petiole shown in Pl. I. fig. 4 really departed opposite the gap seen at A in the outer cortex of the stem. The dilatation of the petiole base occurred both on the upper and under sides.

It is interesting to note that certain fern-like impressions of Carboniferous age have similar dilatations where the pinnæ join the rachis, and this also happens where the latter join the stem. (A similar type of structure may be seen in recent Marattia and Angiopteris pinnæ where they joined the petiole.)

Only one petiole was actually traced into the stem, but several have been followed until the hypoderma disappears and the trace was seen surrounded by a uniform, parenchymatous cortex. A similar disappearance of the sclerotic fibres has been seen in longitudinal section. Behind the departing petiole the sclerotic hypoderma closes in and ultimately fills the gap. Thus the departure of the petiole causes a temporary gap in the fibrous zone of the cortex.

The trace in the free petiole is represented in Pl. III. fig. 19, and although there is considerable crushing, one can easily observe that it consists of a continuous flat band of xylem with abaxial protoxylem groups. Even in the smallest branch discovered, the trace is continuous but with a convoluted outline (Pl. III. fig. 20). In no case does the trace break up into a number of small strands.

The cortical tissues in the petiole are quite similar to those in the stem. The inner cortex is a delicate parenchyma with secretory sacs and ducts, while the outer zone contains the sclerotic hypoderma with its secretory ducts.

HISTOLOGY OF THE ROOT.

One example of an adventitious root has been found in organic connection with the stem, and several similar detached roots have been noted. The root-trace seems to leave the stem close to the point of emission of the petiole-trace, or it may be that it comes from the petiole-trace itself. This particular specimen occurs at a part of the stem where the outer cortex has been stripped off and the root is seen in the inner cortex. Although the trace is not very well preserved, one can see that it was probably tetrarch. A considerable amount of secondary wood has been developed round the primary xylem (Pl. II. fig. 12, x_1 and x_2 respectively).

There are still some points in connection with the anatomy of the petiole and root which require further elucidation, and it is to be hoped that additional well-preserved examples may be discovered.

There is no indication in the specimens of their foliage or fructifications.

SUMMARY.

Rhetinangium arberi had a stem of considerable length, and was probably of scrambling habit, with adventitious roots at intervals on the stem. Petioles were emitted in spiral sequence, and three of them may be seen intersected at different levels in any transverse section.

The vascular axis is protostelic, the primary wood is of the *Heterangium* type, but the protoxylem is exarch, and many secretory sacs and ducts are present in the conjunctive parenchyma. The secondary wood is of cycadean type. The protoxylem elements have scalariform or sub-spiral thickenings on their walls; the other tracheides are reticulately pitted. The phloem consists of elongated elements and parenchyma, while the inner cortex is formed of a zone of delicate tissue with numerous secretory bodies scattered through it. The outer cortex is made up of thick-walled parenchyma, and contains a sclerotic hypodermal zone round which the cortical parenchyma is much elongated radially.

The leaf-trace is peculiar in form and is produced by the union of several peripheral groups of the primary xylem. The protoxylem elements are on the lower (abaxial) surface of the trace and continue throughout in that position. In no case does the petiole-trace divide up into numerous small bundles. Even in the smallest division noticed the trace is a single strand. The cortical tissues are similar to those of the stem.

Close to the emission of a petiole-trace an adventitious root has been observed to leave the stem.

Diagnosis.

Rhetinangium, gen. nov.

The characters of this new genus are, meanwhile, those of the only recorded species, *R. arberi.*

Rhetinangium arberi, sp. nov.

Stem 2 cm. in diameter, circular in transverse section and surrounded by spirally developed leaves. Central vascular axis protostelic, consisting of anastomosing groups of tracheides in a parenchymatous ground tissue with secretory ducts. Protoxylem exarch, and with scalariform or sub-spiral thickening. Xylem (primary or secondary) of long, reticulately thickened, porose tracheides. Medullary rays broad and high. Phloem and inner cortex with many secretory cells and ducts. Outer cortex of thick-walled parenchyma. Hypodermal zone of sclerotic anastomosing fibres associated with elongated secretory ducts.

Petiole-trace an aggregate of several peripheral xylem groups loosely attached together to form a corrugated band. Protoxylems abaxial. Leaf-bases without sclerotic hypoderma, but outer cortex enormously expanded. Diameter of petiole beyond base not abnormally large compared with stem but showing reappearance of sclerotic outer cortex. Roots tetrarch; secondary wood well developed.

Foliage and fructifications unknown.

Localities.—Pettycur, Fife, Scotland, and Edrom, Berwickshire, Scotland.

Horizon.—Calciferous Sandstone Series (= Culm).

Affinities and General Considerations.

The primary wood in *Rhetinangium* is similar in its general structure to the xylem cylinder in certain living protostelic ferns, and, in particular, since the xylem is exarch, to that of *Lygodium.* At the same time the type of the secondary wood, with its numerous broad and high medullary rays, is distinctly cycadean. The structure of the axis thus places *Rhetinangium* in an intermediate position between ferns and cycads. In any case, the new genus possesses all the characters necessary for its inclusion in the group of the *Cycadofilices.*

Although its fructification is unknown, it is quite admissible to refer this new plant to the *Pteridospermeæ* on anatomical grounds alone, but its structure does not indicate any very obvious relationship with other members of that group. The genus, however, is not a perfectly isolated one, since there are marked resemblances between its anatomy and that of certain other forms. The primary xylem recalls the corresponding tissue in *Megaloxylon, Heterangium, Medullosa,* and in a less degree that in *Sutcliffia.* The exarch nature of the xylem, however, at once separates this new type from *Heterangium* and *Medullosa* (which latter, as far as its vascular axis is concerned, is really a polystelic *Heterangium*). With *Megaloxylon,* on the other hand, the affinities are much closer: apart from the difference in size, indeed, the primary wood in both is similar when viewed in transverse section. In each case we find a mixture of tracheidal and parenchymatous tissue in the axis, while secretory cells are also seen in the parenchyma. In longitudinal section, on the contrary, marked differences are at once visible. It is true that the peripheral groups of scalariform or sub-spiral elements are similar in position in each, but here the similarity ends. The remainder of the tracheidal tissue in *Megaloxylon* consists of short, broad elements with multiseriate bordered pits on their walls, while the secretory cells are also short. In *Rhetinangium* the tracheides are long, reticulately thickened, elements, and the secretory bodies are either short cells or long ducts (Pl. III. fig. 25, *s.c.* and *s.s.*). The distinction between the primary wood in these two genera, then, consists essentially in the type of tracheide.

The secondary xylem is of a similar type in each case, but in the new genus it appears to be less compact than in *Megaloxylon.* An interesting point is the clearly marked ring of narrow elements in the secondary wood. Professor SEWARD records the sporadic occurrence of such tracheides in a similar position in his genus.

Although the leaf-trace in Professor SEWARD'S plant is not known outside the zone of secondary xylem, yet its resemblance, in that area, to the stem of *Heterangium* (except for the exarch xylem) is not without interest, for the trace in *Rhetinangium* under the same conditions would have a similar form. In Pl. I. fig. 2, C, the departing trace in *Rhetinangium* is merely a group of xylem strands, with conjunctive parenchyma as in the stem of *Heterangium*, and there cannot be any doubt that if the two ends of the trace B in that figure or in those shown in Pl. III. figs. 16, 17, and 18, were bent inwards until they met, it would also form a leaf-trace similar to the stem of *Heterangium.* (The position of the protoxylem groups, of course, is different.) It is just possible, also, that the breadth of the zone of secondary xylem and its compact nature in *Megaloxylon*, may account for the rounding off of the petiole-trace in that genus, while it is traversing this tissue, and that when the trace became free it would flatten out in a similar fashion to the trace in *Rhetinangium.* In both forms several adjacent exarch strands coalesce to produce the trace, the protoxylem groups being situated abaxially. All these structural resemblances in the two stems show that they were probably related, but *Megaloxylon* appears to be the more specialised type. The peculiar short tracheides in the primary wood of the latter are, no doubt, as Professor SEWARD has pointed out, an adaptation for water-storage.

The affinities of *Rhetinangium* with other members of the *Pteridospermeæ* are not so obvious. The type of the primary xylem cylinder and the monostelic character of the stem, at first sight, suggest affinities with *Heterangium*, but the detailed structure of the stele and also of the petiole-trace proves that the resemblances are more apparent than real. In the primary vascular cylinder of the new genus the tracheidal groups are large and few in number, while in *Heterangium* (Pl. III. fig. 22) the reverse is the case. Then, again, the exarch xylem and the numerous secretory elements in *Rhetinangium* at once distinguish it from *Heterangium.* It must be borne in mind, however, that certain species of the latter genus have protoxylem elements situated much nearer the periphery than in others, and that secretory sacs occur in *H. tiliæoides* in the medullary rays and in the inner cortex. One characteristic feature of *Heterangium*—the sclerotic discs in the inner cortex—finds no parallel in *Rhetinangium*, while the peculiar outer cortex of the latter is not seen in the former.

As far as the petiole-trace is concerned the two types are distinct, yet there seems to be some connection between them. In Pl. III. fig. 21 an exceedingly well-preserved petiole-trace of *Heterangium grievii* is shown; it is sub-triangular in shape, and the protoxylem is mesarch (Pl. III. fig. 21, *prx.*). The petiole-trace in *Rhetinangium*, as we have seen, is much more complex and it is exarch, yet it looks, to some extent, like an aggregation of several traces, each similar to a *Heterangium* trace in which the base of the triangular xylem has disappeared. Now, in *Heterangium* the petiole-trace gradually assumes a **U** shape as it is followed outwards, though it has always mesarch protoxylem in two groups, one in each arm of the bilobed (**U**-shaped) trace.

Relationships with the more complex pteridosperms are not very evident, but the peculiar form of the undivided petiole-trace appears to indicate a transition from the simple type so characteristic of the *Lyginodendreæ* to the much divided type in the *Medulloseæ*. The outer cortex of the stem and petioles, in transverse section, is partly of the *Myeloxylon landriotii* and partly of the *M. radiata* type, both of which are common in the *Medulloseæ* though not confined to that group. But in longitudinal section the sclerotic fibres are occasionally seen to join, thus forming a reticulum. The exarch xylem of *Rhetinangium* suggests affinities also with *Sutcliffia* and *Stenomyelon*.

The nearest relative seems to be *Megaloxylon*, though that genus is more highly specialised in at least one direction. The difference between the two seems exactly parallel to what occurs among the *Osmundaceæ*, and the explanation that the short tracheide is probably a specialisation for water-storage has also been adopted by KIDSTON and GWYNNE-VAUGHAN in their memoirs on the *Fossil Osmundaceæ*.*

Taking the *Cycadofilices* as a whole, the more ancient types show a simpler structure, and, since *Rhetinangium* occurs at a lower horizon than *Megaloxylon*, we would expect it to show a relatively simpler organisation. The primary wood in the former genus contains long tracheides and is much smaller in diameter than is the case in *Megaloxylon*, and it may be argued that the inner tracheides in the latter stem would be too far from the periphery to perform the function of water conduction except near the apex of the stem. They therefore appear to have terminated their growth and become modified for water-storage, whereas those in *Rhetinangium* retain their primary function throughout.

In concluding this paper I desire to express my thanks to Dr ARBER, Dr KIDSTON, F.R.S., and Dr SCOTT, F.R.S., for their unfailing kindness and valuable suggestions whenever difficulties arose, and also for the readiness with which they placed specimens from their collections at my disposal.

My thanks are also due to the Executive Committee of the Carnegie Trust for a grant to defray the expenses of illustrating this paper.

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EXPLANATION OF PLATES.

(Figures all taken from untouched negatives by the author. Unless otherwise stated, the figured specimens are in the author's collection.)

PLATE I.

Rhetinangium arberi.

Fig. 1. Transverse section of stem. x^1 = primary wood; x^2 = secondary wood; *i.c.* = inner cortex; *sc.o.c.* = sclerotic hypoderma. Slide 1045. × 3·7 diameters.

Fig. 2. Transverse section of central vascular axis. x^1 = primary wood; x^2 = secondary wood; *i.c.* = inner cortex; *o.c.* = outer cortex; A, B, C, = points of emission of petiole-traces. Slide 1000. × 8·5.

Fig. 3. Longitudinal section of stem. x^1 = primary wood; x^2 = secondary wood; *m.r.* = medullary ray; *ph.* = phloem; *i.c.* = inner cortex; *o.c.* = outer cortex; *sc.o.c.* = hypoderma. Slide 984. × 9.

Fig. 4. Transverse section of stem and petiole base. x^1 = primary wood; x^2 = secondary wood; *sc.o.c.* = sclerotic hypoderma; *pet. b.* = petiole base; A = point of emission of petiole-trace from the cortex. Slide 1003. × 2·3.

Fig. 5. Longitudinal section to show tracheides. x^1 = primary wood; *c.p.* = conjunctive parenchyma of primary cylinder; x^2 = secondary wood; *m.r.* = medullary ray; *ph.* = phloem; *i.c.* = inner cortex. Slide 984. × 23.

Fig. 6. Longitudinal section of primary cylinder to show protoxylem. x = primary xylem; *prx.* = protoxylem (exarch). Slide 986. × 170.

Fig. 7. Transverse section of primary wood to show secretory sacs. x^1 = primary wood; x^2 = secondary wood; *s.s.* = secretory sacs. Slide 1007. × 19.

Fig. 8. Transverse section of part of axis to show structure of wood. x^1 = primary wood; *prx.* = protoxylem; x^2 = secondary xylem; *m.r.* = medullary rays; *w.r.* = ring of small tracheides. See also Pl. III. fig. 24. Slide 1005. × 19.

Fig. 9. Section similar to fig. 8. x^1, *m.r.*, *w.r.* as in that figure. Slide 1006. × 19.

Plate II.

Rhetinangium arberi.

Fig. 10. Transverse section of part of stem. x^2 = secondary wood; *ph.* = phloem; *i.c.* = inner cortex; *c.t.* = crushed cells at exterior of inner cortex; *o.c.* = outer cortex; *s.s.* = secretory sacs in inner cortex; *s.c.* = secretory cells in inner cortex. Slide 1006. × 30.

Fig. 11. Longitudinal section of inner cortex. Lettering as before. Slide 1077. × 14.

Fig. 12. Transverse section of root-trace. x^1 = primary xylem; x^2 = secondary xylem; *prx.* = protoxylem. Slide 1037. × 70.

Fig. 13. Longitudinal section of part of outer cortex. *p.o.c.* = parenchymatous outer cortex; *sc.o.c.* = sclerotic outer cortex; *s.s.* = secretory sacs. Slide 986. × 36.

Fig. 14. Transverse section of part of outer cortex. *e.o.c.* = elongated outer cortex; *sc.o.c.* = sclerotic outer cortex; *s.s.* = secretory sacs. Slide 1003. × 36.

Fig. 15. Transverse section of cortex. *i.c.* = inner cortex; *e.o.c.* = elongated outer cortex; *sc.o.c.* = sclerotic outer cortex; *s.s.* secretory sacs. Slide 1048. × 23.

Plate III.

Rhetinangium arberi and Heterangium grievii.

Fig. 16. *R. arberi.* Transverse section of petiole-trace while attached to the axis of the stem. x^1 = primary xylem; x^2 = secondary xylem; *prx.* = protoxylem of leaf-trace; *l.t.* = leaf-trace. While transferring this section a crack appeared in the specimen, and although the trace is still complete it has parted from the rest of the section near one end. Slide 994. × 19.

Fig. 17. *R. arberi.* Transverse section of petiole-trace at a slightly lower level. $x^2s.$ = secondary wood of stem; *prx.* = protoxylem groups of petiole-trace. Slide 999. × 34.

Fig. 18. *R. arberi.* Transverse section of petiole-trace at a still lower level. $x^2s.$ = secondary wood of stem; x^2 = secondary wood on back of petiole-trace; *prx.* = protoxylem groups of petiole-trace. Slide 1003. × 34.

Fig. 19. *R. arberi.* Transverse section of petiole-trace in free petiole. Slide 1048. × 16.

Fig. 20. *R. arberi.* Transverse section of trace in smallest observed division of the petiole. *l.t.* = trace; *prx.* = some of the protoxylem groups. Slide 1005. × 60.

Fig. 21. *Heterangium grievii.* Transverse section of petiole-trace while still joined to central axis of stem. (Compare with *R. arberi*, fig. 16.) *l.t.* = petiole-trace; x^1 = primary xylem of stem; x^2 = secondary xylem of stem; *prx.* = protoxylem. Scott Collection 1016. × 60.

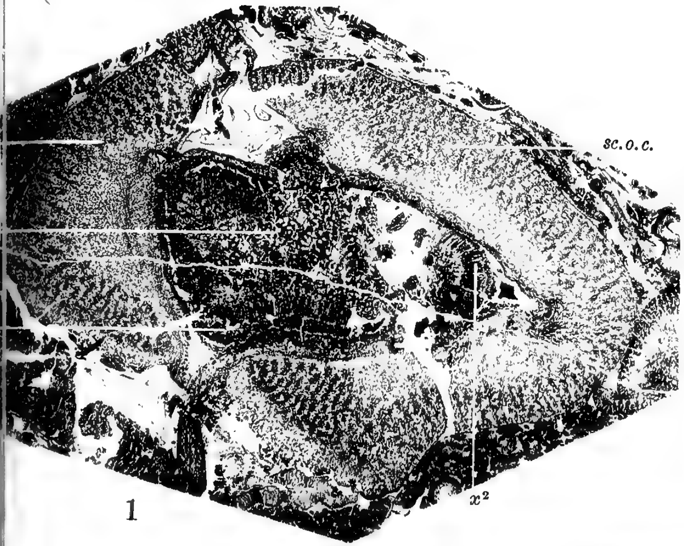
Fig. 22. *Heterangium grievii.* Transverse section of stem. (Compare with *R. arberi*, Pl. I. fig. 2.) Kidston Collection 512. × 8·5.

Fig. 23. *R. arberi.* Longitudinal section of outer cortex showing radial elongation and the occasional division of the inner cortical parenchyma. *p.o.c.* = parenchymatous outer cortex; *sc.o.c.* = sclerotic outer cortex; *a* = radially elongated parenchyma; *c.w.* = wall dividing elongated cells into two. Slide 984. × 36.

Fig. 24. *R. arberi.* Transverse section of peripheral primary wood to show position of protoxylem. Part of section shown in Pl. I. fig. 8. The photographs are reversed in position. x^1 = primary wood; *prx.* protoxylem; x^2 = secondary wood; *c.p.* = conjunctive parenchyma of primary wood; *m.r.* = medullary ray. Slide 1005. × 85.

Fig. 25. *R. arberi.* Longitudinal section of primary xylem cylinder to show secretory sacs and cells. x^1 = primary xylem group; *c.p.* = conjunctive parenchyma; *s.s.* = secretory sacs; *s.c.* = secretory cells. Slide 984. × 45.

W. T. Gordon: On Rhetinangium Arberi.—Plate I.



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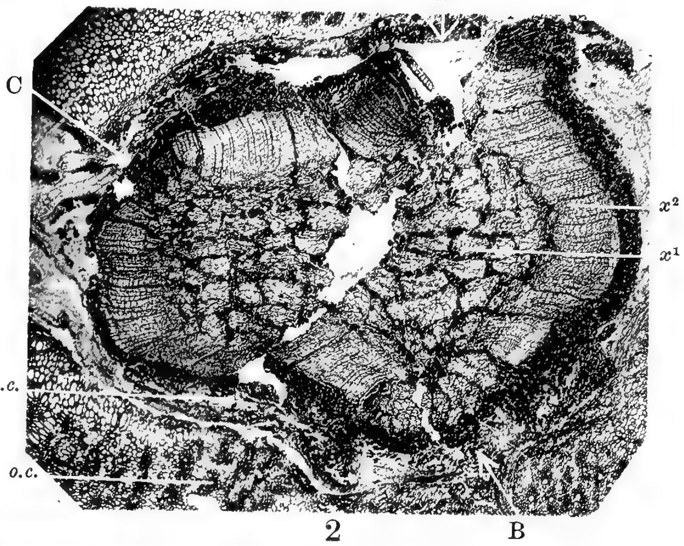

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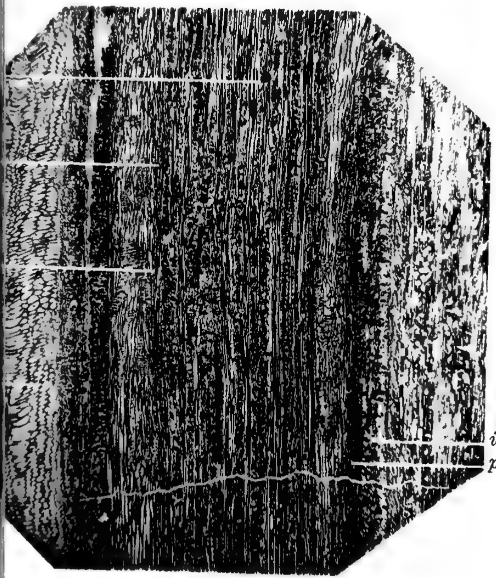

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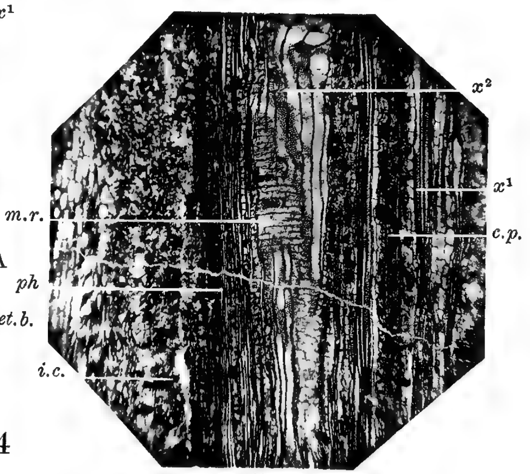

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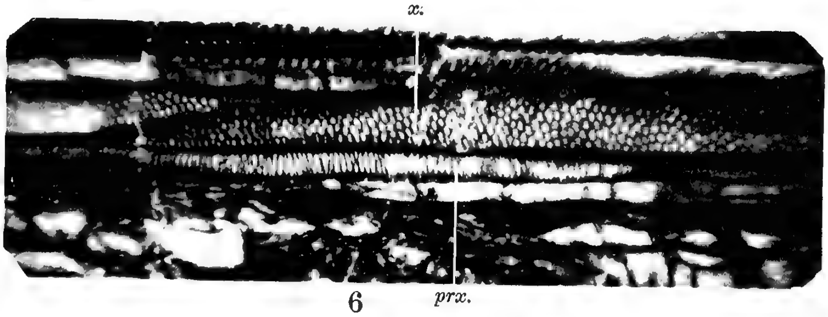

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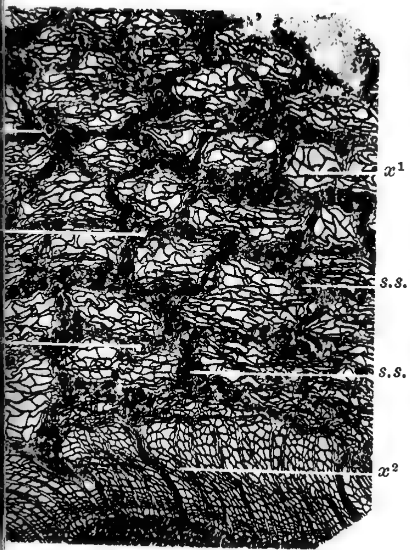

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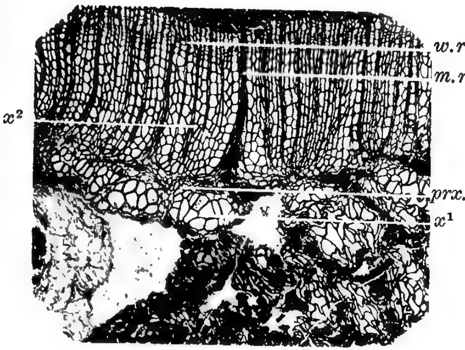

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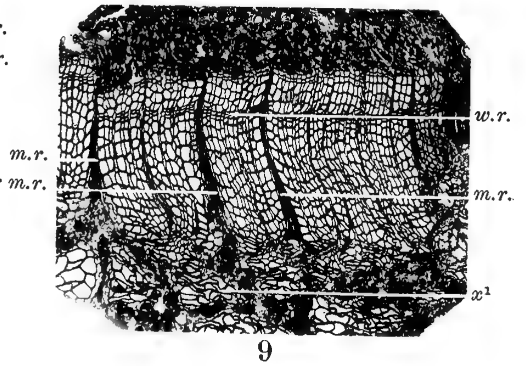

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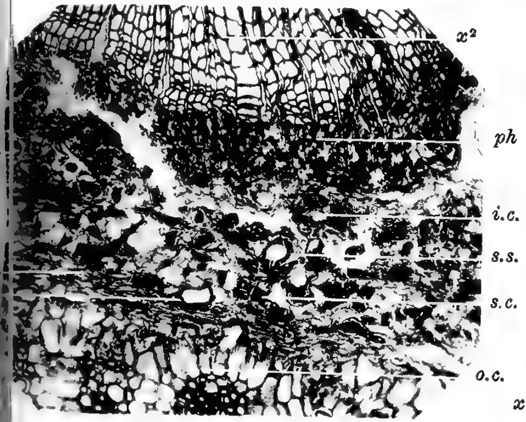
W. T. GORDON: ON RHETINANGIUM ARBERI.—PLATE II.



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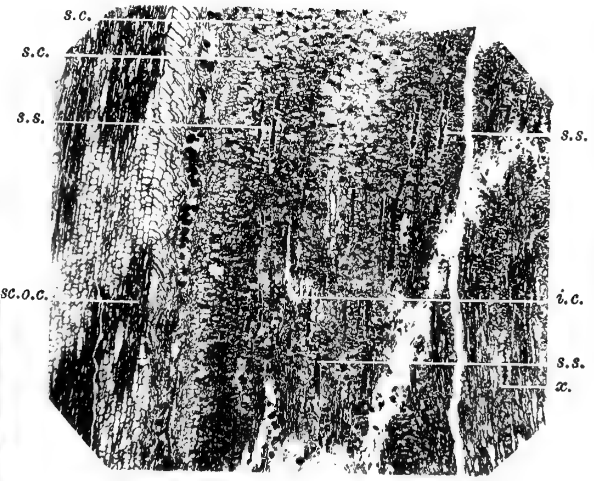

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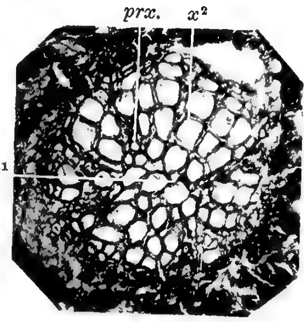

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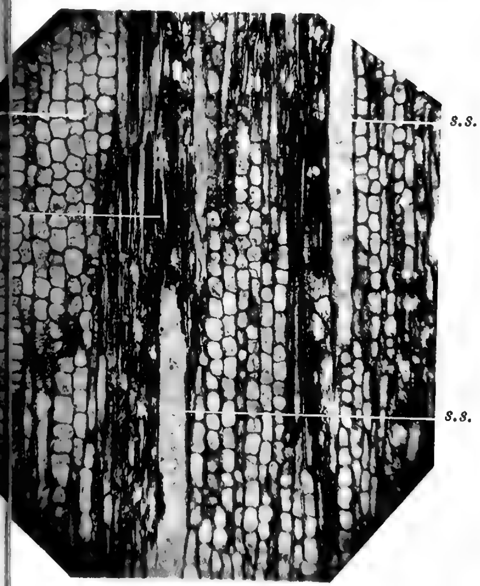

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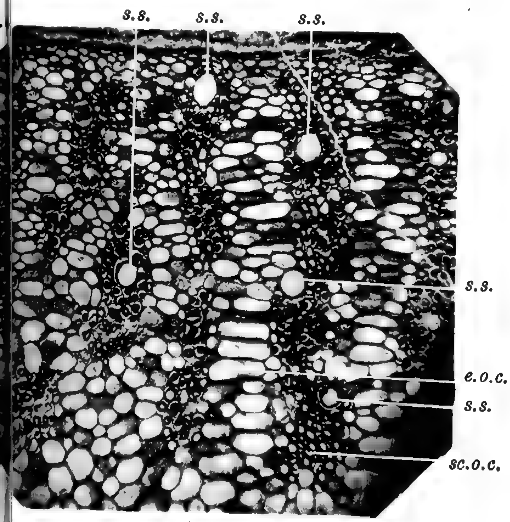

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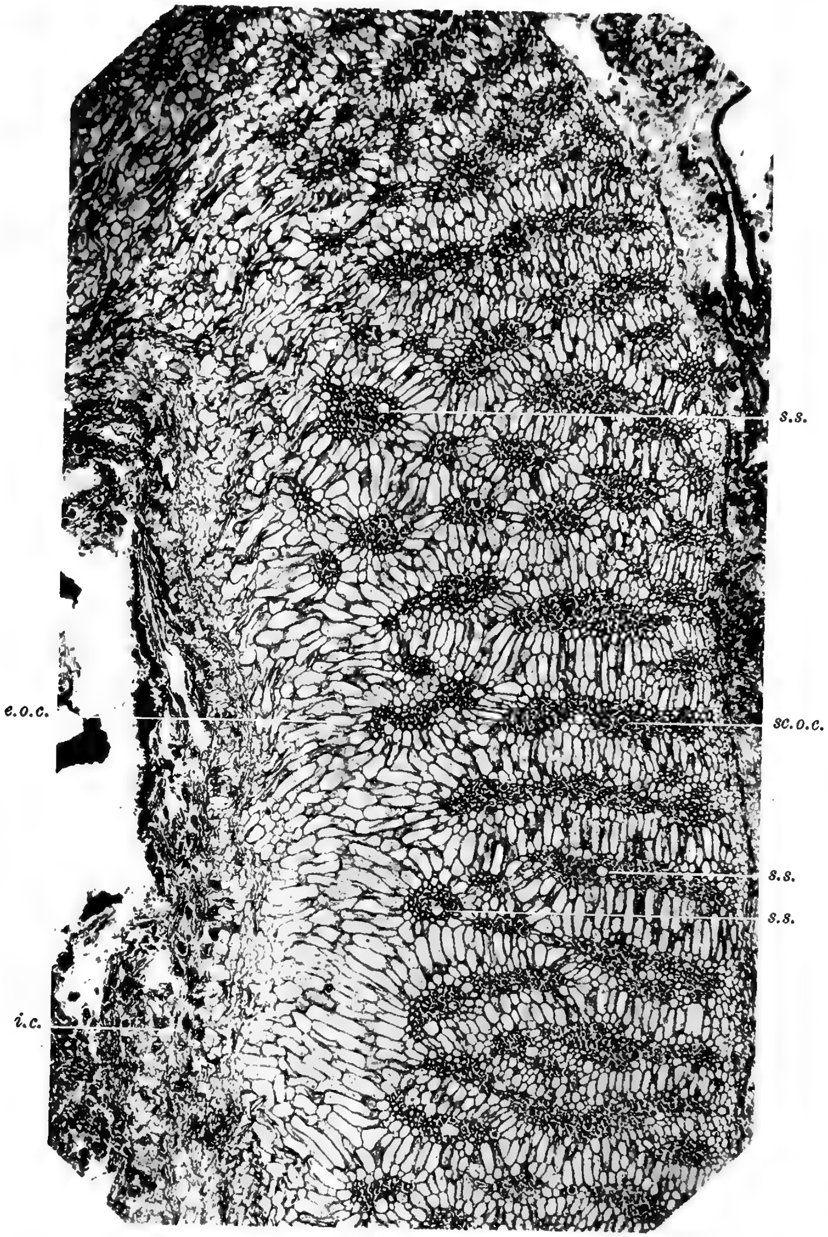

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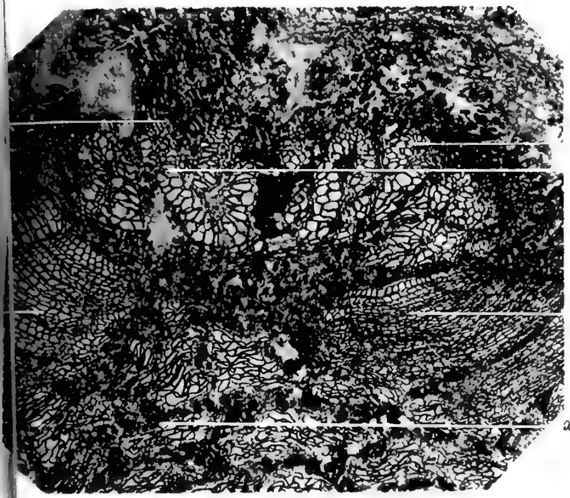
W. T. Gordon: On Rhetinangium Arberi.—Plate III.



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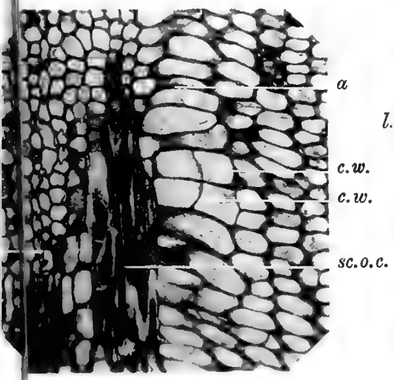

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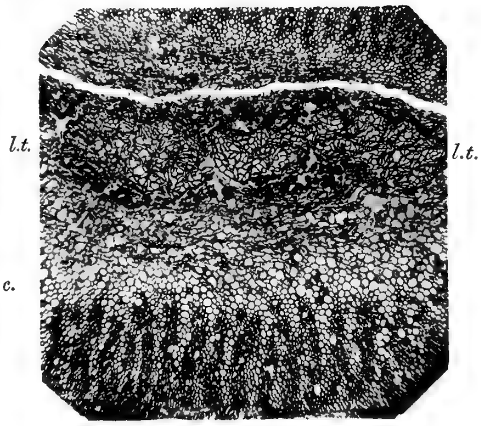

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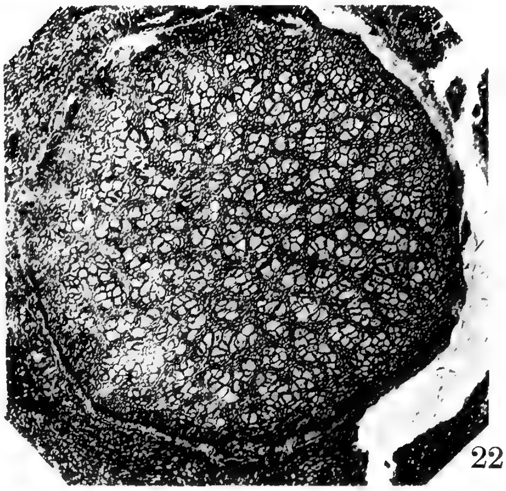

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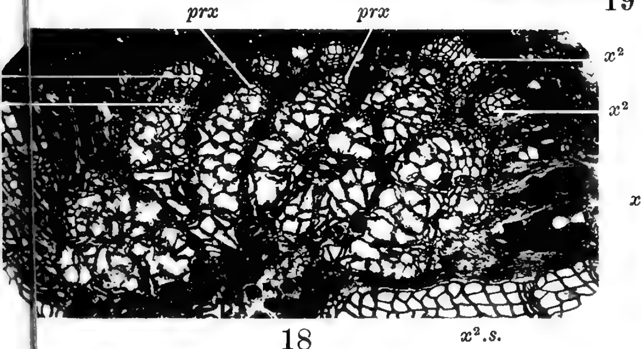

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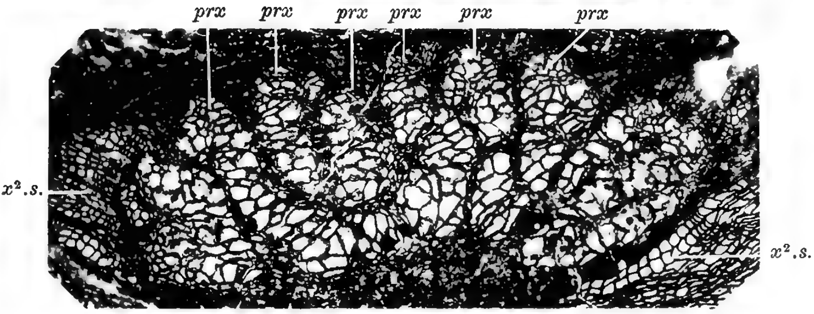

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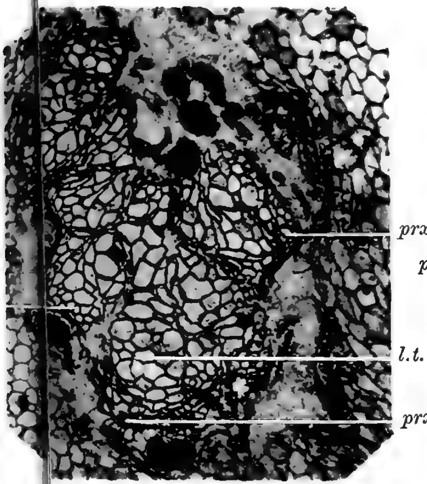

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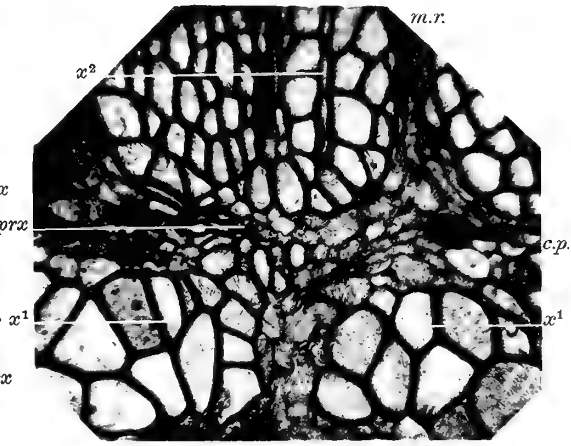

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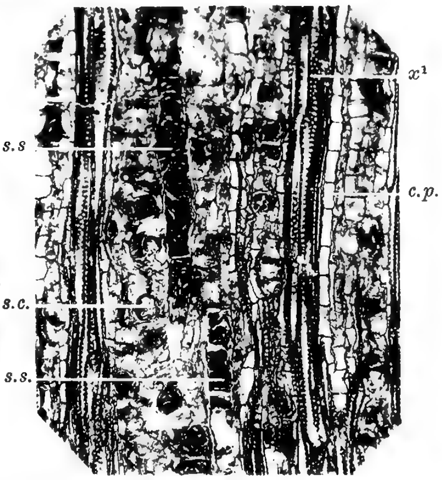

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NATURAL HISTORY

XXX.—Scottish National Antarctic Expedition: Observations on the Anatomy of the Weddell Seal (Leptonychotes Weddelli). Part IV.: The Brain. By David Hepburn, M.D., C.M., Professor of Anatomy, University College, Cardiff (University of Wales). (With One Plate.)

(MS. received June 18, 1912. Read December 2, 1912. Issued separately February 8, 1913.)

The material placed at my disposal for the purposes of this paper comprised the brains of four adult specimens of the Weddell seal, in addition to the brain of the young animal which has formed the subject of my former contributions.* The four adult brains having been removed at the time the animals were killed, and preserved in a solution composed of spirit (90 per cent.) 6 pints and formal (2 per cent.) 4 pints, were, with one exception, in a firm and satisfactory condition for detailed anatomical examination. The body of the young seal had been preserved with a view to ordinary dissection, and therefore its brain was not in the firm state of the adult specimens; but as I had the opportunity of removing this brain from the skull, I was able to observe the disposition of the dura mater to the hemispheres of the cerebrum and cerebellum. While the dura mater presented, as a whole, its usual arrangements, it was noteworthy that the falx cerebri did not act as a septum between the two hemispheres of the cerebrum except to a very slight extent, and certainly for not more than one-third of the distance between the vertex of the cerebrum and the dorsal surface of the corpus callosum. As a result, in the region referred to the opposing mesial surfaces of the two hemispheres lay not only in close apposition with each other, but their convolutions were intimately adapted to each other. Similarly, the tentorium cerebelli only extended a short distance between the cerebrum and the cerebellum, and, as the occipital ends of the cerebral hemispheres fell considerably apart from each other, there was space for the accommodation of the well-developed vermis of the cerebellum as well as for the bulbous pineal body, which occupied a position upon its dorsal aspect. As I removed the brain from the skull the stalk of the pineal body gave way, and probably the same thing had occurred during the removal of the adult brains, for, while different lengths of the stalks had been preserved, there was only one complete specimen of its bulbous extremity. Looked at from the vertex, the general outline of the whole brain was that of a four-sided figure with rounded angles, and the cerebral hemispheres concealed the cerebellum except where the vermis was exposed between them at their occipital ends. The frontal ends of the hemispheres were not rounded into frontal poles; but, on the contrary, they almost formed flat frontal surfaces. Similarly, the occipital ends were rounded and not pointed to form occipital poles. There was a small amount of difference in the absolute size of the adult brains, and the largest specimen measured 120 mm.

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* Part I., *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 57, 1909. Part II., *Trans. Roy. Soc. Edin.*, vol. xlviii. p. 191, 1912. Part III., *Trans. Roy. Soc. Edin.*, vol. xlviii. p. 321, 1912.

in its fronto-occipital diameter; 115 mm. in its greatest transverse diameter at a point well forward on the temporo-sphenoidal lobes; and 71 mm. in vertical height, measured from the pons varolii to the vertex of the cerebrum. Thus, apart from the peculiarity of its general outline in total size, it was only slightly less than an average human brain. Throughout the anterior two-thirds of their extent the cerebral hemispheres were, as already indicated, in very close apposition, and the falx cerebri only dipped into the pallial or superior longitudinal fissure to a slight extent; but in its posterior third this cleft opened to form a wide interval, measuring 65 mm. in the transverse direction at its hinder end and narrowing as it ran forwards towards the posterior end of the corpus callosum. In the deep level of this interval the pineal body and the upper surface of the vermis were visible, as well as part of the upper surface of the cerebellar hemispheres. It should be stated that the backward extension of the occipital lobes of the cerebrum carried them 2 mm. beyond the cerebellar hemispheres.

In its essential features the basal aspect of the brain conformed to current descriptions of the mammalian brain; but it presented many special points of interest, to which reference will be made in the course of my survey.

I. Cerebral Convolutions and Fissures.

Regarded as a whole, the cerebral convolutions (gyri) were large and well defined from each other by deep, well-marked fissures (sulci), and yet many furrows not deep enough to be regarded as sulci were seen crossing the surfaces of convolutions. Invariably these shallow furrows were in the position of blood-vessels ramifying in the pia mater, and it was clearly demonstrable that the furrows were produced by the blood-vessels. In appearance they resembled the arterial grooves upon bony surfaces, and their presence upon the surface of the brain suggested either arterial pulsation or resistance to brain growth as their determining cause. Indeed, from the distinct character of many of them it would not be difficult to credit these vessels with the possibility of determining the position of new fissures in a rapidly expanding hemisphere. In their chief and outstanding characters the two hemispheres corresponded with each other; but in the matter of intimate detail they presented a considerable amount of asymmetry, although neither hemisphere could be said to be more elaborately convoluted than the other.

The general plan of the convolutions and fissures was not simple or easy to determine. In fact, the whole arrangement bore very little if any resemblance to that presented by the brain of a typical member of the carnivora, *e.g.* the dog; and this is somewhat remarkable and unexpected when we remember that the seals are themselves carnivores notwithstanding their numerous adaptations to an aquatic habitat. Partly for this reason, and partly because my observations do not altogether harmonise with those of MURIE[*] in his description of another seal (*Otaria jubata*, the sea-lion), nor with those

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[*] MURIE, *Trans. Zool. Soc. Lond.*, vol. viii., 1874.

of Sir WM. TURNER * in his account of the brain of the elephant seal, I propose to deal at some length with the arrangement of the convolutions and fissures and the possibility of dividing the cerebral surface into subordinate lobes, after the manner adopted in describing the human brain.

The complexity of the convolution pattern of the brain of seals has led observers to devise such an elaborate terminology for the description of the separate convolutions and fissures that it is a matter of considerable difficulty to correlate the different terms. Consequently, bearing in mind the variations which specimens of these brains present among themselves, as well as their divergence from the ordinary type of carnivore brain, I have preferred to restrict the use of terms as much as possible, and to limit the attempt to establish homologies to such characters as were fairly comparable to those presented by the human brain.

1. *The Lateral Surface of the Hemisphere.* (Fig. 1.)

On this aspect the convolutions and fissures were well developed both as regards their size and their numbers, and yet any underlying "pattern" resulting from the disposition of the primary fissures was most elusive and difficult to decide. Fortunately, there was no uncertainty with regard to the *fissure of Sylvius* (sulcus Sylvii). Its commencement in relation to the locus perforatus anticus on the basal surface of the brain, and its position between the orbital and temporo-sphenoidal parts of the hemisphere on the same surface, fixed the position of its main stem without any doubt, and so by its outer end it provided one fixed point from which to unravel the complexity of the lateral surface. TURNER found this fissure traceable on the lateral aspect of the hemisphere "upwards and backwards for 32 mm. on the side of the right hemisphere, but not so far on the left." Nevertheless, for some time I found great difficulty in deciding which, and how many, of the fissures upon the lateral surface were entitled to be accepted as its direct continuations, although, as the dissection proceeded, the decision arrived at in the first instance was verified as correct. My initial difficulty was increased by the fact that in the lateral view of the hemisphere of the brain of the dog, as may be seen in the figure given by WIEDERSHEIM and PARKER,† the fissure of Sylvius is represented as a "closed" fissure, *i.e.* one provided with "opercula," forming an "arcuate gyrus" which surrounds the fissure on all aspects except the basal segment of the fissure. Further, in the brain of the dog, this "arcuate gyrus" is repeated twice, so that altogether on the lateral aspect of its hemisphere, to quote WIEDERSHEIM and PARKER, "In carnivores, cetaceans, and ungulates, three gyri arch over the Sylvian fissure, one above the other, and are separated by the so-called *arcuate* fissures."‡ Certainly this was not the manner in which the convolutions and fissures were disposed on the lateral aspect of the hemisphere of the Weddell seal in relation to the fissure of

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* TURNER, *Challenger Reports*, vol. xxvi., *Zoology*: *Report on Seals.*

† WIEDERSHEIM and PARKER, *Comparative Anatomy of Vertebrates*, 3rd ed., 1907, p. 224.

‡ *Ibid.*, p. 228.

Sylvius. On the other hand, in MURIE'S[*] paper already referred to, there is a fairly close resemblance shown in pl. lxxviii. fig. 40, between the brain of the sea-lion and that of the Weddell seal under consideration (fig. 1), so far as the general position of gyri and sulci is concerned; although, having verified my interpretation of the surface appearances by dissection of the interior of the hemisphere, my conclusions differ considerably from those arrived at by MURIE, and so far as carnivora in general are concerned I am of opinion that at least the Weddell seal presents a very novel arrangement of the fissure of Sylvius, but still one which is quite compatible with, and readily explainable by, reference to the mode of its development from the embryonic to the adult condition. As is well known, the Sylvian fissure, in the course of its embryonic development, results from the more or less close apposition of those portions of the cerebral cortex which, as derivatives from the orbital, frontal, fronto-parietal, and temporal portions of the cortex of the hemisphere, and under the term "opercula," extend beyond so as to overshadow and gradually conceal from lateral observation that portion of the cortex called the central lobe or island of Reil, and thus ultimately the surface of the island of Reil may become completely hidden by convolutions which are no longer upon the same superficial plane as those of the insula. Further, until these "opercula" practically come into contact with each other, not only does the insula remain more or less visible, but the lateral segment of the fissure of Sylvius is represented by a gap or interval of varying width. Again, if the growth of the insula kept pace with the growth of the surrounding "opercula," then the insular convolutions would continue to present themselves upon the same superficial plane as that of the "opercula," and thus instead of a fissure of Sylvius we should find in its place the sulcus which limits and marks off the island of Reil from the surrounding cortex, viz. the limiting sulcus (sulcus insulæ). In other words, we should find the island of Reil presenting or protruding between the "opercula" by whose apposition the fissure of Sylvius derives its lateral characteristics.

In my opinion, that is the interpretation of the condition which is presented by the brain of the Weddell seal. As a result there appear to be two sulci extending from the basal stem of the fissure of Sylvius, and between them the greater part of the island of Reil not only presents itself, but is to a large extent upon the same superficial plane as that of the surrounding gyri.

The convolutions upon the surface of the insula were irregular, and neither upon different brains nor upon the two sides of the same brain were they closely repeated; but I have given in fig. 1 a drawing of the brain in which they showed a tendency to radiate from the basal end of the fissure of Sylvius, and I have done so because in the human brain a radiating arrangement is their normal characteristic. From all this it will be evident that the fissure of Sylvius as such is not represented on the lateral surface of the brain of the Weddell seal; but that in its place there is a vallecula, wide anteriorly and narrower posteriorly, which is occupied by the convoluted surface of the island of

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[*] MURIE, *loc. cit.*, pl. lxxviii., fig. 40.

Reil, whose boundaries are indicated by the limiting sulcus which almost completely separates the insula from the surrounding cortex.

In my opinion, this interpretation of the appearances is in conformity with the facts elucidated by a dissection of the corpus striatum, as well as with the facts of development, although I am not aware that it has hitherto been advanced by any of the observers who have described the brain of the seal. Indeed, in his description of the brain of the elephant seal, TURNER says: "I can make no definite statement as to the presence of the island of Reil, unless the concealed part of the anterior limb of the Sylvian fissure be regarded as representing it." Again, in reference to the brain of the walrus, the same observer says: "I could not speak with any precision of the island of Reil, unless the concealed part of the anterior limb of the sylvian convolution passed deeply into the fissure and was concealed by the anterior limb of the supra-Sylvian convolution, which for some distance therefore formed the anterior lip of the fissure of Sylvius." (In the first of these quotations the reference is to the concealed part of the Sylvian fissure, and in the second to the concealed part of the Sylvian convolution, but probably this is by inadvertence.)

The Plates which illustrate the papers of MURIE and TURNER, if compared with fig. 1 of the present communication, will show how much minor variation the brains of this group of marine mammals may present, while to my own mind they emphasise the interpretation which I have ventured to put forward. It is difficult to conceive a brain of the dimensions of those under consideration *without* an island of Reil; and as this part of the convoluted surface of the hemisphere corresponds more or less exactly to the surface aspect of the corpus striatum, the presence of the latter practically compels us to account for the former.

My next endeavour was to determine which of the sulci could be accepted as the fissure homologous to the fissure of Rolando (sulcus centralis), because of its importance as a guide to the position of the sensory-motor area and its value as a dividing line between the frontal and parietal lobes of the cerebrum. Reference may again be made to the brain of the dog, in which the *sulcus cruciatus* is an outstanding feature, and to WIEDERSHEIM and PARKER'S* description of the fissure, where the following occurs: "Along the lateral surface of the hemisphere, the *cruciate* sulcus (the homologue of the central sulcus or *fissure of Rolando* of primates) extends upwards to the pallial fissure." Now, in the Weddell seal the cruciate sulcus is well marked; but, as may be seen by reference to figs. 1 and 2, it is situated so far forwards that, if it be accepted as the homologue of the fissure of Rolando, practically not only is there no frontal lobe remaining, but the parietal lobe is carried forwards to a position *in front of* the basal limb of the fissure of Sylvius, both of which contingencies are so serious as to compel us to doubt whether the homology be correct in the case of this seal, in view of the importance of the Rolandic area as a sensory-motor centre. For these reasons, therefore, so far as the Weddell seal is concerned, I am driven to accept as the fissure of Rolando that fissure

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* WIEDERSHEIM and PARKER, *loc. cit.*, p. 228.

whose lower end will be seen resting upon the fronto-parietal operculum of the insula, and I have marked it by this name in fig. 1. In this respect my drawing and its interpretation are more in agreement with MURIE's[*] account of the sea-lion, although in his drawing the fissure of Rolando is represented as much more extensive than it appears to be in the Weddell seal.

TURNER describes the cruciate fissure of the elephant seal as seen from the front and not from the norma verticalis, and states that "a large sigmoid gyrus was bent around its outer end." To some extent this description would apply to the Weddell seal, although in the latter the cruciate fissure was visible from the norma verticalis, but it was much more effectively seen from the norma frontalis, while its outer end was blocked by an arched gyrus (fig. 1).

I could not find any satisfactory evidence of a homologue for the external parieto-occipital fissure, and therefore no fixed indication of a limit between the parietal and occipital lobes of the cerebrum on its lateral aspect, or between the occipital and tempero-sphenoidal lobes on the same aspect, for the reason that these areas were freely connected with each other by *annectant* gyri.

The Convolutions on the Lateral Surface.

The frontal lobe having been delimited in the manner described, its convolutions resolved themselves into a pre-central (ascending frontal); the frontal contribution to the opercula of the insula; and two or three short convolutions running forwards from the pre-central convolutions towards the sulcus cruciatus.

The elongation of these short convolutions in a forward, *i.e.* frontal, direction would have the effect of forcing the sulcus cruciatus forwards and downwards towards the roof of the orbit, and would thus bring the cruciate fissure into position as a kind of boundary line between the frontal and orbital aspects of the frontal lobe. It appears to me that the blunt frontal end of the brain of the Weddell seal is due in some measure to the presence of convolutions, which in the human brain would be found in relation to the roof of the orbit. Further, in the human brain there may sometimes be seen a fissure which runs transversely from the pallial fissure across the frontal lobe and close above the orbital margin of the hemisphere. In my opinion this is a fissure which may fairly be regarded as corresponding with the sulcus cruciatus.

In the figure given by MURIE, and already referred to several times, there is, on the *frontal* side of the fissure which is marked "Rolando," a convolution named in three places as the antero-parietal convolution (AP); and I cannot but think that this was an unfortunate term to introduce at such a place so long as the fissure of Rolando is accepted as a boundary line *between* the frontal and parietal lobes of the highly elaborated brain of man.

From the fissure of Rolando (fig. 1), and beginning at a point about its middle, a well-marked fissure ran backwards towards the occipital end of the hemisphere. This

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[*] MURIE, *loc. cit.*, pl. lxxviii., fig. 40.

fissure, which was deepest at its ends and shallowest about half way between them, divided the parietal region of the brain into an upper and a lower lobule, and it might quite fairly be termed the *intra-parietal sulcus.* Each of the lobules above and below the intra-parietal sulcus presented in its turn a short and less defined fissure whose course was roughly parallel to that of the intra-parietal sulcus, but neither of these short fissures opened into the fissure of Rolando. Thus the frontal ends of the convolutions both above and below the intra-parietal sulcus were united together, with the result that the arrangement suggested an interrupted post-central (ascending parietal) gyrus.

It has already been stated that there was no definite guide which could be selected as a demarcation between the parietal and occipital lobes, and therefore I can only say that, as a whole, the convolutions in the occipital region ran from behind forwards, and more or less parallel to each other, to make connections with the parietal and temporo-sphenoidal convolutions. One of these connections seems worthy of special notice. It joined the hinder end of the island of Reil and the hinder end of the temporo-sphenoidal operculum to one of the occipital convolutions. In this relation it should be remembered that the Sylvian fossa (which ultimately becomes the posterior limb of the Sylvian fissure in the primate brain) is shallowest in this region during the process of its development.

The lateral aspect of the temporo-sphenoidal lobe, which provided one of the opercula of the island of Reil, was situated below and behind the Sylvian fossa. It presented two fairly well defined convolutions, an upper and a lower, separated by a definite sulcus, with irregular sulci of smaller dimensions, suggesting the possibility of further subdivision.

2. *The Mesial Surface of the Hemisphere.* (Fig. 2.)

This aspect of the hemisphere presented considerable elaboration and complexity as regards the structures belonging to the pallium, but in the basal region it was simpler and more easy of interpretation. As on the lateral surface, the convolutions and fissures were large and well defined, although the determination of their homologies was a matter of considerable difficulty.

The *corpus callosum* measured 5 cms. in length and 4 mm. in vertical depth over the greater part of its length. The *genu* was 10 mm. long and 9 mm. in vertical depth, while the vertical depth of the *splenium* was 5 mm. From the anterior end of the genu to the frontal end of the hemisphere the distance was 2 cms., and from the posterior margin of the splenium to the occipital end of the hemisphere the distance was 4 cms. Therefore, as a whole, the corpus callosum was situated nearer to the frontal end of the brain. The *rostrum* of the corpus callosum was very short, but the *lamina terminalis* (lamina cinerea), extending from the rostrum to the optic chiasma, was a well-defined object.

The *callosal sulcus*, which separated the dorsal surface of the corpus callosum and the anterior aspect of the genu from the surrounding convoluted surface, commenced at the *locus perforatus anticus,* which to a considerable extent encroached upon the mesial aspect of the hemisphere and presented itself in front of the lamina terminalis below the genu of the corpus callosum. Several shallow extensions of the callosal sulcus, in relation to the anterior half of the corpus callosum, ran forwards and upwards into the superincumbent convolution, thereby complicating the appearance of that gyrus.

The *sulcus cruciatus* was visible upon this aspect of the frontal lobe, and here it divided into several branches, of which the hindermost was the longest.

There also appeared on this surface the fissure which I have accepted as the *fissure of Rolando,* and it extended from the superior margin of the hemisphere downwards and backwards to a point almost half way to the dorsal surface of the corpus callosum.

The *calloso-marginal sulcus* was much interrupted by the invasion of other fissures, so that it was composed of not only the fissure on the dorsal aspect of the callosal gyrus, but also of a branch from the cruciate sulcus anteriorly, and a branch from a fissure situated posterior to the callosal gyrus (fig. 2).

The mesial aspect of the occipital lobe was reduced to comparatively small dimensions in comparison with the size of the hemisphere, a condition which resulted from the fact that occipital structures, which in a human brain of corresponding magnitude would have been visible on its mesial face, were in this seal's brain turned to the inferior or cerebellar aspect of the occipital lobe. For this reason there was very considerable difficulty in selecting a fissure which could be regarded as homologous with the *internal parieto-occipital* sulcus. As the result of a later dissection, which determined the position of the calcarine fissure, I concluded that the fissure which is immediately posterior to the callosal gyrus, and whose course is upwards and forwards towards the supero-mesial border of the hemisphere (fig. 2), should be regarded as the internal parieto-occipital sulcus. Apparently this is the splenial fissure of some authors.

The *callosal gyrus* started by rising gradually from the locus perforatus anticus immediately below the genu of the corpus callosum. It ran forwards, and growing larger as it proceeded it wound round the anterior end of the genu, forming several well-marked folds situated between the callosal and cruciate sulci. Thereafter it passed backwards in a straighter or less elaborate form above the posterior two-thirds of the corpus callosum and between the callosal and calloso-marginal sulci. Posterior to the splenium it turned abruptly towards the basal aspect of the hemisphere, constituting what is known in human anatomy as the *isthmus* of the limbic lobe. Subsequently (fig. 3) it curved along the infero-lateral aspect as the hippocampal gyrus, which steadily expanded as it proceeded forwards to terminate in a wide flattened extremity situated close behind the locus perforatus anticus, but separated from it by the basal segment of the Sylvian fissure. In a later stage of the dissection the *uncus* was found in connection with the hippocampal gyrus.

So far, therefore, as the essential elements which enter into its formation are concerned, the *limbic lobe* in all its parts was fully represented; and only at its frontal end, where several definite sinuosities appeared, and at the widely expanded end of the hippocampal gyrus were there any marked deviations from the much simpler appearances presented by the limbic lobe of the human brain.

3. *The Inferior or Basal Aspect of the Hemisphere.*

As may be seen by reference to fig. 3, the general appearance and the interpretation of this surface were relatively simple in comparison with the other surfaces, except in the occipital region, where again there was considerable complexity due to the fact that so much more of the convoluted surface of the occipital lobe was directed towards the tentorium cerebelli than towards the falx cerebri, with the result that objects which appear on the mesial aspect in the primate brain were found upon the tentorial aspect in that of the seal.

In the mesial plane the two hemispheres were divided from each other in the frontal region by the pallial fissure as far back as the lamina terminalis, below and behind which the *optic chiasma* was situated. The *inter-peduncular space* presented the usual boundaries, viz. : anteriorly, the optic chiasma ; antero-laterally, the optic tracts ; postero-laterally, the crura cerebri ; posteriorly, the pons Varolii. The structures forming the floor of the space were the tuber cinereum, provided with a short infundibulum to which the hypophysis cerebri was attached, this latter being a large object in proportion to the size of other structures ; the corpora mammillaria ; and the locus perforatus posticus. The occulo-motor nerves emerged from the mesial aspect of the crura cerebri.

The basal surface of the frontal lobe was clearly defined posteriorly by the fissure of Sylvius and the locus perforatus anticus. This surface presented the following fissures :—the *olfactory sulcus*, which was occupied by the olfactory tract (fig. 3), pursued a straight course from the locus perforatus anticus forwards towards, but not quite up to, the orbital margin ; the *rhinal sulcus* commenced a short distance in front of the Sylvian fissure and ran forwards in a curved manner, following the lateral contour of the orbital surface, but separated from the margin by a convolution, then, winding round the anterior end of the olfactory sulcus, it turned backwards between the olfactory and pallial sulci, and terminated as a shallow groove upon the gyrus rectus.

The convolutions on the orbital surface were the following :—the *gyrus rectus*, situated between the olfactory sulcus and the mesial orbital border ; the *posterior orbital gyrus*, forming the anterior boundary of the Sylvian fissure and the orbital operculum of the island of Reil ; a *triangular gyrus*, occupying the space between the olfactory and rhinal sulci ; and a long *curved gyrus*, situated between the rhinal sulcus and the lateral margin of the orbital surface. The triangular and curved gyri were both connected with the posterior orbital gyrus behind and with the gyrus rectus in front, but otherwise they were separated throughout their length by the rhinal sulcus. The general arrangement of their surface suggested the possibility of the rhinal fissure being the foundation for the more elaborate fissures which characterise the orbital surface of the higher brains.

The *olfactory tract* presented two distinct roots, separated from each other by a large area of the locus perforatus anticus. Of these, the mesial root came into view from the mesial surface in relation to the anterior end of the callosal gyrus of the limbic lobe. The lateral root emerged from under cover of the expanded end of the hippocampal gyrus. Closely adhering to the locus perforatus anticus, these roots converged and fused to form the olfactory tract, which occupied and moulded itself to the olfactory sulcus.

In all my adult specimens the *olfactory bulb* had been broken off, so that I am not able to state its size, frontal relations, etc.; but it was present in the young specimen as an ovoid enlargement 17 mm. in length and 6 mm. in breadth. It turned upwards upon the frontal surface of the hemisphere, to which it was closely applied.

Behind the fissure of Sylvius, the basal surfaces of the occipito-temporal lobes were much more expanded in the lateral direction than is the case in the primate brain; and, as a consequence, convolutions and sulci which are not found on this aspect in the human brain were visible in the brain under consideration. At the same time, it presented sulci which do not occur in a human brain, and therefore it is not easy to suggest a nomenclature for some of these sulci, nor to be quite certain that they should be accepted as providing boundaries between the occipital and temporal sections of the surface.

The *dentate* and *collateral sulci*, situated respectively on the mesial and lateral aspects of the hippocampal gyrus, were distinctly indicated. Towards the hinder end the collateral sulcus was interrupted by a bridging gyrus, behind which the sulcus corresponded to the general position of the *eminentia collateralis* in the lateral ventricle, as was afterwards revealed by dissection. Further, with the same part of the sulcus, *i.e.* posterior to the annectant gyrus, just mentioned, other two well-marked sulci communicated. Of these, one was directed backwards towards the occipital end of the hemisphere, and the other diverged backwards and outwards towards the infero-lateral margin of the hemisphere in its occipital area. Thus a large segment of the occipito-temporal surface, situated between the collateral sulcus and the infero-lateral margin of the hemisphere, was divided into three wedge-shaped gyri whose bases were directed towards the infero-lateral margin and whose apices converged towards the annectant gyrus above referred to. Indeed, this annectant gyrus connected the anterior and the middle of the three wedge-shaped gyri with the middle portion of the hippocampal gyrus. The posterior one of these three wedges presented a free apex, but the surfaces of each of the three showed indications of further subdivision by additional sulci.

The callosal and hippocampal gyri were united to each other by a narrow gyrus which curved round behind the splenium of the corpus callosum and the crura cerebri.

In the human brain this gyrus is named the *isthmus* of the limbic lobe, and I have used the same term for its description in this account of the brain of the Weddell seal.

Posterior to the isthmus, a distinct deep fissure entered this region, *i.e.* the basal aspect of the occipital end, as the continuation of a fissure well defined upon the mesial aspect of the hemisphere. Upon the basal aspect it was cut off from junction with the hinder end of the collateral sulcus by an annectant gyrus, whereupon it turned abruptly backwards towards the occipital end of the hemisphere (fig. 3). It appears to me that that part of the fissure immediately behind the isthmus should be regarded as the continuation of the internal parieto-occipital sulcus (fig. 2), and that its extension towards the occipital end of the hemisphere is the *calcarine sulcus* (by some observers called the post-horizontal fissure). My reasons for this view will be further elaborated in connection with the description of the posterior cornu of the lateral ventricle, but meantime I may state that the *calcar avis* or *hippocampus minor* was closely related to the position of the deep anterior end of what I have named the calcarine sulcus. Resulting from appearances verified by dissection as well as by transverse section of the posterior cornu of the lateral ventricle (fig. 4), I feel warranted in concluding that the narrow gyrus which is situated on the *lateral* aspect of the calcarine fissure and connected with the hippocampal gyrus must be regarded as the *lingual gyrus*, while the larger gyrus situated on the *mesial* aspect of the calcarine fissure and posterior to the internal parieto-occipital fissure (fig. 3) must be regarded as the foundation for the *cuneate* lobule, which is found in a corresponding position on the mesial surface of the human cerebrum.

Although the foregoing account shows that there was great deviation from the convolution pattern characteristic of a typical carnivore brain on the one hand, and by the human cerebrum on the other, yet the internal appearances exposed by dissection underwent an entire change and became simplified to a remarkable degree. So much was this the case that, in consideration of its size and with certain points of exception as to the details, the various objects were as readily recognised as they are in a human brain.

II. DISSECTION OF THE CEREBRUM.

The method of procedure followed was that adopted in the dissection of the human brain.

In the first place, the hemisphere was divided by a horizontal transverse section at about 4 mm. distance above the mesial free surface of the corpus callosum, in order to expose the white core or *centrum ovale minus*, which, considering the total size of the hemisphere, was smaller than one expected. The reduction in the size of the central white core could be explained by the depth of the sulci. Many of the sulci at the frontal end were 2 cms. in depth, and at the occipital end some were 2·3 cms. deep. As, of course, all the sulci were bounded by a zone of grey matter, the general effect was a reduction in the apparent size of the central white core.

Another unexpected result was, that at the level mentioned, viz. about 4 mm. above the corpus callosum, the section opened into the cavity of the lateral ventricle, which therefore rose to a higher level than the mesial surface of the corpus callosum, and consequently there must be a corresponding deviation from the horizontal direction of those fibres of the corpus callosum which form the roof structures in relation to the body of the cavity of the lateral ventricle. This upward extension of the ventricle, taken in conjunction with the large size of the convolutions as indicated by the depth of the fissures, shows that notwithstanding its superficial dimensions the brain of the seal falls considerably short of a human brain of similar size as regards the amount of grey and white matter.

In addition to what has already been stated with regard to the corpus callosum, the following additional facts may be noted. The mesial faces of the two hemispheres were so closely in apposition that opposing gyri practically interlocked with each other, and therefore the dorsal surface of corpus callosum was entirely concealed. When this surface was exposed it showed feeble *striæ longitudinales mediales* and still feebler *laterales.* The *cingulum* was present, but much smaller than the size of the surrounding gyri led me to anticipate. The *forceps major* and *forceps minor* were easily dissected and were of characteristic appearance.

On removing the roof of the lateral ventricle and of its cornua I was impressed by the apparent simplicity of the basal ganglia, which were large, and at the first glance suggested strongly such appearances as one is familiar with in the human brain. Taking into consideration the somewhat elaborate and intricate condition of the convolutions of the pallium, the simple nature of basal objects was remarkable. The *anterior* or *frontal cornu* of the lateral ventricle was very shallow. Its course was outwards and forwards into the substance of the frontal lobe, where it terminated in a blind recess. Its relations to the *septum lucidum* and to the *caput* of the *nucleus caudatus* were similar to the arrangements seen in the human brain.

The *middle* or *descending cornu* likewise followed the human plan in its chief features and direction. On its floor there were the *choroid plexus,* the *fimbria hippocampi,* and the *hippocampus major* terminating in the *pes hippocampi.* The choroid plexus was continuous with the pia mater of the dentate sulcus, and thus, as in man, the termination of this cornu was situated on the lateral aspect of the crus cerebri and closed by the ependyma ventriculorum. The choroid plexus, however, was wider than in man, and spread itself out so as to form a vascular sheet which separated the objects in the roof of this cornu from the other structures on its floor. Further, the hippocampus major and the fimbria, with the overlying choroid plexus, were pressed upwards against the roof of the cornu, where they adapted themselves to a deep furrow which was bounded mesially by the optic tract and laterally by the tail of the caudate nucleus. Again, on its *convex* margin the hippocampus major was separated from the *floor* of the cornu by a deep fissure which almost completely detached this object from the floor of the cornu. Indeed, the connection between the hippocampus major and the floor of the cornu was reduced to a narrow band in close relation to the concave margin of the hippocampus. Consequently, in the brain of this seal the hippocampus major could not be described as the *reverse* or ventricular surface of the sulcus hippocampi.

Again, the *pes hippocampi* terminated as a rounded end, only slightly wider than the general body of the object and not expanded or notched as in man.

The *fimbria hippocampi* occupied the concavity of the hippocampus major, but it only spread over the surface of the hippocampus major for about a fourth of the width of the latter. Both the concave and convex margins of the fimbria were free, so that it only adhered to the surface of the hippocampus to a slight extent. So far as could be seen, the fimbria became continuous with the lower end of the gyrus dentatus and the adjacent part of the gyrus hippocampi close to the uncus.

The *posterior cornu* was not narrow and pointed towards its occipital end as in man. Indeed, it appeared more like a wide backward extension of the middle cornu, for at its commencement it was 2 cms. wide, and at this place the *eminentia collateralis* appeared as a large well-defined elevation indented anteriorly by the convex face of the hippocampus major, but these two objects were separated from each other by the upward extension of the fissure already referred to on the floor of the middle cornu. On the mesial aspect of the cornu, and above the eminentia collateralis, there were two strongly defined convex ridges, the one above the other. Both of these ridges appeared from under cover of the hinder end of the corpus callosum, with which they were continuous. The *lower* of the two was directed outwards and backwards. It descended to the floor of the cornu, and ceased to be an elevated object immediately behind the eminentia collateralis. As already indicated in an earlier part of my description, this elevation corresponded to the general position of the calcarine fissure on the inferior aspect of the occipital lobe of the cerebrum, and for that reason I have regarded the elevation just described as the *calcar avis* or hippocampus minor. The *upper* of the two elevated ridges seen in the posterior cornu was the larger at its commencement, but it narrowed down rapidly, and disappeared on the floor of the cornu behind the calcar avis. This object may be taken as the *bulb* of the posterior cornu. Fig. 4 shows these two structures in relation to the calcarine fissure, and it will be observed that the bulb of the cornu has a more direct relation to the calcarine fissure than the calcar avis has. The posterior cornu extended backwards for a distance of 2 cms., and terminated in a blind rounded extremity which, from the size of the eminentia collateralis, appeared to dip downwards. Certainly it showed no tendency to bend towards the mesial surface of the occipital lobe.

The *body* of the lateral ventricle was roofed over, as already stated, by the tapetal fibres of the corpus callosum. On its floor the following structures were noted :—

Anteriorly the *nucleus caudatus*, which was particularly well shaped ; to the mesial side of its tailed part, there was the choroid plexus of the velum interpositum, and this choroid plexus was spread out sufficiently to entirely conceal the tænia semicircularis ; behind the choroid plexus there lay the widely expanded lateral half of the body of the fornix, which, although attached to the under side of the corpus callosum in the mesial plane, nevertheless was spread outwards as far as the tænia semicircularis, thus forming a complete layer above the velum interpositum and the optic thalamus, of which, indeed, no part was visible until the fornix was removed.

At the hinder and outer end of the optic thalamus, the fornix was raised from below by a subjacent object so that it appeared as if the fornix itself contained a rounded mass of material in the position just stated. However, this underlying rounded projection was the corpus geniculatum externum of the optic thalamus, which would have been visible in the floor of the lateral ventricle but for its concealment by the expanded overlying base of the triangular fornix. The *foramen of Monro* was clearly defined and occupied its customary position.

The *fornix* was remarkably well developed and of large size as compared with that of man ; but, as in man, its body or central portion was triangular in shape and flattened from above downwards. By its upper or callosal surface it was attached to the under surface of the corpus callosum along a narrow mesial line which extended from Verga's ventricle posteriorly to the septum lucidum in front. Elsewhere the cavity of the lateral ventricle on each side extended between the corpus callosum and the fornix. The lateral margins of the fornix were sharply defined and free. The deep surface of the fornix rested upon the velum interpositum, but no vessels could be seen passing between the two structures. The two anterior pillars of the fornix followed their usual course towards the base of the brain, curving round in front of the foramen of Monro. The two posterior pillars were wide like the body from which they started. Each entered the descending horn of a lateral ventricle having its anterior margin closely adapted to the concave margin of the hippocampus major, so as to form the fimbria hippocampi in the manner already described. A closer examination of its disposition now revealed a somewhat remarkable fact which had so far escaped observation—viz. the surface of the hippocampus major, although rounded and solid in appearance, was now found to consist for the most part of the fibres of the posterior pillar of the fornix arranged somewhat like an incomplete hollow tube, within which there lay concealed a much smaller ridge of grey substance representing the grey matter of the hippocampus major, which became continuous with the isthmus of the limbic lobe at a point below the splenium of the corpus callosum.

It is probable, therefore, that the longitudinal fibres of the posterior pillars of the fornix are distributed to the hippocampus major; to the hippocampal gyrus with its uncus, as well as to the gyrus dentatus. Further, such an increase of the amount of grey matter in the hippocampus major as would deepen the sulcus dentatus would also probably lead to the obliteration of the fissure on the floor of the descending horn and to a thinning out of the fibres of the posterior pillar of the fornix, and thus produce appearances which are characteristic of the brain of man without materially increasing the total size of such a hippocampus major as is presented by the brain of the seal.

The *velum interpositum* was chiefly notable on account of its large choroid fringes and for its extreme thinness under the body of the fornix, where it covered the optic thalami and formed one of the roof structures in relation to the mesial or 3rd ventricle, for which it likewise provided the usual choroid plexuses. It transmitted numerous vessels into the upper or dorsal surface of the optic thalamus, to which it was closely adherent, but especially so at the hinder part.

The third ventricle was situated as usual between the optic thalami, and its most noteworthy character was the large size of the middle commissure (fig. 2). The position of its anterior and posterior commissures did not call for special comment, and the structural arrangements and composition of its boundaries were not in any way peculiar.

The *optic thalami* formed large well-developed masses, and, as already described, no part of their upper surfaces was visible within the lateral ventricles until the fornix and velum interpositum were removed. When the upper surface of the optic thalamus was fully displayed, it presented certain very interesting features. At its postero-lateral end—that is, close to the entrance to the descending horn of the lateral ventricle, but upon the upper surface of the optic thalamus—the *corpus geniculatum externum* constituted a well-marked elevation which was related to the fornix as previously explained. Along the mesial margin of its upper surface, a flattened ridge—the *tænia thalami* or stalk of the pineal body—ran backwards towards the anterior end of the mesencephalon above the posterior commissure of the 3rd ventricle and the entrance to the aqueduct of Sylvius, where it was joined by its fellow from the opposite thalamus, and thus formed the peduncle of the pineal body.

The *pulvinar* was situated between the corpus geniculatum externum and the tænia thalami. It formed a flattened area which did not project backwards with an overhanging border as in man. The *habenula* was situated partly to the lateral side and partly to the mesial side of the tænia thalami. In other words, the tænia thalami ran across the surface of the habenula. Considered as a whole, the habenula formed a narrow pyriform projection whose wider end was directed backwards and presented itself on the lateral wall of the 3rd ventricle high up in the interval between the middle and posterior commissures.

The *corpus striatum* was displayed by making horizontal transverse sections from the surface of the insula towards the mesial plane so as to include the caudate nucleus, but it was not until the lower levels of the island of Reil were reached that definite evidence of striation was observed. The grey substance of the surface convolutions and that of the caudate nucleus were always distinctly seen, but it was only after the sections had been subjected to the staining influence of a saturated solution of bichromate of potash for forty-eight hours that the other grey masses were clearly visible.

The *lenticular nucleus* occupied its usual position on the postero-lateral aspect of the head of the caudate nucleus. Its mesial border was convex and separated from the caudate nucleus and the optic thalamus by the *internal capsule*. This band was quite definite, but very narrow; and it presented the characteristic anterior and posterior limbs with an intermediate genu. The lateral margin of the lenticular nucleus in its higher levels presented the ridges and depressions which are the characteristic of the claustrum, and it was only after the sections had passed below the level of the general mass of the lenticular nucleus that the claustrum was seen as a separate structure, with a definite external capsule between it and the more deeply placed grey mass. Indeed, the appearance of striation, which was directed forwards and outwards, was more definite below the level at which the lenticular nucleus still retained its biconvex outline and while the striated substance intervened between the claustrum and the head of the caudate nucleus. The effect of this disposition of the grey and white masses of the corpus striatum was to suggest that the differentiation of the *external capsule* was incomplete and had not advanced to the stage of separating the claustrum from the lenticular nucleus.

A band of white substance intervened between the cortical grey matter and wavy margin of the claustrum, and, since the claustrum is usually regarded as a detached and submerged portion of the grey cortex of the insula, it would appear the white fibres which separate the grey cortex from the claustrum are developed earlier than those which, in the higher brains, separate the claustrum from the caudate nucleus and are known as the external capsule. In TURNER's account of the elephant seal, it does not appear that he submitted his specimen to this dissection. The grey nature of the tail of the caudate nucleus was always distinct, and an extension of the sections through the optic thalamus revealed quite plainly its grey substance, bounded laterally by the posterior limb of the internal capsule. The grey matter, however, did not resolve itself into the subordinate nuclei (anterior, mesial, and lateral) which characterises the human brain.

The Pineal Body.—I was able to examine three specimens of this interesting object, and in each case it presented widely different characters. Indeed, the differences were so pronounced that they were not easy to reconcile and certainly not easy to explain.

In the brain which I removed from the skull of the seal which was two days old at the time of its death, the pineal body was a large prismatic object resting upon the vermis of the cerebellum and wedged into the interval between the occipital ends of the cerebral hemispheres. It projected about 27 mm. behind the splenium of the corpus callosum. The peduncle broke in the process of removal, but it was very short and apparently just sufficiently long to permit the expanded part to clear the splenium. The dimensions of the expanded, prismatic part were as follows:—greatest length, 27 mm.; width, 18 mm.; vertical depth, 12 mm.

In a second specimen, belonging to one of the adult brains, the peduncle was again broken, but the expanded part still occupied its natural position. In this case the peduncle was cylindrical and the expanded end was pyriform in shape, its measurements being:—length, 20 mm.; width, 15 mm.; vertical depth, 9 mm. It showed no signs of faceting by pressure from surrounding structures, as might have been expected, supposing the reduction in its size as compared with the young specimen to have resulted from the effects of preservative solutions. In the third specimen, also that of an adult brain, the complete object was in an undisturbed position. The peduncle was very thin, flattened from above downwards, and measured 6 mm. in the transverse direction. It was closely enveloped in the pia mater, and extended backwards on the vermis of the cerebellum to terminate in a disc-like expansion 12 mm. in width. The discoid part was flattened upon its cerebellar surface, while it was slightly conical on the opposite side. From the commencement of the peduncle to the extreme edge of the disc it measured 25 mm., of which the peduncle represented 15 mm. and the disc 10 mm. Numerous vessels travelled between the pineal body and the pia mater. These two adult brains had been preserved in precisely the same way, and therefore it would appear as if the pineal body of the Weddell seal underwent a gradual reduction in size subsequent to birth, but that the shrinkage is not accompanied by any marked shortening in the total length of the object. Similar facts have been recorded by TURNER in connection with the pineal body of the elephant seal, in which the measurements were:—length, 16 mm.; greatest breadth, 8 mm.; greatest vertical diameter, 6 mm. In two specimens taken from the walrus the dimensions were, in one case, 30 mm. long and 18 mm. wide; in the other case, 29 mm. long and 13 mm. wide. There is thus satisfactory evidence that, so far as the seals are concerned, the pineal body attains an unusual size as compared with other mammals; although in the case of *Otaria jubata*, described by MURIE, the size of this structure may not have been so noteworthy as in the specimens above detailed, otherwise such a competent observer could scarcely have confined his account of its size to the statement that it was "relatively large."

The *optic tract* followed the usual course from the optic chiasma backwards and outwards to wind round the lateral aspect of the crus cerebri. Thereafter—owing to its relations to the hippocampus major, as already described—it became compressed into a somewhat triangular band upon the under side of the thalamus, and sweeping past the *corpus geniculatum internum*, with which it became closely associated, it continued its course, spreading out certain of its fibres towards the *pulvinar*, but reserving a bundle of considerable bulk for the *corpus geniculatum externum*. So far as the eye could judge, some of the fibres also reached the *superior* of the *quadrigeminal* bodies, but it did not divide into the *brachia* which characterise its human arrangement.

III. THE MESENCEPHALON.

The mesencephalon presented the *corpora quadrigemina* on its dorsal aspect, and each one of these was quite distinctly defined from the other by longitudinal and transverse furrows. On its ventral surface the *crura cerebri* were also well marked. Latterly, the *corpus geniculatum internum* constituted a large oval elevation, larger than either of the corpora quadrigemina and separated from them by a deep furrow through which many vessels entered the brain substance. The *aqueduct of Sylvius* (fig. 2) was a fairly wide canal, and was not reduced to a T-shaped chink as in man.

IV. The Hind Brain.

(*a*) *The Cerebellum.*—As is usual among carnivores, the cerebellum possessed a relatively large *vermis* in proportion to the size of the *hemispheres.* When examined in longitudinal section (fig. 2), the relation of the vermis to the 4th ventricle and the other constituents of the hind brain presented a great similarity to the corresponding appearances seen in the human brain.*

The *central lobe* rested upon the *superior medullary velum* and possessed a *lingula.* The *culmen* and *declive* were similarly recognisable, as were also the *nodule* and the *tonsil* upon the inferior or ventricular aspect of the vermis. The *pyramid*, the *tuber valvulæ*, and the *folium cacuminis* were not so easily determined in the brain of the seal as they are in the brain of man, because, whereas in the latter these structures are turned towards the floor of the skull, in the former they were turned more towards the hinder end of the vermis.

The *hemispheres* were small and practically impossible of the detailed subdivision which is customary in the descriptions of the human cerebellum, and any attempt to do so would introduce unnecessary risks of error. In a measure, the points of entrance of the *middle cerebellar peduncles* from the pons Varolii provided a guide to what might be regarded as the dorsal and ventral portions of the cerebellum. On this assumption, the *biventral lobe* and the *tonsil* projected laterally some distance beyond any other part of the hemisphere, while the *flocculus* formed a mass of considerable size which overlapped the middle peduncle from behind. If we accept the position of the middle cerebellar peduncle as a sufficiently reliable guide from which to continue the great horizontal fissure by means of which the upper and lower aspects of the human hemisphere are located, then in the brain of this seal all that remained of each hemisphere, in addition to the objects already mentioned, occupied the same aspect and was directed towards the tantorium. Nevertheless, it was divided into two clearly defined areas by a fissure which commenced at the point where the middle peduncle entered from the pons Varolii. If, now, we name these lobes respectively *superior-anterior* and *superior-posterior*, then all the parts of the cerebellum of the seal have been accounted for. It may be noted that the part which I have just named the superior-anterior lobe is reduced to a single folium in relation to the vermis, and it is this folium which is named the folium cacuminis (fig. 2).

Compared with the human cerebellum, it would appear that whereas in the seal the vermis and its subordinate parts are well developed, and the flocculus, biventral lobe, and tonsil are produced on a large scale, the remainder of the hemisphere is much reduced in proportion. On the other hand, in man the hemisphere proper has become much expanded and thickened, with corresponding reduction in the size of the flocculus, the biventral lobe, and the tonsil. In fact, a theoretical enlargement of the superior-anterior and superior-posterior lobes of the hemisphere of the seal, accompanied by their

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* *Text-Book of Anatomy*, edited by Cunningham, 3rd ed., p. 512.

expansion backwards as well as laterally, and a reduction in the size of the flocculus, biventral lobe, and the tonsil, would be capable of producing a cerebellum with practically the same superficial characters as that of man.

The *pons Varolii* was well developed, and measured 25 mm. from its anterior to its posterior border in the line of its very definite basilar groove. The anterior and posterior borders converged upon each other so rapidly, as they travelled outwards to form the middle cerebellar peduncles, that the outline of the posterior border was interrupted by the emergence of the large root of the 5th cranial nerve. As a result of this arrangement, the greater part of this nerve-root made its appearance from the side of the medulla oblongata between the olivary eminence and the pons, but of course close up to the latter. In the elephant seal Turner notes that the 5th cranial nerve arose from the pons Varolii and not from the bulb, whereas, in describing the same nerve in the walrus, he remarks that some fibres of the sensory root "passed backwards between the facial and auditory nerves to the anterior and outer part of the medulla oblongata."

The *medulla oblongata* was wide at its upper end, where it measured 40 mm.; but it narrowed rapidly towards the lower end, and instead of being conical it was markedly flattened in the dorso-ventral direction. Its upper or "open" part was associated with the 4th ventricle, while the "closed" or lower part contained the central canal in its unexpanded condition. Its bilateral character was indicated by the anterior and posterior medium fissures, the former shallow and terminating in relation to the posterior border of the pons Varolii at the foramen of Vicq d'Azyr. On each side of the anterior median fissure or groove the *pyramid* formed quite a distinct tract. The point of emergence of the 6th cranial nerve was not between the pyramid and the pons as in man, but from a flattened area situated external to the pyramid, so that the nerve-stem made its appearance close to the mesial side of the large medullary root of the 5th nerve and without any fibres of the pons intervening between them. The 7th and 8th cranial nerves emerged from the side of the medulla oblongata close behind the 5th and 6th nerves, but slightly nearer the dorsal or ventricular aspect of the bulb.

The *olivary eminence* was small and not so prominent as in man, but it distinctly separated the 9th and 10th cranial nerves from the 12th or hypoglossal nerve.

The closed part of the medulla oblongata presented the general appearances and proportions of the adjacent part of the spinal cord as regards its fissures and main columns. Posteriorly, the *funiculus gracilis* with the *clava* at its upper end, the *funiculus cuneatus* with its upper expansion, the *cuneate tubercle*, and also the *tubercle of Rolando* were all definitely recognisable. They turned outwards in a common bundle from a point immediately below the *obex*, and skirting the infero-lateral margin of the 4th ventricle they entered the cerebellum as the restiform body or *inferior cerebellar peduncle.* The visible *decussation of the pyramids* began at a point 32 mm. from the hinder margin of the pons Varolii, so that we may consider the total length of the bulb to be distinctly less than its width at its upper end.

The *rhomboid* or *4th ventricle* was distinctly lozenge-shaped, but neither in regard to its size nor in regard to the detailed modelling of its floor was it so well marked as in man. The floor presented a median furrow, as well as an inferior and a superior *fovea* in relation to each quarter of the lozenge. Associated with the *fovea inferior*, the *trigonum hypoglossi* and the *trigonum vagi* formed quite recognisable elevations. The *area acusticæ* was likewise a well-marked elevation on the floor, but its surface was smoother than in man because of the absence of visible striæ on its free surface. The *eminentia teres* was placed to the mesial side of the *superior fovea*, but it was prolonged upwards as well as downwards by a longitudinal ridge which ran upwards along the floor of the aqueduct of Sylvius in the one direction, and downwards to join the trigonum hypoglossi in the other.

The *obex* was a distinct object in the roof of the ventricle in relation to its inferior angle, and the *ligula* could be seen extending from it on each side.

Summary.

In making a general summary of the naked-eye anatomy of the brain of the Weddell seal, the features which have impressed me most and seem most deserving of special reference are the following:—

1. Its angular appearances in association with its large size, suggesting that the general fish-like outline of the entire animal has to a certain extent influenced the shape of its skull, and thereby the shape of the brain within the cranium.
2. The size and elaborate ramification of the cerebral convolutions, together with the considerable amount of asymmetry in the details of the arrangement of the convolutions of the one hemisphere as compared with the other.
3. The width of the interval between the two hemispheres posterior to the hinder end of the corpus callosum.
4. The marked departure from the arrangement of the cerebral convolutions in such a typical carnivore as the dog.
5. The presence of those convolutions belonging to the island of Reil upon the same superficial plane as that of the surrounding convolutions which form the opercula.
6. The definite and complete character of the limbic lobe.
7. The position of the calcarine fissure, and thereby of the visual area upon the inferior aspect of the occipital end of the hemisphere.
8. The large size of the fornix, and particularly of its posterior pillars, in association with a well-marked hippocampus major, of which the greater part is composed of fornix fibres and only a small part of grey substance.
9. The long stalk and the large size of the pineal body and its position upon the vermis of the cerebellum, in the open interval between the cerebral hemispheres.
10. The well-developed but, on the whole, simpler characters of the basal structures as compared with the elaboration of the pallium.

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HEPBURN: BRAIN OF WEDDELL SEAL.

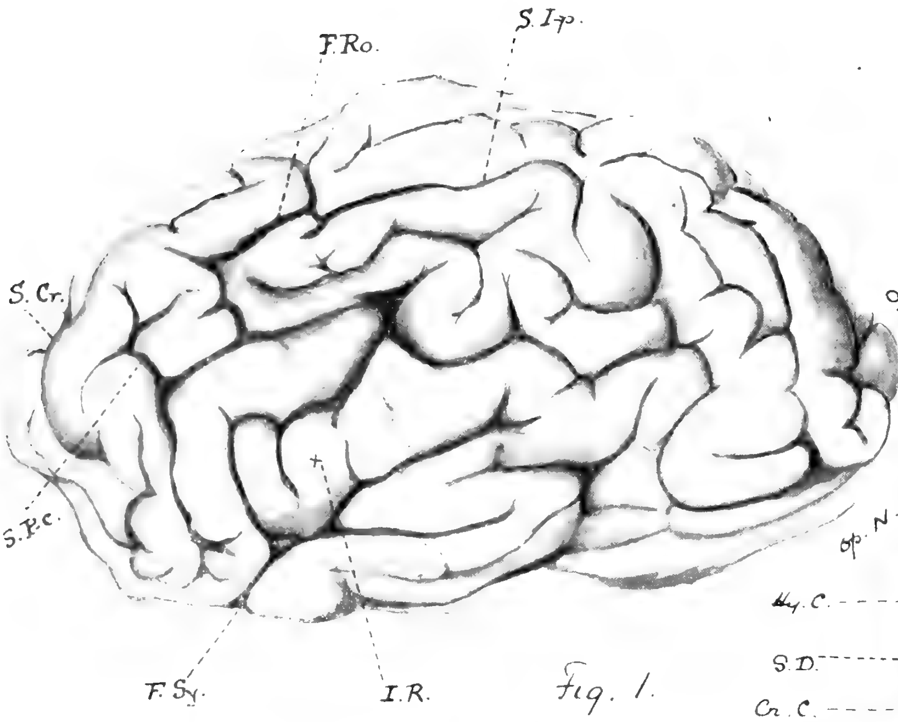

Fig. 1.

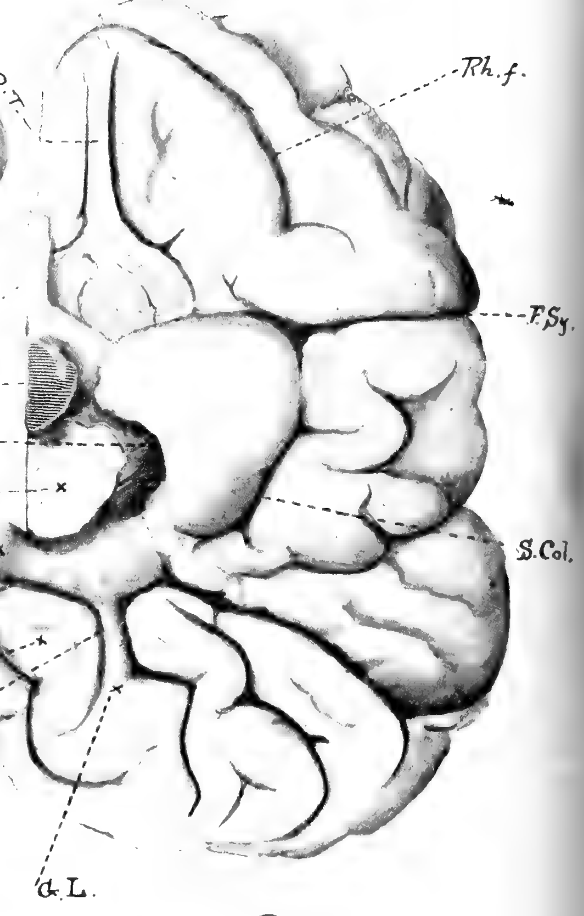

Fig. 3.

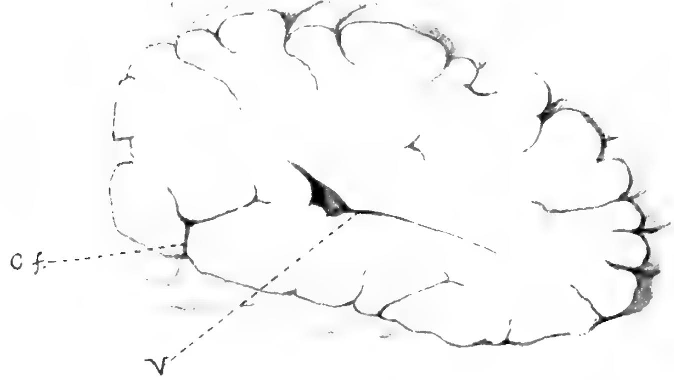

Fig. 4

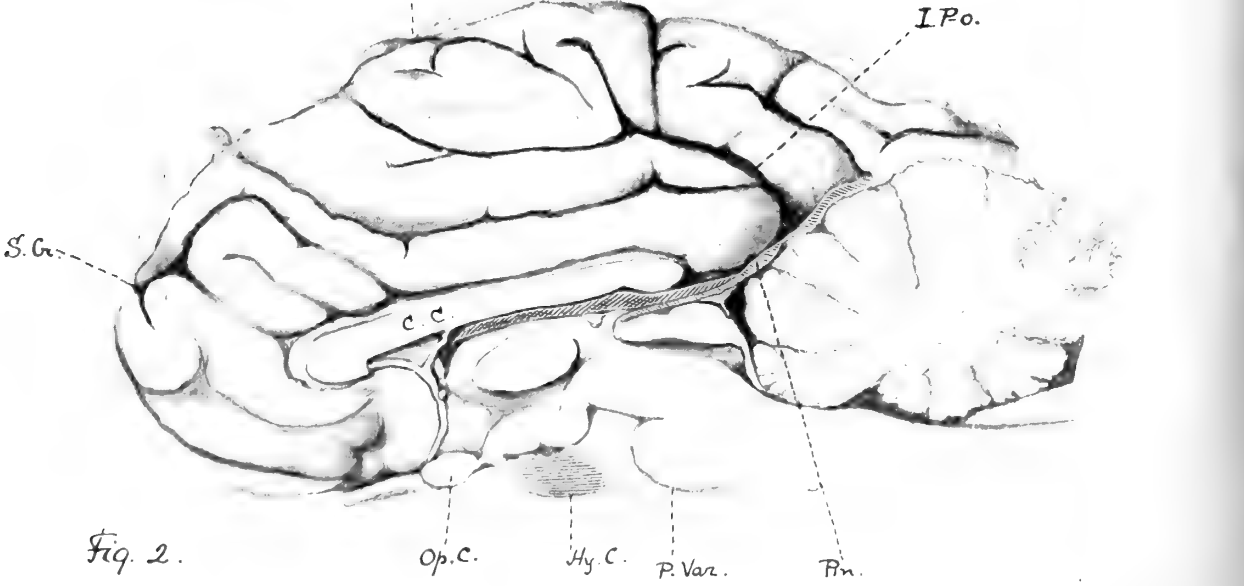

Fig. 2.

D. Hepburn, del.

M'Farlane & Erskine, Edin.

11. The relatively simple character of the mesencephalon.

12. The small size of those parts of the cerebellar hemispheres which in man would constitute their main bulk; and the large size of those objects in relation to the vallecula, which in man would be relatively small.

13. The reduction in the posterior margin of the pons Varolii, which thereby permits the bulbar root of the 5th cranial nerve to emerge directly from the side of the medulla oblongata.

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DESCRIPTION OF PLATE.

Fig. 1. The left cerebral hemisphere, natural size.

F. Sy.	Fissure of Sylvius.
F. Ro.	Fissure of Rolando.
S. P-c.	Pre-central sulcus.
S. Cr.	Sulcus cruciatus.
S. I-p.	Intra-parietal sulcus.
I. R.	Island of Reil.

Fig. 2. Mesial surface of the right cerebral hemisphere.

S. Cr.	Sulcus cruciatus.
F. Ro.	Fissure of Rolando.
I. P-o.	Internal parieto-occipital fissure.
Op. C.	Optic commissure.
C. C.	Corpus callosum.
Hy. C.	Pituitary body.
P. Var.	Pons Varolii.
Pin.	Pineal body.

Fig. 3. Basal surface of cerebral hemisphere.

Rh. f.	Rhinal fissure.
F. Sy.	Fissure of Sylvius.
S. Col.	Sulcus colateralis.
C. f.	Calcarine fissure.
P. o.	Parieto-occipital fissure.
S. D.	Sulcus dentatus.
O. T.	Olfactory tract.
Op. N.	Optic nerve.
Hy. C.	Pituitary body.
Cr. C.	Crus cerebri.
Is.	Isthmus.
Cun.	Cuneus.
G. L.	Gyrus lingualis.

Fig. 4. Vertical transverse section through the posterior horn of the lateral ventricle of the right hemisphere, viewed from behind.

C. f.	Calcarine fissure.
V.	Lateral ventricle.

XXXI.—Scottish National Antarctic Expedition: A Contribution to the Histology of the Central Nervous System of the Weddell Seal (Leptonychotes weddellii). By Harold Axel Haig, M.B., B.S. (Lond.), M.R.C.S. (Eng.), L.R.C.P. (Lond.), Lecturer in Histology and Embryology, University College, Cardiff. *Communicated by* Dr W. S. Bruce. (With Two Plates and Nine Text Figs.)

(MS. received June 18, 1912. Read December 2, 1912. Issued separately February 17, 1913.)

CONTENTS.

PART I.

PART II.

PART I.

Introductory and Practical Details.

The specimens submitted for examination were:

(*a*) Portions of the brain (labelled Specimen XXXI.).
(*b*) Portions of spinal cord (labelled Specimen XXIV.).

Both were in excellent condition as regards fixation and hardening, having been preserved for many years in a fluid composed of formol and 95 per cent. alcohol (the fluid was also injected into the cerebral vessels). They were, previous to histological examination, submitted to the following processes:—

i. Comparatively thin slices were taken from various regions and placed for twenty-four hours in absolute alcohol.
ii. Then transferred to acetone for twelve hours.
iii. Placed in xylol until permeated.
iv. Embedded in paraffin of melting-point 52° C. Sections were then taken with an improved form of the Cambridge rocking microtome, and fixed to slides by means of the albumen method.

Staining of the Sections.

The best stain for differentiating the grey and white matter was found to be *Weigert's method* with acid fuchsin, used alone, or subsequent to treatment with Delafield's hæmatoxylin. Other stains were tried (Bismarck brown with acid fuchsin as counterstain, aniline blue-black, hæmatoxylin and orange-G., etc.), but acid-fuchsin alone appeared to give the best results. The Weigert-Pal method was given a trial, but with negative results, owing to the special means of preservation and hardening employed.* The following regions were studied histologically :—

(*a*) Mid-lumbar, dorsal, and cervical regions of the *spinal cord.*
(*b*) *Medulla oblongata :*

  i. In the region of the pyramidal decussation.
  ii. At the lower level of the olivary body.
  iii. At the middle of the olivary body.
  iv. At the upper level of the olivary body.

(*c*) *Pons*, lower, middle, and upper regions.
(*d*) The *mesencephalon :*

  i. At the level of the posterior corpora quadrigemina.
  ii. At the level of the anterior corpora quadrigemina.

(*e*) The *optic thalamus.*
(*f*) The motor region of the cortex of the cerebral hemispheres (*precentral gyrus*).
(*g*) The *cerebellar vermis* (mesial region).
(*k*) The *optic chiasma.*
(*i*) The *pituitary gland.*
(*k*) The *uncinate gyrus* of the hippocampus major.

I. HISTOLOGY OF THE SPINAL CORD.

A. *Cervical Region.* (Text-fig. 1.)

A transverse section across the upper region of the *cervical cord* shows a very marked breaking up of the grey matter into four main groups in each half, viz. :—

(*a*) A posterior mass extending from the posterior grey commissure into the posterior median column of Goll ; in this mass at the base small nerve-cells are seen, and a few at the peripheral part near the surface of the cord. The latter represent the beginning of the nucleus gracilis, which soon becomes prominent even in the cervical region.
(*b*) A postero-lateral mass, into which the fibres of the posterior roots may be seen to extend. In this mass small nerve-cells may be made out, but they are very scattered and not at all conspicuous.
(*c*) An intermedio-lateral mass, at the central portion of which some large nerve-cells are to be made out, these representing the cells of Clarke's column.
(*d*) An anterior mass (anterior cornu) of wide extent, and possessing four or five groups of very large nerve-cells (motor cells of anterior cornu).

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* The pituitary gland sections were stained with Delafield's hæmatoxylin, followed by eosin to differentiate.

The postero-lateral and intermedio-lateral masses of grey matter are united by strands of neuroglial tissue, which break up the lateral regions of the cord into a well-marked reticular formation. The grey matter in general is characterised by its deeply staining neuroglia fibres, which are of a somewhat coarse nature, and are apparently less in number per unit area as compared with the supporting tissue of higher types of cord.

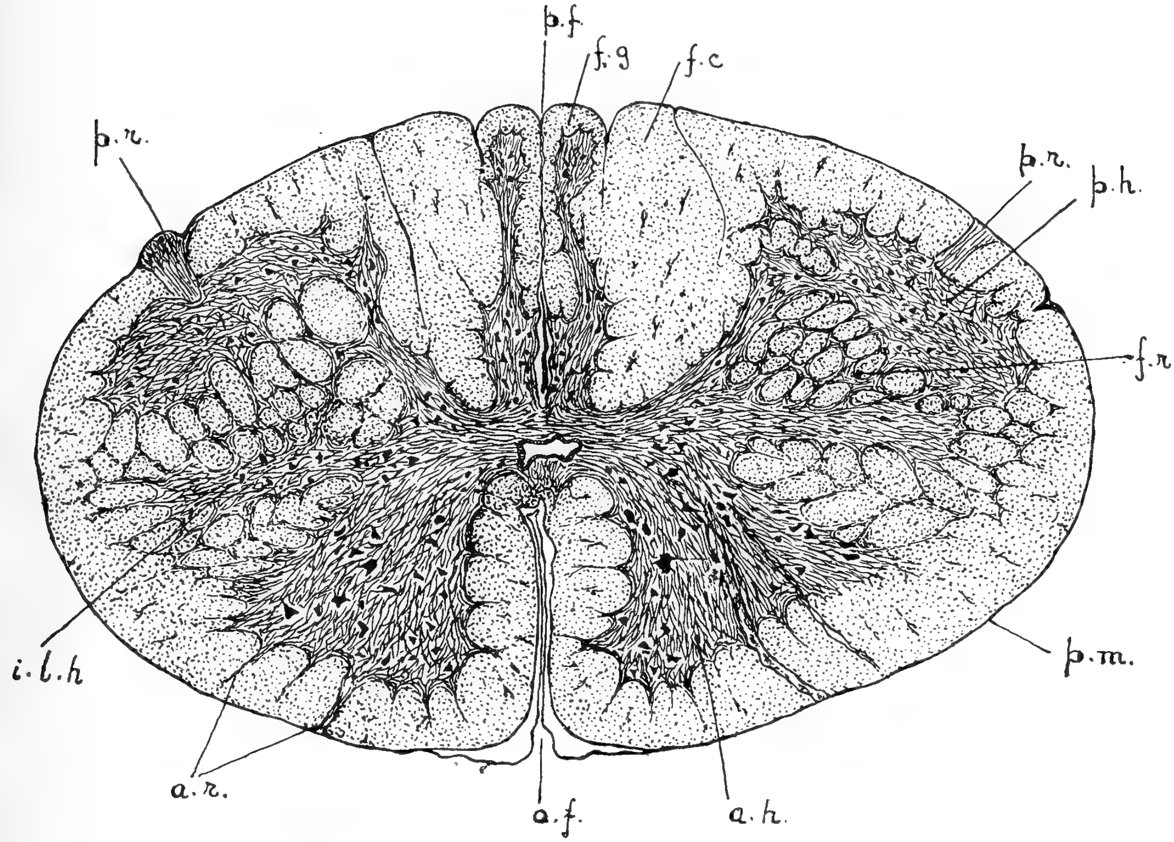

FIG. 1.—A transverse section of the spinal cord (upper cervical region).

a.f.	Anterior median fissure.
p.f.	Posterior median fissure.
p.r.	Posterior root-bundles.
a.r.	Anterior root-bundles.
f.g.	Funiculus gracilis (posterior median column), showing an indication of the beginning of the nucleus gracilis.
p.h.	Posterior horn of grey matter (beginning of the substantia gelatinosa of Rolando).
i.l.h.	Intermedio-lateral horn.
f.r.	Formatio reticularis.
a.h.	Anterior horn.
p.m.	Pia mater.

In the central region of the section the posterior grey commissure is of wide extent, and a small amount of neuroglia is to be seen anterior to the central canal of the cord: the latter is flattened antero-posteriorly, and is lined by a well-marked layer of columnar ciliated epithelium.

The postero-median fissure is of about the same length as the anterior median fissure, perhaps slightly longer; but the cord has apparently been subjected to a certain amount of mechanical pressure, causing flattening, and giving the whole section the appearance of abnormal transverse as compared with antero-posterior diameter. The postero-median fissure, which normally is of greater extent than the anterior, would thus be reduced in length.

The *white matter* of the cord appears to consist of very fine medullated nerve-fibres: in the posterior region, the columns of Goll (mesial) and Burdach (lateral) are very well marked, the pia mater dipping into the cord and marking off these two wedges of white matter. The pial septum, separating the postero-lateral column from the crossed pyramidal and direct cerebellar tracts, passes almost to the postero-lateral horn of grey matter.

The fibres of the anterior roots of the spinal nerves pass out through the white matter in three or four main bundles: those of the posterior roots in one thick bundle of fibres situated at the middle of the postero-lateral horn.

Comparison with higher type of mammalian cord (cervical region).

The main points in the comparative histology are the following:—

(*a*) The early appearance of the nucleus gracilis, which in the human cord does not appear before the medulla has been reached.

(*b*) The extensive spreading out of the grey matter of the posterior and intermedio-lateral horns.

(*c*) The wide disproportion between the transverse and the antero-lateral diameter of the cord, due account being of course taken of any pressure which may have arisen.

(*d*) The marked development of the formatio reticularis.

(*e*) The relatively enormous size of the motor cells in the anterior cornu: this is perhaps not sufficiently emphasised in text-fig. 1, but is nevertheless a very striking feature in the actual section. This feature is possibly related to the highly developed powers of locomotion shown by members of the seal family.

The proportion of grey to white matter is as 3 to 4 approx.

B. *Dorsal region.* (Text-fig. 2.)

The cord appears in this region to have been submitted to mechanical pressure in the transverse diameter: for this reason, the central canal appears elongated antero-posteriorly and somewhat distorted. The postero-median fissure is longer than the anterior and reaches to the grey commissure; the anterior fissure stops short of the central grey matter, leaving a well-defined anterior or white commissure. The antero-posterior diameter appears greater than the transverse. The grey matter is divided in each lateral half into three main masses, viz.:—

(*a*) A posterior horn, in which are to be seen a few medium-sized nerve-cells.

(*b*) An intermedio-lateral horn, at the tip of which a group of medium-sized nerve-cells is situated; the cells of Clarke's column are also seen, having been displaced below the base of the posterior horn by mechanical pressure.

(*c*) A broad anterior horn possessing several groups of large nerve-cells.

The *white matter* in the posterior region shows but slight indication of a division into postero-mesial and postero-lateral columns: the lateral columns are of relatively wide extent.

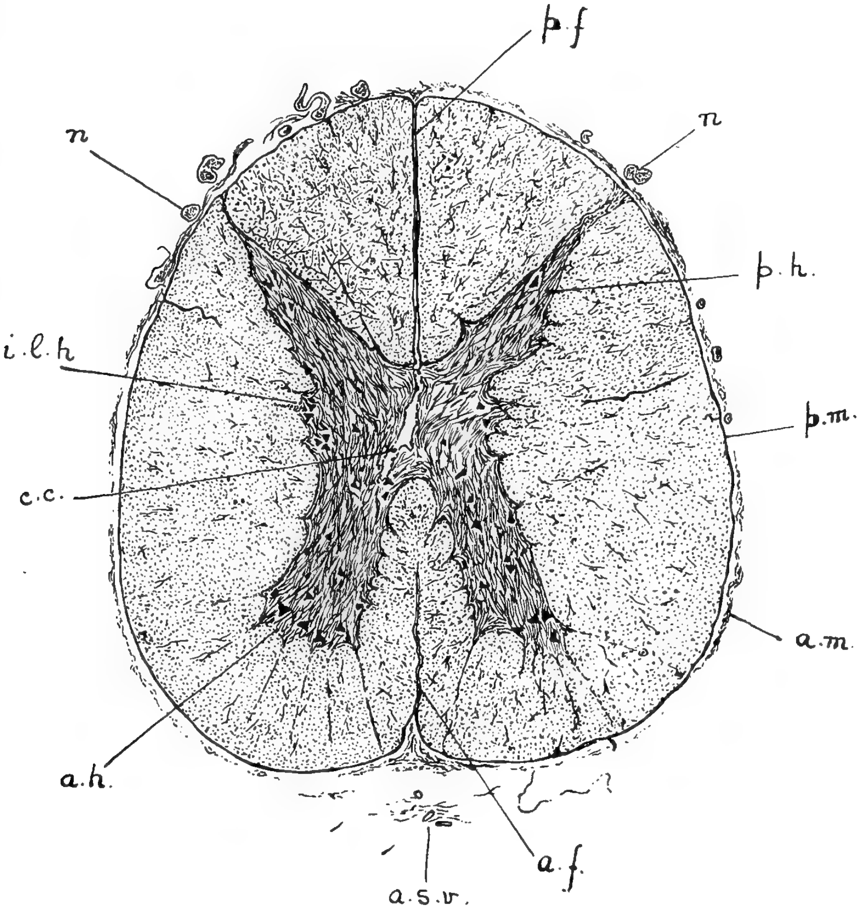

FIG. 2.—A transverse section of the spinal cord (mid-dorsal region). Lettering as in fig. 1, except:—

a.m. Arachnoid mater.	*n.* Posterior roots.
c.c. Central canal of cord.	*a.s.v.* Anterior spinal vessels.

The posterior nerve-roots are narrower than in the cervical region, but are very well defined: the root-bundles lie just outside, and are seen cut across in the section. The anterior roots pass out in three or four narrow strands.

The proportion of grey matter to white is as 9 to 20 approx.

Compared with higher types, the dorsal cord shows but few divergences: the posterior horn of grey matter is rather shorter than in the human cord, and Clarke's column of nerve-cells is but feebly developed. On the other hand, the motor cells in the anterior horn are very well defined.

C. *Lumbar region.* (Text-fig. 3.)

The three main subdivisions of each lateral crescent of grey matter can be distinguished, viz. posterior, intermedio-lateral, and anterior horns.

A few nerve-cells are present about the middle of the posterior horn, and a well-marked group is to be seen at the base of the posterior horn (Clarke's column). Groups also occur at the tip of the intermedio-lateral horn, and to the number of three in the anterior horn, these being very obvious and the component cells very large.

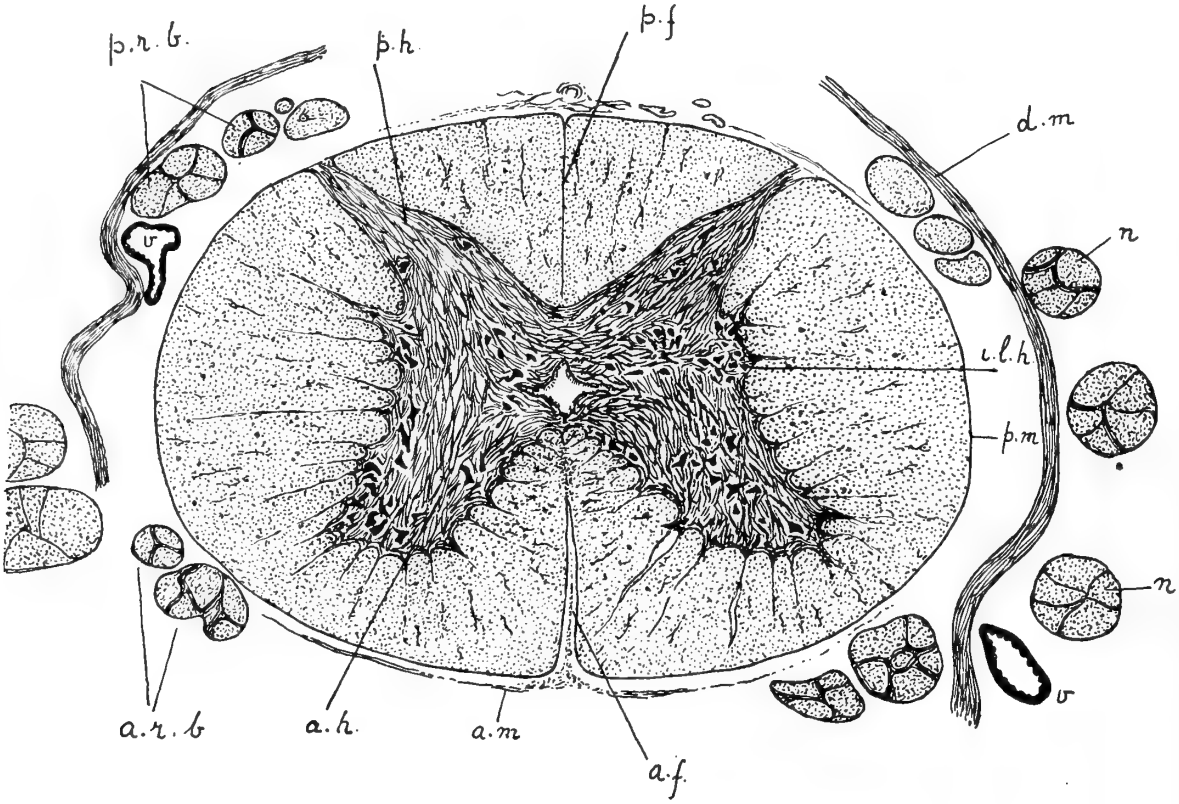

Fig. 3.—A transverse section of the spinal cord (lumbar region). Lettering as in figs. 1 and 2, except:—

d.m. Dura mater.
p.r.b. Posterior root-bundles.
a.r.b. Anterior root-bundles.
n. Bundles of the cauda equina.
v. Large branches of the vertebral vessels.

The posterior or grey commissure is wide, and the anterior white commissure is relatively broad in the antero-posterior direction: the central canal appears as a four-sided space lined by an ependyma possessing an internal layer of ciliated epithelium.

The posterior root-bundles are very large and number three or four on each side posteriorly, lying between the dura mater and the pial investment of the cord; the anterior bundles are two in number on each side antero-laterally.

Of the white matter, the lateral columns are of fairly wide extent, as also are the anterior columns; there is no marked distinction between Goll's and Burdach's columns posteriorly, although a small pial septum does show the superficial division.

In the section figured the postero-median and antero-median fissures are of about the same length, but in a normal specimen the posterior would be rather longer than the anterior.

Outside the dura mater may be seen nerve-bundles representing a high origin of the cauda equina: this feature is very marked in the seal, the cord ending in a filament at a much higher level than in the human.

The proportion of grey matter to white is as 1 to 3 approx.

The chief features of comparative value are the relative shortness of the posterior horn as compared with the human, and the presence of the surrounding bundles of the cauda equina even high in the lumbar region of the cord. The motor cells of the anterior cornua are, as in the dorsal and cervical regions, larger relatively than those found in the cord of man.

II. HISTOLOGY OF THE MEDULLA OBLONGATA.

A. *At the middle of the pyramidal decussation.* (Pl. I. fig. 1.)

Several marked points of difference are seen here as compared with the upper cervical region: firstly, the transverse diameter of the section is twice the antero-posterior diameter, and the anterior fissure is about twice the length of the posterior. The central canal is approaching the posterior surface of the cord, but there still remains a fairly wide grey commissure.

Indications of the beginning of a restiform body may be made out laterally, and the intermedio-lateral horn of grey matter now forms a well-defined mass, known as the substantia gelatinosa Rolandi (*s.g.R.*).

The grey matter generally exists in relatively large proportion: the large motor cells of the anterior horn are still very obvious, and in the postero-median and postero-lateral columns are to be seen respectively the nucleus gracilis and nucleus cuneatus (*n.g.* and *n.c.*).

The *pyramidal decussation* is a marked feature, fibres passing across from the lateral column of one side to the anterior column of the opposite half, and to a certain extent separating the grey matter of the posterior region from that of the lateral and anterior regions.*

The proportion of grey to white matter is as 3 to 4 approx.

B. *At a point just below the calamus scriptorius of the 4th ventricle.* (Pl. I. fig. 2.)

In this region the central canal is fast approaching the floor of the 4th ventricle to open out into that cavity. The pyramidal decussation is now no longer noticed, the upper level having been passed.

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* The decussation of the pyramids is of greater extent longitudinally than in the human medulla, being found quite close to the calamus scriptorius at its upper level.

The substantia gelatinosa Rolandi is now quite separate from the rest of the grey matter and lies enclosed by white fibres which partly arch round it and partly form the lower limit of the restiform body. The pyramids form marked protuberances anteriorly in the middle line.

No trace of an olivary body is seen as yet, a feature which is of comparative value; the nuclei gracilis and cuneatus are well defined, the latter lying now well to the outer side of the former.

Large nerve-cells are to be made out in the grey matter of the still visible representatives of the anterior cornua.

The proportion of grey to white matter is as 3 to 5 approx.

The transverse diameter of the section markedly exceeds the antero-posterior diameter: this feature is now prominent throughout the whole extent of the medulla, until, when the pons is reached, the disproportion becomes less obvious.

C. *At the lower limit of the olivary body.* (Pl. I. fig. 3.)

A median raphe has now appeared, and the central region is occupied by intercrossing strands of fibres (*internal arcuate fibres*), and just dorsal to the pyramids the *tract of the fillet* may be seen.

The central canal has opened out on to the floor of the 4th ventricle, the latter being covered by a layer of ependyma.

The *restiform body* is now becoming a more obvious feature, and outside this fibres forming a well-marked covering, passing from the pyramid regions round the restiform body towards the dorsal region.

Two well-defined nuclei have now taken the place of the nuclei gracilis and cuneatus: these are respectively the nucleus of the 12th cranial nerve and the dorsal nucleus of the 10th cranial nerve (*n.* 12th, *n.* 10th).

The *olivary body* is peculiar in that in section it shows an internal mass of grey matter, loaded with rather large nerve-cells, having the form of a U-shaped fold, which however does not possess any folds of the second order such as are to be seen in the grey matter of the human olivary body. In some regions this olive is open centrally (hilus), but in the lower regions takes the form of a closed oval of grey matter (*o.n.*). The olive does not form a very marked external projection, and, moreover, especially in the higher regions of the medulla, appears to be further removed from the pyramids. A few of the internal arcuate fibres may be traced from the hilus olivæ across the median raphe to the opposite restiform body.

The rest of the grey matter is of a somewhat scattered aspect: the substantia gelatinosa still forms an obvious mass laterally enclosed by the curved restiform body: some of the masses of grey matter lying ventrally may possibly represent accessory olivary bodies, but some certainly belong to the category of arcuate nuclei.

Just below the floor of the 4th ventricle in the middle line is a tract of fibres representing the posterior longitudinal bundle: and ventral to this another band, not well defined, which is the anterior longitudinal bundle.

D. *At the middle of the olivary body.* (Pl. I. fig. 4.)

The main points in this region of the medulla are: the olivary nucleus, the restiform body, the nuclei of the 12th and 10th cranial nerves, and outside both of these a group of nerve cells which apparently represent the nucleus of the vestibular division of the 8th cranial nerve.

Other well-marked features are the issuing fibres of the 12th, 10th, and 9th nerves: the first of these pass down through the internal arcuate fibres to emerge from the medulla between the olive and a mass of grey matter which has become separated from the substantia gelatinosa (? nucleus ambiguus): the fibres of the 10th nerve pass through the arcuate fibres between the restiform body and the fibres of the 12th nerve to emerge at the inner edge of the restiform: the fibres of the 9th nerve are only seen for a short part of their course and emerge further forward (see next section). The pyramids are now very well defined, and the tract of the fillet and the posterior longitudinal bundle form characteristic features.

E. *At the upper level of the olivary body.* (Pl. I. fig. 5.)

In this section, a layer of grey matter appears spreading over the floor of the 4th ventricle, quite distinct from the subjacent nuclear groups; of the latter groups, two, representing nuclei of the 9th nerve, are to be seen just below and external to the very obvious posterior longitudinal bundle. The fibres of the 9th nerve are seen issuing between the olivary body and the restiform body, whilst external to the latter some fibres of the 8th cranial nerve are to be distinguished.

Several small groups of grey matter, just mesial to the olivary nucleus, may possibly represent accessory olivary nuclei.

The anterior longitudinal bundle, the fillet, and the pyramids all form marked features from above downwards; and the fibres which enclose and arch round the restiform body (? continuation of the external arcuate fibres) form also a point worthy of notice.

III. Histology of the Pons Varolii. (Pl. I. figs. 6, 7, and 8.)

A section across the *lower pontine region* of the brain shows the 4th ventricle closed over by the superior medullary velum, and the floor of the ventricle lined by a well-marked ependyma; a thick layer of grey matter lies subjacent to this, and, in the middle line, the posterior longitudinal bundle is one of the most prominent features of the section. In the middle of this region there is to be seen the formatio reticularis, and ventral to this, a fairly wide trapezium makes its appearance ventral to the trapezium, the pyramid bundles form two very distinct masses, and between them lies grey matter representing the nuclei pontis; two small masses of grey matter dorso-external to the pyramid bundles may possibly represent superior olivary nuclei. Pontine nuclei are also to be seen lying ventral and external to the pyramids.

The nucleus of the 7th cranial nerve lies at the outer and upper angle of the formatio reticularis, and the issuing fibres of the 7th nerve pass down close to and parallel to a wide bundle of fibres which arises (partly) from a nucleus close to the inner side of the restiform body; this bundle is the issuing root of the auditory or 8th cranial nerve. Outside the restiform body and the above-mentioned nerves lies part of the white matter of the cerebellar hemisphere (*c*).

Pontine fibres pass ventrally to the pyramid bundles, and form characteristic parallel strands.

The *mid-pontine region* shows a very thick layer of grey matter beneath the ependyma of the floor of the 4th ventricle, on either side of the middle line: beneath this, the posterior longitudinal bundle forms a conspicuous band, the two lying close together in the middle line. The tract of the fillet is also well defined, lying just above and to the outer side of the pyramid bundle; whilst the intercrossing fibres of the pons alternate with parallel streaks of grey matter, breaking up the majority of the central part of the section (Pl. I. fig. 7) into a reticular formation of wider extent than that in the lower pontine region.

The nuclei of the 5th cranial nerve (motor and sensory nuclei close together) appear as a large group of nerve-cells just internal to the restiform body, which latter is now known as the superior cerebellar peduncle, and the issuing fibres of the 5th nerve are seen at the lateral part of the section just ventral to the white matter of the cerebellar hemisphere.

The trapezium is represented by the dorsal portion of the reticular formation, and can hardly be distinguished histologically from that, except by appropriate methods, inapplicable in the case of the present material. The central bundle of the 5th nerve forms a rather narrow band of fibres lying just beneath the grey matter of the floor of the ventricle.

The pontine fibres which lie at the lower (ventral) aspect form very marked parallel strands curving outwards towards the 5th nerve: and the grey matter just dorsal to these fibres (nuclei pontis) are distinguished by their relatively wide extension laterally.

The *upper pontine region* appears in some respects very similar to the mid-region; the tract of the fillet is, however, becoming divided into two main portions, viz. the intermediate fillet and the lateral fillet (Pl. I. fig. 8 *f*).

The posterior longitudinal bundles are now slightly separated in the mid-line by a small amount of grey matter, and the grey matter of the floor of the 4th ventricle is not quite so thick as in the middle region of the pons.

The crossing of the 4th cranial nerves is seen as a band lying just above the ventricle, forming a kind of roof to the cavity at this point; the superior cerebellar peduncles are very distinct, and their decussation may be seen about the middle of the section, although this does not form so obvious a feature as it does in the human pons. A noteworthy feature is the absence of any sign of substantia nigra, as also is the fact that the pyramid bundles are still isolated masses lying well in the grey matter of the lateral regions. Pontine fibres are also well marked.

The anterior longitudinal bundle lies ventral to the posterior longitudinal bundle, but is not a marked feature, since a large proportion of grey matter is present in the mid-region. Below the decussation of the superior peduncles in the mid-line is some grey matter, which, although ill-defined, would represent the so-called central nucleus of the higher types.

The root-bundle of the 4th nerve appears just external to the grey matter of the floor of the ventricle, and indications of the nucleus of the 4th nerve are to be made out at the outer limit of the grey matter in the floor.

IV. Histology of the Mesencephalon. (Pl. I. figs. 9 and 10.)

A section across the mid-brain *in the region of the posterior corpora quadrigemina* shows a structure very like that seen in the human mid-brain; the aqueduct of Sylvius is, however, much nearer the dorsal surface, and moreover is rhomboidal in shape.

Each corpus quadrigeminum possesses an outer coat of white fibres and intermediate mass of grey matter, and an inner thin band of white fibres separating it from the central grey matter round the aqueduct.

The reticular formation of the tegmentum is very distinct, and the posterior longitudinal bundles show clearly just below the grey matter surrounding the aqueduct of Sylvius.

The nuclei of the 3rd and 4th cranial nerves are very well defined, lying mesially just ventral to the lower angle of the aqueduct.

The substantia nigra forms a layer, containing some very large nerve-cells, lying between the fillet tracts and the crustæ; prolongations from the substantia nigra pass into the crusta and tend to subdivide it into two or more regions on either side.

There is an ill-defined mass of grey matter between the two crustæ, representing an inter-peduncular ganglion, and above this a tract of decussating fibres which form the crossing (upper part) of the superior cerebellar peduncles. The decussating fibres of the tegmenta are well marked in the mid-region above the substantia nigra.

A section across the *anterior corpora quadrigemina* shows some divergence from the human type; the Sylvian aqueduct is still rhomboidal in shape, and is some distance from the dorsal surface. The fibres of the 3rd cranial nerve are seen issuing through the posterior longitudinal bundles, and a portion of the section which in the human is occupied by the red nucleus: the latter, however, cannot be markedly distinguished as such in the section in question.

Each anterior corpus quadrigeminum possesses a very thin covering of white fibres, grey matter in the intermediate region, and a narrow layer of white fibres internally;

the grey matter surrounding the aqueduct shows mesioventrally the nuclei of the 3rd nerve, and ventral to the latter the posterior longitudinal bundles are fairly obvious. The crustæ are of less extent than those of the former section.

The posterior commissure of the brain shows dorsal to the aqueduct of Sylvius, and is of moderate antero-posterior dimensions.

Points of comparative value in connection with the medulla, pons, and mid-brain are as follows:—

(*a*) The disproportion between the transverse and antero-posterior diameters of the medulla, the former being about twice or two and a-half times the length of the latter.

(*b*) The relatively large proportion of grey matter in all these regions, much of it, however, being composed of purely neuroglial tissue.

(*c*) The aberrant shape of the olivary nucleus and the outward displacement of the whole olive.

(*d*) The marked development of the restiform body and its early distinction in a comparatively low region.

(*e*) The late formation of the crustæ, the mid-brain being reached before these are well defined. Other minor points will be made out by reference to Plate I., and comparison of the figures with sections of normal human material.

V. The Histology of the Optic Thalamus. (Text-fig. 4.)

The main features to be made out from a vertical (sagittal) section of the optic thalamus consist mainly in the relative distribution of grey and white matter; the white matter occurs in two main masses—an external, thick superiorly and thinning off towards the anterior aspect, and an internal oblique mass which divides the internal

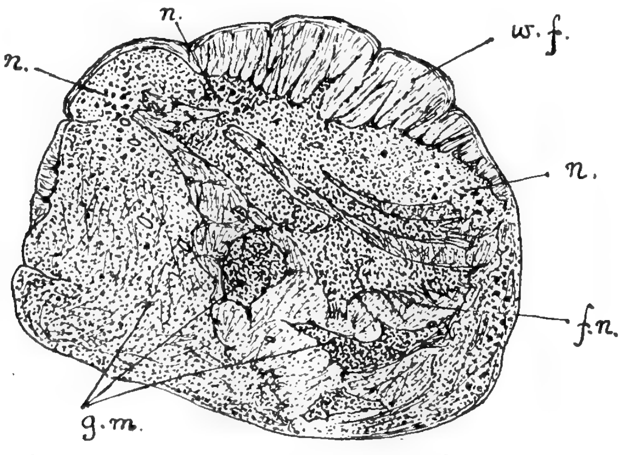

Fig. 4.—A mesial sagittal section of the optic thalamus (semidiagrammatic). × 4 times.

w.f. Superficial layer of white fibres into which septa of neuroglia pass from the deeper grey matter.
n.n.n. Groups of large nerve-cells in the grey matter.
g.m. Central grey matter. The internal mass is not sharply differentiated into grey and white matter: small nerve-cells appear scattered throughout the former.

grey matter into two main groups, an anterior and a posterior. Just beneath the superficial white matter several well-defined groups of nerve-cells may be seen (*n.*), and posteriorly a group is also to be distinguished. Many small nerve-cells are scattered throughout the masses of grey matter.

VI. The Histology of the Convolutions of the Precentral Gyrus.
(Text-fig. 5.)

The *cortex of the motor area* presents a fairly typical structure, except that large multipolar nerve-cells occur at a relatively deep level, forming a deeply staining layer lying next the fibres of the white centre; in all, about four layers of nerve-cells may be distinguished. The following layers are quite distinct:—

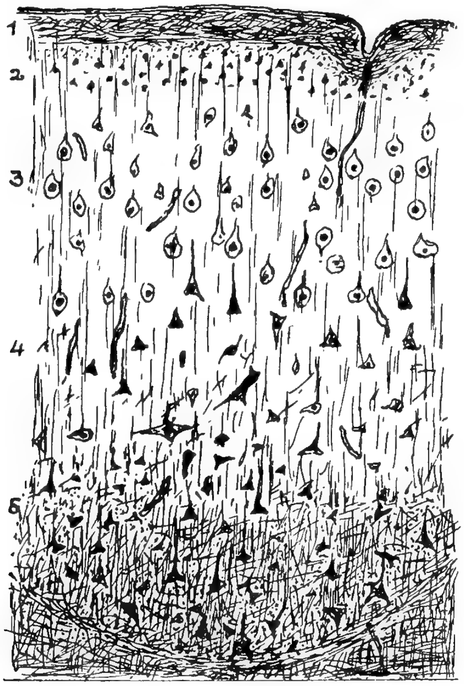

Fig. 5.—Semidiagrammatic vertical section of a part of the motor cortex cerebri (precentral convolution). × 6.

1. Plexiform layer.
2. Layer of small nerve-cells (granules).
3. Layer of large flask-shaped nerve-cells, the axons passing centrally, dendrons peripherally.
4. Layer of large pyramidal cells (comp. to Bett's cells of human motor cortex).
5. Deep layer of large pyramids, lying next to the white centre : there is much dense neuroglia in this layer.

(*a*) A superficial layer formed of interwoven fibres (plexiform layer).

(*b*) A second layer of small nerve-cells, the axons of which are not very obvious.

(*c*) A third layer of large flask-shaped cells not unlike the Purkinje cells of the cerebellum, with axons passing centrally and dendrons peripherally.

(*d*) A fourth layer of rather large pyramidal cells, the axons passing centrally.

(*e*) A fifth layer of large multipolar cells, the axons passing in many directions; this layer contains much deeply staining neuroglia.

VII. The Histological Features of the Vermis of the Cerebellum.
(Text-fig. 6.)

A section across the lamellar of the vermis (or of the hemisphere) shows the typical arrangement characteristic of higher mammals, viz. a white centre, an inner layer of "granules" (small nerve-cells, the axons of which pass peripherally), an intermediate layer of the large flask-shaped cells of Purkinje, the axons of which pass centrally, the dendrons passing peripherally, and a superficial "molecular" layer, consisting of small nerve-cells, the dendrons of Purkinje cells and fibres derived from neuroglia cells, and the "climbing" and "moss" fibres coming from the deeper layers.

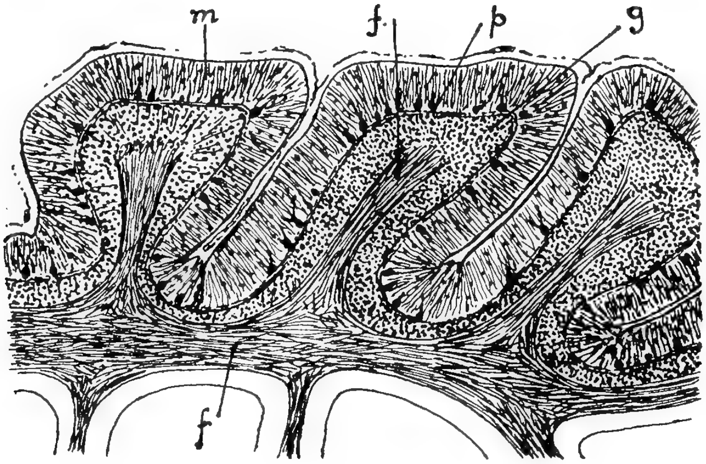

Fig. 6.—A portion of a vertical section of the vermis of the cerebellum. × 6.

f. Fibres of the white centre.
m. Molecular layer.
p. Layer of large Purkinje cells.
g. Layer of granules (small nerve-cells and axons of the Purkinje cells).

The only point of comparative value is the relatively large size of the Purkinje cells; these are not only large, but exist also in greater numbers than are usually met with in an equivalent area of the human type.

[The uncinate gyrus and optic chiasma present much the same features as the same regions in the human type: no points of comparative value were made out in the sections.]

PART II.

The Histology of the Pituitary Gland. (Pl. II. and Text-figs. 7, 8, 9.)

The pituitary gland of the Weddell seal is a body of considerable histological interest, inasmuch as all three portions are well developed, and in addition there occurs upon its upper aspect a small portion of tissue the structure of which is not represented in the human pituitary.*

The gland (text-fig. 7) is a large one, and is made up of three main portions, viz.

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* It is possible that this structure is represented in some of the lower types by the sacci vasculosi found in connection with the pituitary gland.

a large anterior lobe, a narrow but well-defined intermediate part, and a posterior lobe; the hinder portion of the intermediate mass is bent at an angle upon the rest of that part, so as to come to lie posteriorly between the lower limit of the posterior lobe and the projecting posterior part of the anterior lobe. From the surface, the upper part of the posterior lobe appears wedge-shaped and folded over the hinder part of the anterior lobe so as to cover about a third of the upper surface.

The atypical tissue on the upper surface takes the form of a small ovoid mass folded upon itself, and the upper leaf appears to be continuous with the floor of the 3rd ventricle; its structure, however, in no way resembles either grey or white matter, being made up of strands of conglomerate cells (syncytium) between which is a considerable amount of connective tissue and some relatively large vessels (text-figs. 8 and 9). Below this body comes a layer continuous with the posterior lobe, then the persistent cleft continues with the third ventricle and passing some way into the "neck" of the posterior lobe, and below this again the lower part of the neck in which a small amount of the above atypical tissue also occurs, but, as will be seen, quite separate from the main mass.

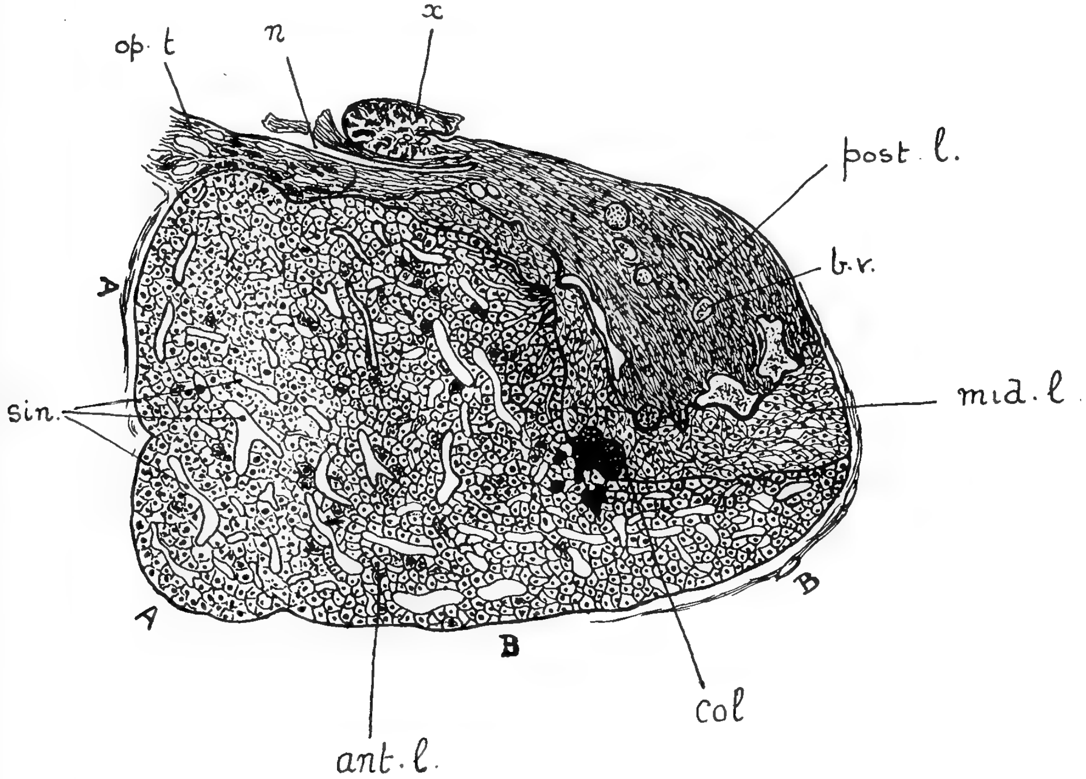

FIG. 7.—A mesial sagittal section of the pituitary gland (*Leptonychotes weddellii*). (Semidiagrammatic.)

ant.l.	Anterior lobe: A A, its front part; B B, its posterior part (see Plate II.).
mid.l.	Intermediate portion.
post.l.	Posterior lobe.
n.	Neck of the infundibulum.
op.t.	Optic tract.
x.	Hypothetical mass on the superior aspect of the infundibulum.
sin.	Sinusoids.
col.	Colloidal substance formed in the middle lobe.
b.v.	Large blood-vessels in the posterior lobe (often filled with colloid).

The large anterior lobe appears to be made up of two distinct portions (histologically distinct), viz. a front part composed of syncytial strands of cells, with well-defined nuclei and a few intervening sinusoids, or rather capillaries, since the endothelial walls are present (Plate II. B). The hind part of the anterior lobe is made up of fairly large clumps of cells, the cell-outlines being quite distinct and the majority of them having deeply stained cytoplasm of a somewhat granular character; the nuclei are large and distinct.* In this part many large sinusoids occur, filled with erythrocytes; a few of the above-mentioned deeply-staining cells occur in the front part of the anterior lobe, but the majority in the front part are syncytial and the cytoplasm but lightly

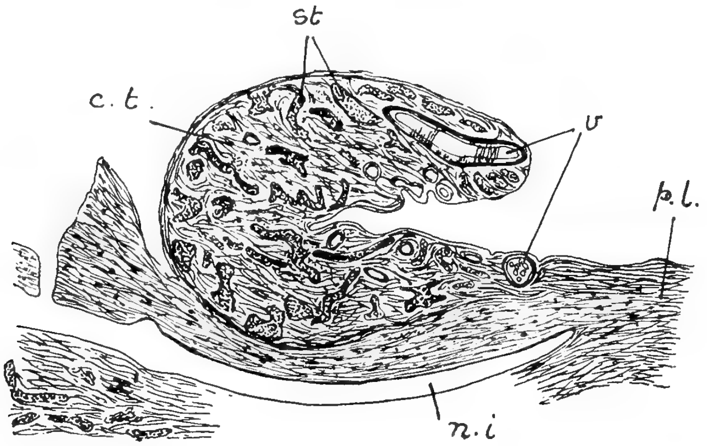

FIG. 8.—Mesial section of the portion lettered *x* in fig. 7 (moderately magnified).

n.i. Neck of infundibulum.
p.l. Posterior lobe of pituitary.
st. Strands of epithelial cells.
c.t. Connective tissue.
v. Large blood-vessels.
x^1. Similar tissue to above seen in the tissue above anterior lobe.

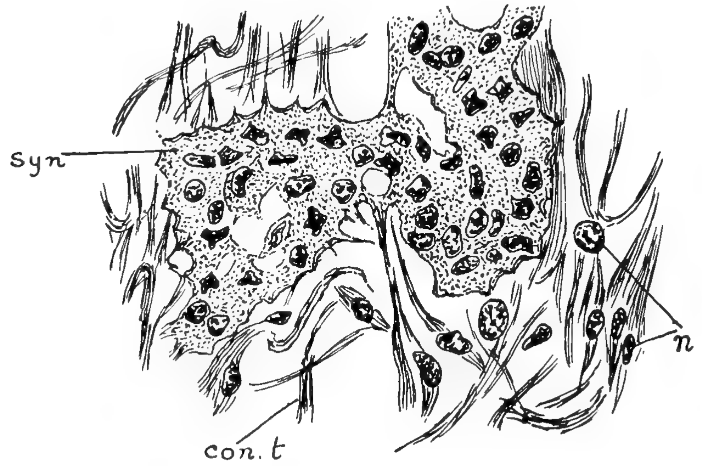

FIG. 9.—A small portion of fig. 8 more highly magnified.

syn. Syncytial strand (*st.* of fig. 8).
con.t. Connective-tissue fibres and cells.
n. Nuclei of fibroblasts (lamellar cells).

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* In these clumps, some of the cells possess much clearer cytoplasm, which is not deeply stained with eosin; in this respect the anterior lobe resembles that of the human pituitary gland.

stained with eosin and clear. The intermediate portion is a typical syncytium of clear protoplasm in which are embedded many large nuclei; colloidal substance occurs at various points bordering on the anterior lobe (Plate II. C, and text-fig. 7, *col.*).

No sinusoids are present in the intermediate portion, there being, however, cleft-like spaces between the strands of the syncytium. At the upper part of the gland the intermediate portion seems to pass insensibly into the anterior lobe—in fact, almost to blend with that lobe, and the above structure would thus lead to an inference that the middle portion is a derivative of the *front* part of the anterior lobe, since both these portions are syncytial in character. The posterior lobe (Plate II. D) is made up of a large amount of neuroglia in which large nuclei occur (nuclei of neuroglia cells), and also here and there small masses of colloid which are passing through the lobe from the intermediate portion. The large vessels of the posterior lobe (not sinusoids) are also occasionally seen to be filled with masses of colloid in which are embedded small bi- or tri-lobed masses which are either leucocytes or degenerating nuclei from the intermediate portion.

EXPLANATION OF PLATES.

PLATE I.

Serial sections of the medulla oblongata, pons, and mid-brain (*Leptonychotes weddellii*).

1. At the decussation of the pyramids:
    - *S.G.R.* Substantia gelatinosa Rolandi.
    - *n.c.* Nucleus cuneatus.
    - *n.g.* Nucleus gracilis.
    - *py.d.* Pyramidal decussation.
2. Just above the pyramidal decussation:
    - *Py.* Pyramids.
    - Other lettering as in 1.
3. At the lower region of the olivary body:
    - *C.R.* Corpus restiforme.
    - *f.* Tract of the fillet.
    - *o.n.* Olivary nucleus.
    - *s.a.* Superficial arcuate fibres.
    - *p.l.b.* Posterior longitudinal bundle.
    - *n. XII.* Nucleus of 12th cranial nerve.
    - *n. X.* Dorsal nucleus of 10th cranial nerve.
4. At the mid-olivary region:
    - *i.a.* Internal arcuate fibres.
    - *n. IX.* Nucleus of the 9th cranial nerve.
    - *n.d.* Part of Deiter's nucleus.
    - *X.* and *XII.* Issuing fibres of the 10th and 12th cranial nerves.
    - Other letters as in preceding figures.
5. At the upper olivary region:
    - *IX.* and *VIII.* Issuing fibres of the 9th and 8th cranial nerves.
    - *a.n.* Arcuate nuclei.
6. Across the lower pontine region:
    - *v. 4.* Cavity of the 4th ventricle.
    - *VII.* and *VIII.* Issuing fibres of 7th and 8th cranial nerves.
    - *D. VII.* Nucleus of 7th cranial nerve.
    - *p.n.* Pontine nuclei.
    - *f.p.* Pontine fibres.
    - *f.r.* Formatio reticularis.
    - *s.o.* (?) Superior olivary nuclei.
    - *bi.* Trapezium.
7. Across the middle of the pons:
    - *n. V.* Nucleus of 5th cranial nerve (motor nucleus).

V. Issuing fibres of 5th nerve.
s.c.p. Superior cerebellar peduncle.
p.l.b. Posterior longitudinal bundle.
f. Tract of the fillet.

8. Across the upper region of the pons:

IV. Intercrossing fibres of 4th cranial nerves.
n. IV. Root-bundles of 4th nerves.
s.p.d Decussation of superior peduncles of cerebellum.
f. Fillet.

9. Across the posterior corpora quadrigemina (mesencephalon):

Sy. Aqueduct of Sylvius.
f.ret. Reticular formation.
p.l.b. Posterior longitudinal bundle.
s.c.p. Superior peduncles of cerebellum.
$f_1 f_2$. Intermediate and lateral fillet.
t.d. Decussation of trapezium.
i.p.g. Interpeduncular grey matter.
n. III., *n. IV.* Nuclei of the 3rd and 4th cranial nerves.
p.p. Crusta (pes pedunculi).
s.n. Substantia nigra.
C.Q.p. Posterior corpus quadrigeminum.

10. Across the anterior corpora quadrigemina:

p.c Posterior commissure of brain.
C.Q.a. Anterior corpus quadrigeminum.
n. III. Nucleus of 3rd nerve.
f_3. Issuing fibres of 3rd nerve.
f. Fillet.

PLATE II.

A. Portion of the posterior part of the anterior lobe of the pituitary gland (*Leptonychotes weddellii*). × 500:

g. Large granular cells, staining deeply with eosin.
sin. Sinusoidal blood-spaces, some of them containing erythrocytes, and occasionally showing an endothelial lining (*n.ep.*) indicative of a true capillary.

B. Portion of the anterior part of the anterior lobe of the pituitary gland. × 500:

syn. Syncytium, including here and there large isolated cells typical of the posterior part of the anterior lobe (*g*).
v. True capillaries.

C. Part of the pars intermedia of the pituitary gland. × 500:

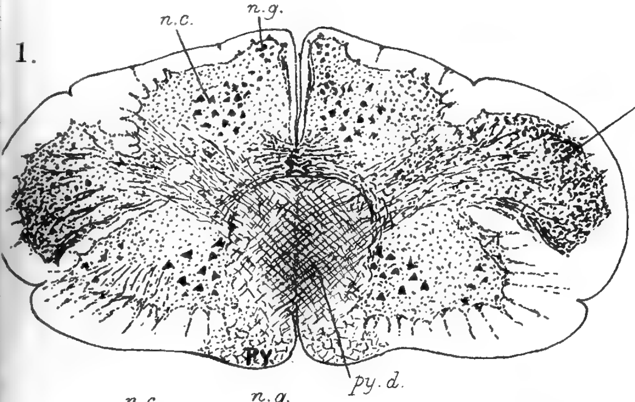
syn.p. Syncytium = fused spindle-shaped cells with nuclei (*n.*) embedded in the protoplasm.
col. Colloidal substance at the edge of the pars intermedia.

D. Part of the posterior lobe of the pituitary gland:

n.f. Neuroglia fibres.
n. Nuclei of neuroglia cells.
col. Isolated colloid masses.
col^1. Large mass of colloid in a vessel (*v.*).

HAIG: CENTRAL NERVOUS SYSTEM OF THE WEDDELL SEAL—PLATE I.

1.



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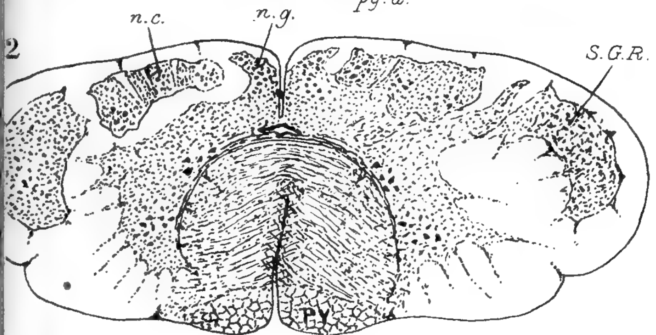

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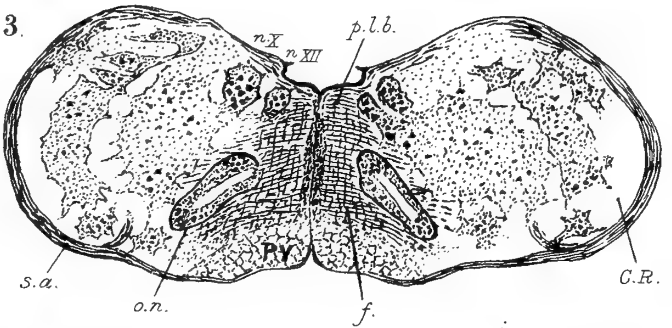

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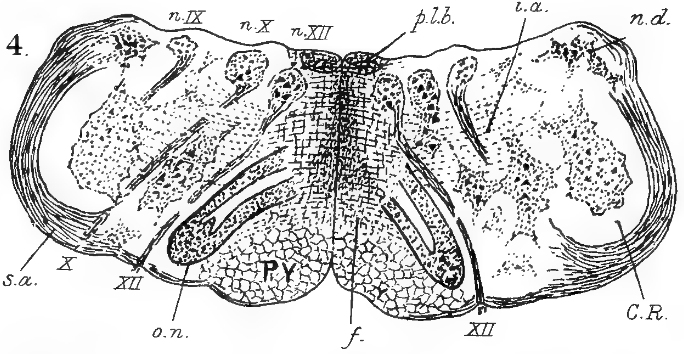

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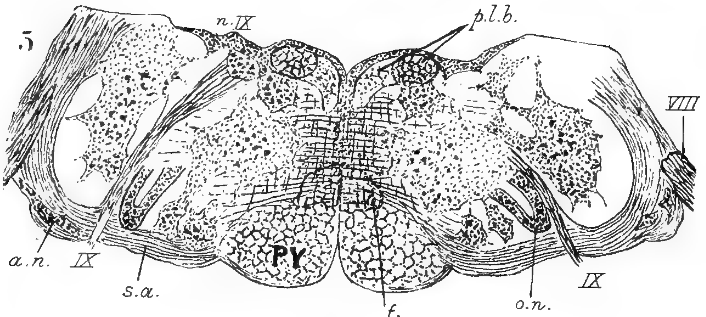

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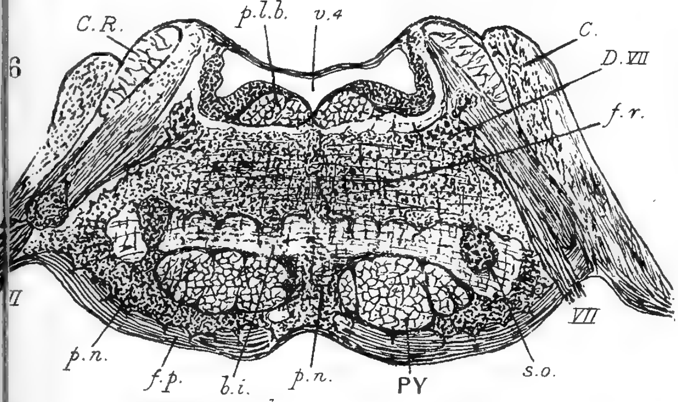

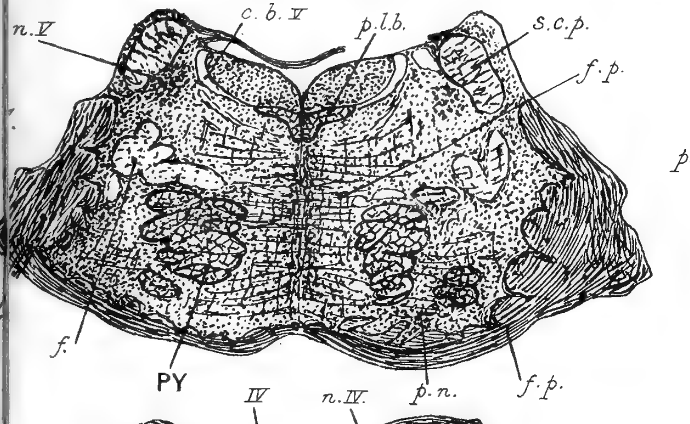

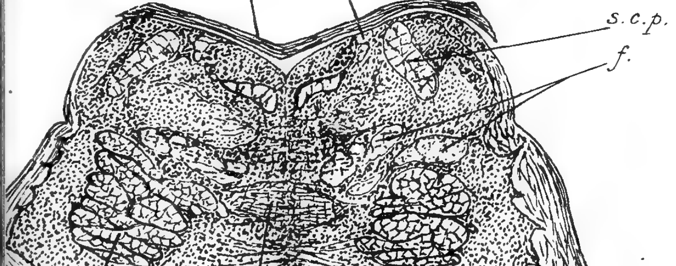

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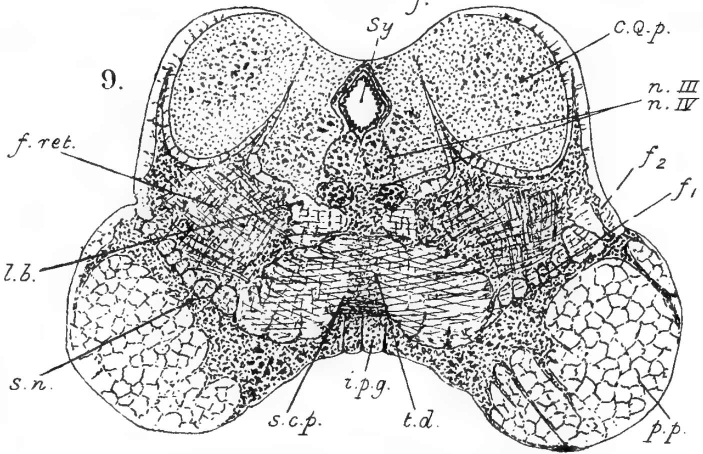

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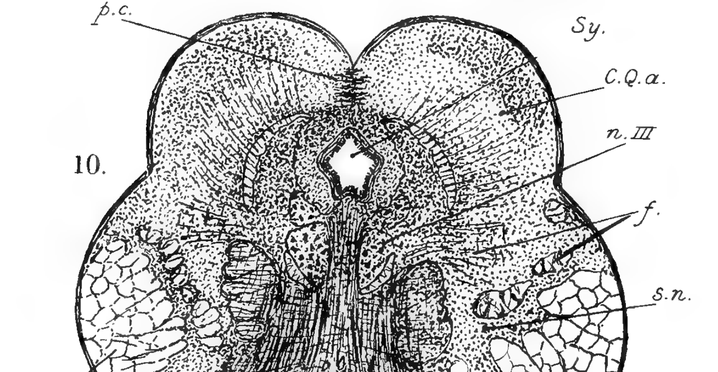

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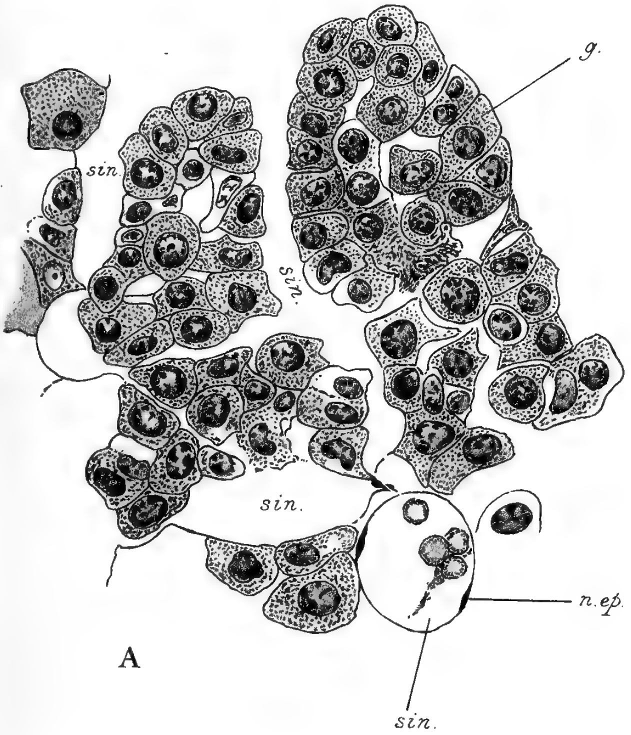
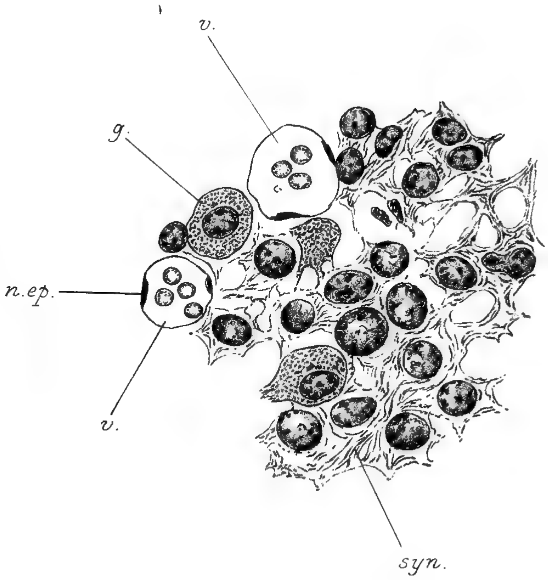
BRITISH MUSEUM
NATURAL HISTORY

HAIG: CENTRAL NERVOUS SYSTEM OF THE WEDDELL SEAL—PLATE II.



A



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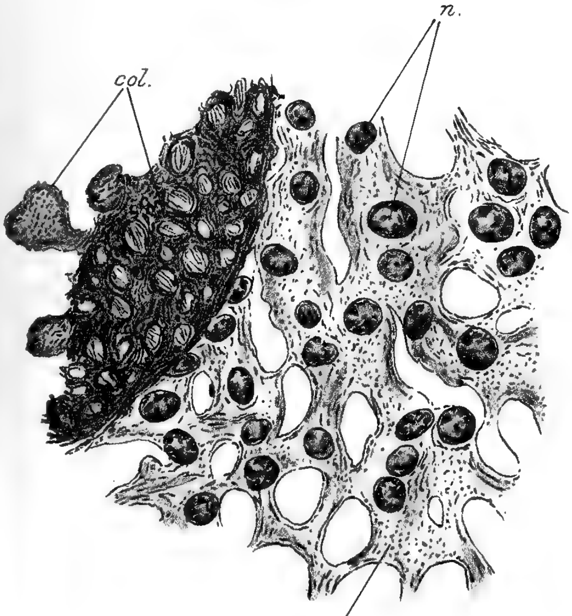

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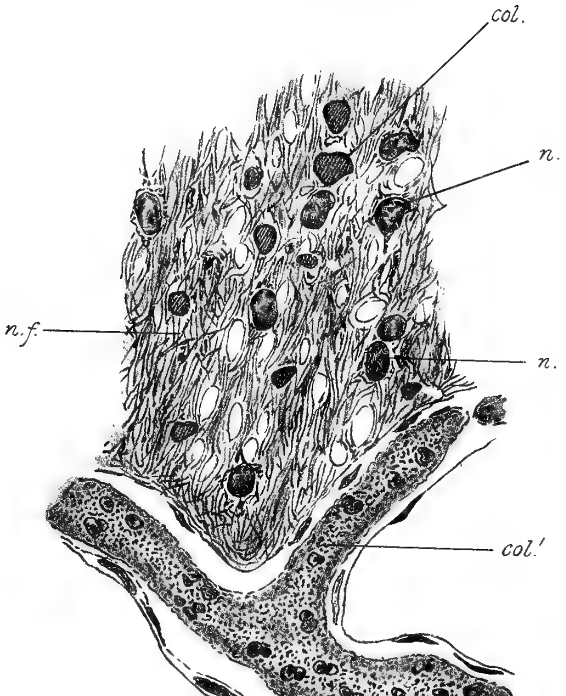

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XXXII.—Jurassic Plants from Cromarty and Sutherland, Scotland.

By **A. C. Seward**, M.A., F.R.S., Professor of Botany, Cambridge; and **N. Bancroft**, B.Sc., F.L.S., Newnham College, Cambridge. *Communicated by* Dr R. Kidston, F.R.S. (Plates I. and II.; text-figs. 1–6.)

(MS. received December 2, 1912. Read December 16, 1912. Issued separately February 19, 1913.)

Introduction.

In an account of the Jurassic flora of Sutherland, published in 1911,[*] it was stated that a few petrified specimens from Eathie Bay, Cromarty, and from Helmsdale on the coast of Sutherland, would be dealt with in a subsequent paper. One of the best preserved of them forms the subject of a recent communication to the Royal Society of London.[†] The majority of the specimens described in the following pages are from the Hugh Miller collection in the Royal Scottish Museum, Edinburgh. We take this opportunity of expressing our thanks to the Director of the Museum for the loan of the fossils, and for permission to have sections prepared for microscopical examination. For the loan of the section reproduced in Plate II. fig. 19 we are indebted to the generosity of Dr Kidston. Some pieces of petrified wood from Helmsdale, in the possession of the Geological Survey of Scotland, were kindly submitted to us for examination by Dr Horne. The specimen of *Thinnfeldia scotica* we owe to the courtesy of Dr Nathorst, by whom it was collected in 1883.

The Eathie plants are preserved in weathered calcareous nodules which were no doubt picked up on the beach by Hugh Miller, by whom they were assigned to a Liassic horizon; but, as Professor Judd has shown, there is no adequate reason for regarding the Cromarty fossils as different in age from the Kimeridgian plants from Culgower Bay, between Brora and Helmsdale.[‡] Several specimens of petrified wood from Helmsdale have been examined: some of these were collected by the late Dr Marcus Gunn, others were sent to us by Dr Horne, and a few pieces were obtained by one of us in 1910. The preservation of the material, though in some cases satisfactory, is frequently not sufficiently good to afford conclusive evidence as to systematic position. It is hoped that additional specimens may be obtained which will enable us to describe more species from the narrow strip of Jurassic strata which borders the Palæozoic hills of East Sutherland.

The preservation of the fossils with which we are now concerned is unfortunately far from satisfactory, and it is seldom possible to give more than an incomplete diagnosis of the species or to determine their affinities with confidence. The very small amount of petrified material available from Mesozoic strata is, however, an

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[*] Seward (11), p. 649.

[†] Seward (12).

[‡] Seward (11), p. 648.

adequate reason for placing on record such information as can be extracted from the imperfect specimens in our hands. Further search on the shores of Eathie Bay and in the neighbourhood of Helmsdale may enable us to make good some of the many deficiencies in the present contribution.

DESCRIPTION OF THE FOSSILS.

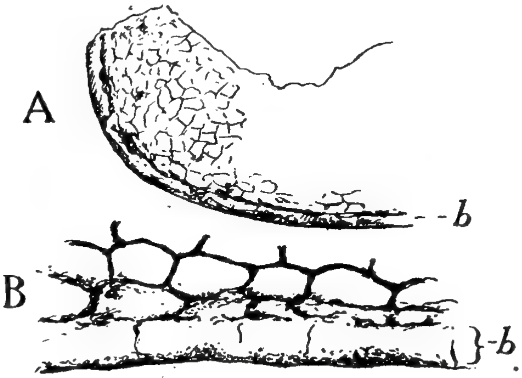
FILICALES or GYMNOSPERMÆ (?).

Thinnfeldia scotica sp. nov. (Pl. I. fig. 1; text-fig. 1.)

1911. *Thinnfeldia sp.*, *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 676, text-fig. 7.

We are indebted to Dr NATHORST for the photograph reproduced in fig. 1, Pl. I., and for a cuticular membrane of a single pinnule which on treatment with chlorate of potassium and nitric acid showed very clearly the form of the epidermal cells and stomata. The specimen was collected by Dr NATHORST near Helmsdale in 1883.

The linear segments, the lower margins of which are decurrent on the broad and flat axis, are characterised by short, bluntly rounded lobes, thick and straight epidermal cell-walls, by the occurrence of numerous scattered stomata occupying two broad strips on the lower surface of the lamina, and by the presence of a cuticular border (·05 mm. broad) at the edge of each leaflet (text-fig. 1, A, B). The middle region of each pinnule is occupied by a broad band of elongated cells, and on either side of this the epidermis consists of smaller polygonal cells which are not elongated parallel to the long axis of the pinnule. The stomata show no tendency towards regular arrangement in rows: each pair of guard-cells is enclosed by five or six cells as in Rhætic species of *Thinnfeldia* described by SCHENK [*] and other authors. It is noteworthy that the stomatal guard-cells with the enclosing auxiliary cells bear a closer resemblance to those of Gymnosperms than to the stomata of Pteridophytes; in size they agree more closely



TEXT-FIGURE 1.—*Thinnfeldia scotica* sp. nov. Cuticle showing cell outlines and the thick broad cuticularised marginal band.

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[*] SCHENK (67), pl. xxvi. figs. 4–8; pl. xxvii. figs. 8, 11, 12.

with those of Conifers than with the larger stomata of Cycads. The marginal band (text-fig. A, B, *b*) resembles that in some larger specimens referred to *Thinnfeldia rhomboidalis* Ett. from English Liassic strata,* and, though much narrower, is comparable with the thickened margins of the pinnules of Jurassic species assigned to the genus *Lomatopteris.* In *Thinnfeldia scotica*, as in the English *T. rhomboidalis*, the dark marginal band is simply the thickly cuticularised epidermal layer at the edge of the lamina, and is not due to any folding over of the pinnules. The lines traversing the marginal band seen in text-fig. 1, B, are breaks in the membrane and not cell-walls.

In habit, Dr NATHORST's specimen resembles *Thinnfeldia incisa* Sap.,† a French Liassic species, but it differs, apparently, in the absence of lateral veins.

Dr GOTHAN‡ has recently instituted a new generic name *Dicroidium* for such forms as *Thinnfeldia odontopteroides* (Morr.); this southern-hemisphere type GOTHAN distinguishes from the true Thinnfeldias for the following among other reasons: in *Dicroidium* the frond is forked, the epidermal cell-walls are thin and undulate, the stomata are scattered and not enclosed by accessory cells as in *Thinnfeldia.* It is by no means unlikely that the southern species *Thinnfeldia odontopteroides* is a well-defined type distinct from European examples of *Thinnfeldia*, but for the present we prefer to suspend judgment as to the validity of the arguments advanced by Dr GOTHAN in favour of the institution of a new generic name. In the Scotch fragment the stomata are scattered and not in rows, a character associated by GOTHAN with *Dicroidium*, though it may well be the case that the arrangement in rows is not a constant feature in *Thinnfeldia.* It is, moreover, open to question whether the European *Thinnfeldia* fronds are always unbranched: a specimen previously described from Sutherland§ as a piece of *Thinnfeldia* exhibits a form of branching like that of *T. odontopteroides*, though it must be admitted the reference to *Thinnfeldia* rests on unsatisfactory evidence. Whether or not Dr GOTHAN's conclusions are confirmed by fresh discoveries, his critical examination of the impressions hitherto included in *Thinnfeldia* is a very welcome contribution. The evidence at present available is inadequate to enable us to define with confidence either the systematic position of the fossils referred to *Thinnfeldia*, *Dichopteris*, *Lomatopteris*, etc., or to make any definite statements as to the value to be attached to the generic distinctions implied by the use of these different designations for fronds of the *Thinnfeldia* type, whether simple, forked, or tripinnate.

CONIFERALES.

Brachyphyllum eathiense sp. nov. (Text-fig. 5, A, Pl. I. figs. 2–4.)

1857. "Imbricated stem," Miller, *Testimony of the Rocks*, p. 491, fig. 149.
1911. *Brachyphyllum sp.*, Seward, *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 683, pl. ix. fig. 33.

The specimen from Eathie, figured by MILLER half natural size, though very incompletely petrified, reveals on microscopical examination certain features worthy of

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* SEWARD (04), pl. iv. figs. 1–3.

† SAPORTA (73), pl. xlii.

‡ GOTHAN (12); see also GOTHAN (12^2).

§ SEWARD (11), p. 678; pl. vii. fig. 14.

description. The branched shoot, 1 cm. in diameter, contains a crushed stele, approximately 1·5 mm. broad, separated by an irregular space from the partially preserved broadly triangular imbricate leaves some of which show on the exposed face numerous small longitudinal ridges such as characterise the foliage of many *Brachyphyllum* * and *Pagiophyllum* † shoots. These ridges no doubt mark the position of hypodermal strands (*cf.* fig. 4, Pl. I.). The shattered xylem shows some spiral bands on the innermost tracheides, but no pits have been recognised on the walls of the metaxylem elements. The medullary rays appear to be one-cell deep. The pith consists of parenchyma with a few scattered thick-walled cells.

The short fleshy leaves have a well-protected epidermis succeeded by a compact tissue of cells elongated at right-angles to the surface, many of them containing a dark-brown substance; occasional groups of elongated thick-walled cells occupy a hypodermal position (fig. 4). The rest of the mesophyll is composed of imperfectly preserved parenchyma including a few large elements with dark contents, probably secretory sacs, and an occasional piece of a leaf-trace. The most striking feature is the occurrence of groups of reticulately pitted isodiametric tracheæ (figs. 2–4, *t*) identical with the transfusion tracheæ in the leaves of recent Conifers. As seen in fig. 4, those tracheæ groups bear a very close resemblance to the transfusion elements in the leaves of existing species of *Araucaria*,‡ especially in the upper part of the leaves, where the short tracheæ replace the water-conducting tracheides. In the piece of lamina shown in fig. 2, Pl. I., the transfusion tracheæ form a continuous band, *t*, abutting on the palisade tissue, *p*, and internal to this is a very imperfectly preserved vascular strand. In the longitudinal section represented in fig. 3, the thick-walled epidermis is succeeded by a single layer of hypodermal cells and short palisade tissue; the greater part of the mesophyll is destroyed, but there are a few groups of transfusion tracheæ, *t*, and portions of strands of long and narrow tracheides. There are cells with dark contents in the pith and in the mesophyll of the leaves, but, with the exception of a secretory duct near the outer edge of the xylem, as seen in longitudinal section, no well-defined canals have been detected; but this may be due to imperfect preservation of the tissues. Three groups of transfusion tracheæ are seen at *t*, fig. 4, and in another leaf five such groups occur. In a few leaves in which the superficial tissues are cut tangentially, stomata are clearly shown (text-fig. 5, A, p. 884), and it is interesting to find that they bear a very close resemblance to those of *Brachyphyllum macrocarpum* described by JEFFREY.§ In both species there appear to be four accessory cells surrounding the guard-cells.

The Eathie specimen agrees in many respects with *Brachyphyllum macrocarpum* Newb. as described by HOLLICK and JEFFREY from strata in Staten Island referred to a Middle Cretaceous horizon. The leaves are of the same form and agree in certain anatomical features. Strands of hypodermal cells occur in both species, also palisade

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* HOLLICK and JEFFREY (09), pl. ix.

† SEWARD (04), pl. v. fig. 3.

‡ BERNARD (04), figs. 87, 88; SEWARD and FORD (06), fig. 20, p. 349.

§ JEFFREY (10), pl. lxv. figs. 5–8.

tissue, though this is more prominent in *B. eathiense.* Transfusion tracheæ are abundant in the American type, though they do not appear to form such well-defined groups as those shown in fig. 4; it is noteworthy, however, that HOLLICK and JEFFREY [*] speak of the transfusion tracheæ as forming a continuous band, as is the case in the leaf reproduced in fig. 2.

The leaves of the *Brachyphyllum eathiense* possess certain features in common with those of *Yezonia vulgaris*, a species described by Dr STOPES and Dr FUJII [†] from Upper Cretaceous strata of Japan, and regarded by them as the type of a new family for which they proposed the name Yezoniaceæ. It has, however, been shown by JEFFREY [‡] that the Japanese species should be referred to the genus *Brachyphyllum*, and with this conclusion Dr STOPES [§] has expressed her agreement.

Attention has already been called to the resemblance of the leaves of *B. eathiense* as regards the groups of transfusion cells to those of some recent species of *Araucaria.* There is no indication in the *Brachyphyllum* leaves of any of the large sclerous idioblasts which form so conspicuous a feature in those of recent Araucarias, and it is hardly likely that their absence is the result of partial preservation of the tissues. In the absence of any information as to the pitting of the metaxylem elements we cannot speak with confidence as to the degree of affinity with recent Araucarieæ, though in view of the agreement of the leaf-structure with that of *Brachyphyllum macrocarpum*, in which Araucarian pitting has been demonstrated, it is highly probable that *B. eathiense* is more closely related to *Araucaria* than to any other existing genus.

Taxites Jeffreyi Seward. (Pl. I. fig. 5.)

1857. "Conifer twig," Miller, *Testimony of the Rocks*, p. 473, fig. 131, A.
1911. *Taxites Jeffreyi*, Seward, *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 688, pl. v. fig. 73.

MILLER's specimen consists of an axis bearing branches with spirally disposed linear leaves of the *Taxites* type, this designation being used in a wide sense as embracing leafy shoots with leaves like those of the Taxaceæ, species of *Podocarpus*, and some other Conifers. In habit the branches agree closely with *Stachyotaxus*,[||] a genus founded on the characters of the inflorescence.

The main axis, 3·5 mm. in diameter, has a xylem cylinder of two annual rings enclosing a pith of rather large parenchymatous cells some of which, as seen in longitudinal section, are slightly elongated in a transverse direction, while others are three or four times as long as broad. The pith may be described as consisting of a more or less regular alternation of a few layers of horizontally extended and vertically elongated elements. The bands of horizontally extended elements suggest comparison with the pith of *Abies magnifica*,[¶] in which bands of flat sclerous cells form transverse

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[*] HOLLICK and JEFFREY (09), p. 36.

[†] STOPES and FUJII (10), p. 23; pl. ii. figs. 5–8; pl. iii. fig. 9; pl. iv. fig. 19.

[‡] JEFFREY (10).

[§] STOPES (11).

[||] *Cf.* NATHORST (08), pl. ii. figs. 20–24.

[¶] JEFFREY (05), pl. iii. fig. 21.

diaphragms at fairly regular intervals. Professor JEFFREY, in describing similar diaphragms in *Araucariopitys*,[*] states that this feature is met with in the medullary regions of *Abies*, *Picea*, and certain species of *Pinus*. In the pith of *Taxites Jeffreyi* there is, however, no satisfactory evidence that the transversely elongated cell layers have thicker walls than the cells in the intervening layers. A few protoxylem elements show spiral bands, and on the radial walls of some of the metaxylem elements there is a single row of bordered pits [†] which are occasionally almost contiguous. The medullary rays, so far as can be ascertained from the very imperfectly preserved specimen, are 1–3 cells deep. In the crushed cortex are a few tangentially elongated oval spaces which may be referred to resin-canals—a feature opposed to a generic identity with *Taxus*. The cortex also contains some thick-walled cells, and the epidermis has strong outer walls.

In section the leaves are almost plano-convex, with a broad ridge in the middle of the flatter side (fig. 5, Pl. I.): there is a single median vascular bundle with a space below it which may be a resin-canal. There is no palisade tissue, and no clear indication of any hypodermal fibres. The leaf reproduced in fig. 5 is cut near the apex, and is much smaller than the average breadth of the lamina, which may reach 2 mm. The data are clearly inadequate to serve as a basis for precise determination of affinity; and it is impossible to say whether or not transfusion tracheides were abundant.

The general appearance of the leaf shown in fig. 5, though the preservation is too incomplete to admit of accurate comparison, agrees closely with that of a transverse section of a leaf of *Podocarpus andina*.

Masculostrobus Woodwardi sp. nov. (Pl. I. figs. 6–8.)

1857. Miller, *Testimony of the Rocks*, fig. 132, p. 475.
1911. *Masculostrobus sp.*, Seward, *Trans. Roy. Soc. Edin.*, vol. xlvii. p. 650.

The generic name *Masculostrobus* was recently proposed as a convenient designation for small Gymnospermous strobili affording evidence, "either by the presence of microspores or by their habit, of a microsporangial nature." [‡] In addition to the type species *M. Zeilleri* Sew., founded on a specimen in the Gunn collection of Sutherland plants, a second specimen from the same collection and the fossil figured by MILLER were spoken of as *Masculostrobus sp.* It is the Miller specimen with which we are now concerned. In view of the additional facts revealed by sections, though insufficient to settle beyond doubt the nature of the fossil, we replace *Masculostrobus sp.* by *M. Woodwardi*, the specific name being selected in acknowledgment of the valuable services of Mr H. B. WOODWARD in connection with the stratigraphy of the Jurassic rocks of N.E. Scotland. MILLER's figure of the Eathie fossil is fairly accurate, the

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[*] JEFFREY (07) p. 438; pl. xxix. fig. 10.
[†] No pits had been recognised when the former description of this specimen was written [SEWARD (11), p. 638].
[‡] SEWARD (11), p. 686.

specimen consists of a slender axis bearing three oval bud-like appendages approximately 1 cm. long and 5 mm. broad. Two of these appendages are shown in fig. 6. An examination of the upper strobilus, which was facilitated by the application of immersion-oil to the surface of the rock,* revealed the occurrence of several broadly triangular imbricate bracts (fig. 7), the laminæ of the lateral bracts (or sporophylls) being torn into ragged strips. Externally the appearance of the short branches is more suggestive of microstrobili than of vegetative buds. The centre of the strobilus examined is occupied by a pith of parenchymatous cells containing a thick-walled idioblast surrounded by the fragmentary remains of a cylinder of secondary wood. The rest of the section is made up of the partially preserved tissue of the bracts with a few pieces of vascular strands composed in part of spiral tracheides. The peripheral region consists of torn strips of tissue (*cf.* fig. 7). The general appearance of the sporophylls is suggestive of young organs of fairly homogeneous structure. In some of the imperfectly preserved sporophylls there are more or less spherical groups of apparently delicate cells which we are disposed to regard as immature sporogenous tissue (fig. 8, *a*). The section partially reproduced in fig. 8 shows a portion of the cortical tissue with several crowded sporophylls, but for the sake of clearness only one of these is represented; it consists of parenchymatous cells, many of which have dark contents, and the group of thinner sporogenous elements is seen at *a*.

The anatomical features, so far as they can be made out, favour the identification of the specimen as a branch of a conifer bearing immature microstrobili.

Conites Juddi sp. nov. (Text-figs. 2–4; Pl. I. figs. 9–12; Pl. II. figs. 14–21.)

The most puzzling specimens in the collection with which we are now concerned are some imperfectly petrified cones collected by Hugh Miller at Eathie Bay; they differ from one another in size, but agree generally in the form and structure of the cone-scales. While for the most part the tissues were partially destroyed before petrifaction, the preservation in some cases leaves little to be desired. We include all the specimens under one specific name, but for the sake of convenience the individual fossils are distinguished as varieties or "forms."

The species may be defined as follows:—Cones vary in size from 3 cm. long by 2·5 cm. broad (forma α, text-fig. 2, B) to 9 cm. long and 4 cm. diameter (forma β, text-fig. 2, C); they are almost spherical or elongate-oval in form. A thick axis bears spirally disposed thick scales attached by a comparatively slender base and expanded to a thick and bluntly terminated distal portion characterised by a slightly upturned and projecting upper margin (text-fig. 2, B, C; Pl. II. fig. 19). The scales are more or less cuneate or kite-shaped in surface-view, resembling the scales described by Heer and other authors as species of *Dammara*, and by Hollick and Jeffrey as *Protodammara*. They consist of parenchymatous tissue containing numerous thick-

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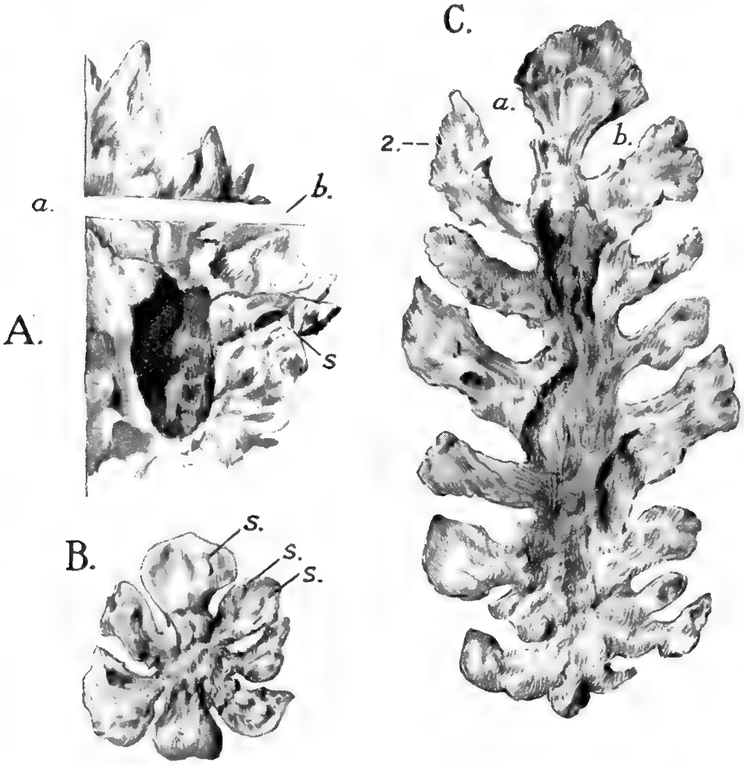
* A method adopted by Dr Halle of Stockholm.

walled idioblasts and large resin-canals; in some cases there is a superficial periderm and the parenchymatous tissue next the lower surface may assume a short palisade form. A single series of collateral vascular bundles traverses the scales in a radial direction and there are indications of the occurrence of concentric steles in the basal portions of some scales. The seeds, the number of which has not been determined, lie on the upper surface of the scales in a depression near the proximal end, and there is a ligular outgrowth close to the abaxial end of the seeds.



TEXT-FIGURE 2.—*Conites Juddi* sp. nov. Nat size. A, forma γ; B, forma α; C, forma β. (Drawn by M. SEWARD.)

Conites Juddi sp. nov. *forma α.* (Text-fig. 2, B; text-fig. 3.)

This smallest cone (approximately 3 cm. × 2·5 cm.), represented natural size in text-fig. 2, B, bears a comparatively small number of scales attached to a very imperfectly preserved axis with a small-celled parenchymatous pith surrounded by a partially destroyed xylem cylinder. The apical scale (text-fig. 2, B) illustrates the close resemblance in shape between the appendages of this cone and the detached scales referred by HEER* to the genus *Dammara* and some smaller forms made by HOLLICK and JEFFREY† the type of the genus *Protodammara*. On this scale, 1·3 × 1 cm., is an oval, slightly projecting body, *s*, at first sight thought to be a seed, but which is in all probability a piece of crystalline material filling a space in the substance of the

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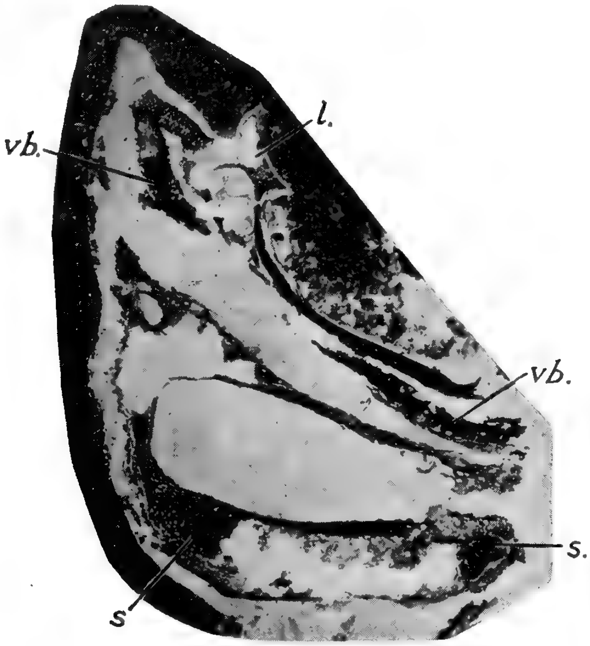
* HEER (82), p. 54, pl. xxxvii. fig. 5.

† HOLLICK and JEFFREY (09).

scale. There are three similar elevations on the scale to the right of the apex of the cone (text-fig. 2, B, *s*, *s*). The spaces, the filling material of which forms the elevations, *s*, are probably resin-cavities enlarged by decay; they correspond to the clefts containing an amber-like substance to which attention has been drawn by NEWBERRY * and other authors in the case of American examples of scales referred to *Dammara*. Similar patches of resin form a conspicuous feature in scales of the same form from Greenland.†

One of the scales, cut in an approximately median plane, shows (text-fig. 3) a large cavity and two dark patches of resinous (?) cells at *s*, *s*; above the cavity is a vascular strand (*vb*). The distal end is characterised by a short and broad apical portion in the base of which is a continuation of the vascular strand (*vb*). The two-pronged projection from the upper surface of the scale (*l*) is regarded as a ligular outgrowth; below this are irregular spaces. The depression on the adaxial side of the outgrowth we believe to have been occupied by a seed. Sclerous cells are abundant in the ground-tissue.



TEXT-FIGURE 3.—Cone-scale of *Conites Juddi*, forma *α*. × 6.

Forma β. (Text-fig. 2, C.)

This specimen, which, like forma *α*, is preserved in a weathered calcareous nodule from Eathie, has a length of approximately 9 cm., and is 4 cm. at its broadest part. As the preservation appears to be very imperfect, no sections have been prepared. A thick axis bears broad and deep sporophylls arranged in a lax spiral. The uppermost

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* HOLLICK and JEFFREY (09), p. 196.

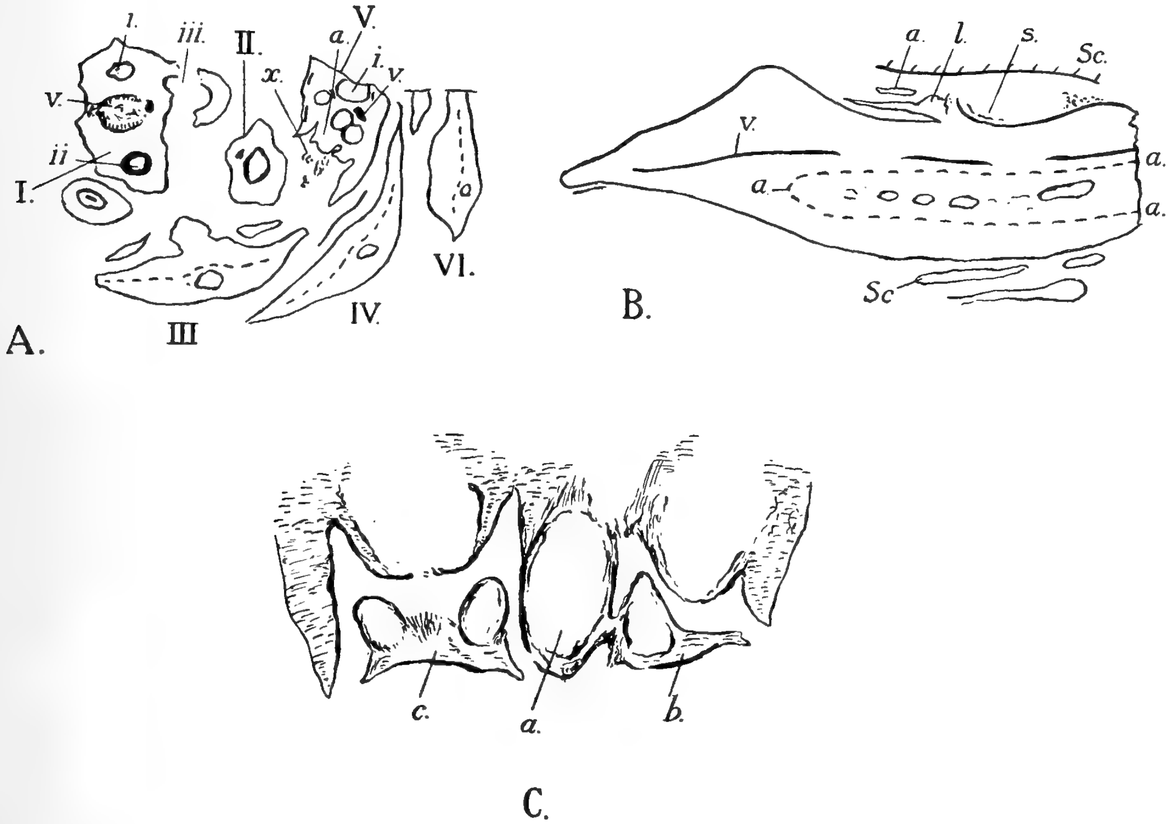
† Specimens of such scales were seen by one of us in Dr NATHORST'S collection, Stockholm.

sporophyll seen in surface-view has the same kite-shaped form as the smaller scales of forma α; the narrower basal portion is longitudinally striated and is separated from the rougher distal portion by a slight ridge, *ab*, formed doubtless by the tearing of the superficial tissue. The upper margin in the lower part of scale 2 corresponds in its well-defined striated surface with the inner portion of the apical scale. The absence of seeds and the open habit of the cone afford indications that the seeds had been shed, and that the sporophylls were persistent and not deciduous, as in the case of *Agathis*, *Cedrus*, and *Abies*.

Forma γ. (Text-figs. 2, A; 4, A, B; Pl. I. figs. 9–12; Pl. II. figs. 14–16.)

This is an imperfectly preserved cone (3 cm. × 2·3 cm.) with an axis approximately 1 cm. in diameter bearing thick, crowded, kite-shaped sporophylls. The boundary between the individual sporophylls and between them and the axis is ill-defined (text-fig. 4, A). The oval and slightly compressed body shown at *s*, text-fig. 2, A, is probably the cast of a seed lying on the upper surface and near the proximal end of the scale.

In the transverse section diagrammatically represented in text-fig. 4, A, cut along *ab*, text-fig. 2, A, the imperfectly preserved section I. at the left-hand upper corner of the whole includes two spaces, i. and ii., and between these a partially destroyed mass of vascular tissue, *v*. The vascular strand, which was probably cylindrical, may belong to the axis of the cone. The space i. is partially filled with a structureless yellow substance, and the large space ii. (enlarged in fig. 9, Pl. I.) is bounded by crushed tissue abutting on a broad band of radially disposed elements which we believe to be periderm, *p*, produced on the inner side of a cambium, *c*, and separating the decayed central region from the peripheral tissue. This periderm cylinder corresponds with the band of similar tissue shown in text-fig. 4, B, *a*, *a*, and in fig. 10, *a*, *a*, Pl. I. The imperfectly preserved tissue shown at *v* in fig. 9 is part of the vascular cylinder, *v*, of text-fig. A. The space ii. (text-fig. 4) is, we believe, the central region of a partially preserved sporophyll which is cut across by the section transversely and close to its base, where it becomes continuous with the axis of the cone. Similarly, the spaces i. and iii. occur in other sporophyll bases in intimate association with the cone-axis (*cf.* the lower part of fig. 19, Pl. II.). The detached sporophyll II. is cut across transversely near its proximal end; the central space, shown on a larger scale in fig. 12, is bound by crushed tissue, including a few traces of periderm occupying the position of the much broader periderm band in fig. 9. At *v*, fig. 12 (shown also in text-fig. 4, A, II.), is an imperfect xylem strand, the form of which suggests a concentric vascular bundle. A band of periderm occurs close to the surface of the sporophyll at *p*, *p*. Figs. 9 and 12 represent transverse sections of sporophylls like that shown in longitudinal section in text-fig. 4, B, and in fig. 10. The sporophylls III., IV., and VI. in text-fig. 4, A, are cut across in a more or less transverse direction further from the cone-axis; in these as in the other sporophylls the ground-tissue consists of parenchyma with numerous thick-walled fibres. Sporophyll IV., shown on a large scale in fig. 14, has lateral wings and a broadly rounded ridge in the middle of the upper face (*a*, fig. 14); the dark line at the sides of the area *a* is the result of crushing of the parenchymatous tissue. The thick fibres or idioblasts, *f*, are clearly seen in the more highly magnified photograph of the area *a* reproduced in fig. 15. An almost continuous line of vascular strands is seen stretching across the cone-scale at *v*, fig. 14; the xylem appears to be normally orientated, the protoxylem being next the upper surface; but the preservation is very imperfect. Below the vascular strands is a median space, and some palisade parenchyma occurs next the lower surface similar to that shown in fig. 16.



TEXT-FIGURE 4.—*Conites Juddi*. A, transverse section (diagrammatic) along the line *ab*, text-fig. 2, A, of forma γ; B, radial section of the cone-scale of forma γ, reproduced in fig. 10, Pl. I.; C, diagrammatic sketch of part of cone-scale E of forma δ, reproduced in fig. 19.

Cone-scale III. (text-fig. 4, A) is similar to IV., but the ridge in the middle of the upper face is much more prominent. In cone-scale VI. also the structure of the ground-tissue is very clearly preserved; the line of vascular bundles is seen stretching across the scale, and a space is present like those in scales III. and IV.

Cone-scale V. (text-fig. 4, A) is cut obliquely; there is a large space i. and three smaller spaces separated from it by some crushed and partially destroyed vascular tissue, *v*, some of which appears to have a concentric arrangement. This scale is similar in structure to that from another cone, shown in fig. 17, Pl. II. Some periderm occurs on the edge of the scale. A broad ridge, *a*, projects from the inner (upper) face of the scale, separated by a narrow sinus on each side from the rest of the cone-scale; this ridge we believe to be a ligular outgrowth, the relation between the ridge and the rest of the scale being very similar to that in a recent Araucarian sporophyll. The three cavities below the ridge *a* bear a close resemblance to the large resin-canals which occur in a similar position in a transverse section of a cone-scale of *Araucaria Cookii.*

Close to the cone-scale V. there are some obscure fragments of tissue (*x*, text-fig. 2, A) with which are associated a few spores of triangular form and with smooth walls, also some tubular hypha-like cells; these spores and tubes may be pollen-grains and tubes, or they may be portions of a fungus.

Text-fig. 4, B, and fig. 10, Pl. I., represent an almost complete cone-scale in radial longitudinal section, 1·7 cm. long. Above the broken apex the upper surface forms a rounded prominence and then dips downwards to the attachment of the ligule at *l*, beyond which is an oval depression, *s*, which was most probably occupied by a seed. This portion of the scale is more clearly seen in fig. 11. The upper strip of tissue at *a* (fig. 11, and text-fig. 4, B) is a detached portion of the ligule, and at *Sc* (text-fig. 4, B) is the lower edge of another cone-scale. A vascular strand (*v*, fig. 10) extends through the greater part of the scale, the protoxylem being on the upper margin. Indications of bordered pits are visible on the walls of some of the lower tracheides; these occur in a single row, and though close together are not actually in contact. In one place there is an indication of contact of the pits. The epidermis has thick outer walls, and idioblasts are abundant in the ground-tissue (*f*, fig. 16). A band of periderm (*a*, text-fig. 4, B, and fig. 10) encloses an oval area occupied by crushed and disorganised tissue. It is this area which is shown as a space bounded by periderm in the transverse section reproduced in fig. 9. The hypodermal tissue next the lower surface is characterised by a well-marked palisade-like arrangement of the cells (fig. 16).

Forma δ. (Text-fig. 4, C; Pl. II. figs. 17–21.)

The fourth form of cone, which agrees closely with the more compact type (text-fig. 2, A, B), is represented by an oblique longitudinal section (4·5 × 3·5 cm.) in Dr Kidston's collection, cut from one of Miller's specimens. The secondary xylem, *x*, fig. 19, enclosing a small-celled pith, is not sufficiently well preserved to afford any information as to the nature of the pits on the tracheal walls. The cone-scales exhibit several of the features already described; thick-walled idioblasts are abundant in the imperfectly preserved ground-tissue, the lower epidermis is succeeded by palisade-like cells (as in fig. 16), and a large space occurs in the proximal half of each cone-scale. Cone-scale A, fig. 19, enlarged in fig. 21, is cut in an approximately median radial plane; a vascular strand, *v*, occurs between a large lower space and a smaller upper space; the ligular outgrowth is seen at *l*. No seeds are preserved, but what is believed to be the position of the seed is shown at *s* on the adaxial side of the ligule. Sporophyll B, fig. 19 (enlarged in fig. 17), is cut across in an obliquely transverse direction; the large space is seen to the left, and above it are smaller spaces with part of the ligule at *l*. The section reproduced in fig. 18 (C, fig. 19) shows the large central space with vascular bundles above at *v*, and several smaller spaces in the broadly arched superficial region which is regarded as the ligule (*cf.* *c* and *b*, text-fig. 4, C). Both this scale and that shown in text-fig. 4, A (scale V.), agree very closely, in the occurrence of large resin-canals near the upper surface, with the scales of *Araucaria Cookii.* Cone-scale E, fig. 19 (part of which is diagrammatically represented in text-fig. 4, C), is cut obliquely and approximately parallel to the upper face; there is an oval projection enclosing a space (*a*, text-fig. 4, C) in the middle of the broad end, and to one side of this is attached a strip of tissue, *b*, containing a smaller space; the detached piece *c* (text-fig. 4, C) no doubt also belongs to the median projection. The median projection and the lateral pieces (*b* and *c*) probably belong to the ligule and correspond with the upper part of the cone-scale shown in fig. 18, which is characterised by a row of spaces.

The cone-scales at the lower end of the axis (fig. 19), which are cut close to their proximal ends, are of the same type as those represented in figs. 9 and 12. In the cavity of the cone-scale D, fig. 19 (shown on a larger scale in fig. 20), there is a delicate structure, *a*, with incurved ends and below it a smaller V-shaped body, *b*; these two bodies may be sections of one structure bent on itself like a folded embryo. A single V-shaped body identical with *b* in fig. 20 is seen in the large space at *a* in fig. 17. We are unable to interpret these peculiar structures; if the large cavities in the cone-scales were homologous with the seed-containing portion of an Araucarian sporophyll, it might be reasonable to regard the enclosed structures as portions of the seeds, possibly of the embryos; but if our interpretation of the cavities as spaces in the cone-scales below the vascular strands, which are not connected with the seeds, is correct, the bodies shown in figs. 17 and 20 are in all probability the remains of some foreign organism.

Affinities of Conites Juddi.

The large form of *Conites Juddi* (forma β, text-fig. 2, C) is similar in habit to some strobili from the Bunter Sandstone of the Vosges, referred by SCHIMPER and MOUGEOT to *Voltzia heterophylla,*[*] and the cone-scales may be compared also with those of POTONIÉ's genus *Voltziopsis,*[†] but there is no evidence of actual affinity between the Scotch cones and those of Triassic and Permian age which present a superficial resemblance to them. A closer similarity, especially as regards the form of the cone-scales, is afforded by a Lower Cretaceous species, *Fricia nobilis,*[‡] described by VELENOVSKY from Bohemia; it is by no means unlikely that in this case there may be a relationship

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[*] SCHIMPER and MOUGEOT (44), pl. xvi.

[†] POTONIÉ (99), p. 303.

[‡] VELENOVSKY (85), pl. iii., especially fig. 3.

underlying the external similarity. The reasons given by VELENOVSKY for regarding the sporophylls of *Fricia* as microsporophylls do not appear to be convincing, and in the absence of microsporangia attached to the peltate appendages of the cone it would seem much more probable that the scales originally bore seeds.

The smaller and more spherical cone figured by VELENOVSKY * as *Sequoia fastigiata* (Sternb.), and similar cones referred by HEER and other authors to *Sequoia*, agree fairly closely in habit with the smaller Eathie specimen (text-fig. 2, B), but this agreement is not confirmed by a comparison of the cone-scales of *Conites Juddi* with those of existing species of *Sequoia*. Similarly, the anatomical features exhibited by the cone-scales of *Cunninghamia sinensis* do not afford any satisfactory evidence of relationship between *Cunninghamiostrobus yubariensis*,† described by Drs STOPES and FUJII from Upper Cretaceous rocks of Japan, and *Conites Juddi*.

In several respects the cone-scales of *Conites Juddi* resemble those of *Protodammara speciosa* described by HOLLICK and JEFFREY from Middle Cretaceous rocks of Kreischerville, New York.‡ The generic name *Protodammara* was instituted by these authors for detached kite-shaped scales 4–6 mm. long and 4–6 mm. broad, identical in shape, though smaller in size, with scales previously assigned by HEER to the genus *Dammara*. In view of the additional information supplied by the lignitic American specimens, a new generic designation was wisely instituted for *Dammara*. It is, however, questionable whether such a name as *Protodammara* is appropriate, implying as it does that in these Cretaceous fossils we have a type which is the ancestral or earliest form of the existing genus *Dammara* (*Agathis*). We do not dispute the correctness of the conclusions of HOLLICK and JEFFREY in regard to the probable relationship between *Protodammara* and *Agathis*; but it is by no means clear that the Cretaceous sporophylls, each bearing three seeds, are more primitive than the single-seeded sporophylls of recent species, and we are far from believing that they represent the "first" form of sporophyll exhibiting evidence of affinity with existing members of the Araucarieæ. In size the sporophylls of *Protodammara speciosa* are much smaller than those of *Conites Juddi*, but other scales of the same form, of which nothing is known as to their anatomy, have been described by HEER from Greenland, and by other authors from American localities.§ The Scotch and Kreischerville sporophylls agree in the presence of large resin-canals, in the abundance of thick-walled idioblasts, and in other anatomical features. The Cretaceous scales referred to *Dammara* and *Protodammara* occur singly and were almost certainly deciduous, while in *Conites Juddi* the scales remained attached to the cone-axis; the presence of a ligule in the Scotch sporophylls is another distinguishing feature. In *Protodammara* the scales have a double vascular supply like that of recent cone-scales; in those of *Conites Juddi* we have not discovered any inversely orientated vascular bundles above the main vascular

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* VELENOVSKY (85), pl. xi. fig. 1.

† STOPES and FUJII (10), p. 45, pl. v. fig. 27.

‡ HOLLICK and JEFFREY (06), p. 199; HOLLICK and JEFFREY (09), p. 46, pls. iv., x., xiv., xv., xvi.

§ For references see HOLLICK and JEFFREY (09).

supply, though this difference may be due to imperfect preservation. We have, unfortunately, no satisfactory evidence in regard to the number of seeds borne on the sporophylls of *Conites Juddi*, though such data as are available suggest that one or probably more small seeds were attached to the upper face of the thick sporophylls between the free end of the ligule and the cone-axis. In the case of the American specimens there is a strong probability that the xylem tracheides possessed the Araucarian type of pitting such as is clearly shown in the elements of the wood (*Brachyoxylon*) associated with the cone-scales; the few pits we have detected in the case of the Scotch cones do not appear to be typically Araucarian, but on the other hand it is worthy of note in this connection that the xylem elements in the cone-scale of *Agathis* are frequently characterised by the presence of spiral bands in place of the typical Araucarian pits.

In the presence of a ligule and in the general anatomical features the Eathie cone-scales closely resemble those of recent species of *Araucaria, e.g. A. Rulei.* The chief difference would seem to be the occurrence of the seeds above the sporophyll in the fossil species, as in *Agathis*, instead of being enclosed in the tissues of the scales as is the case in *Araucaria*; in other words, characters now met with in *Araucaria* and *Agathis* respectively are combined in the sporophylls of *Conites Juddi.*

The result of a comparison of the fossil sporophylls with those of the recent Araucarieæ and with the scales of *Athrotaxis*, *Cunninghamia*, *Sequoia*, and other genera is that we consider them to agree more closely with the Araucarian type of sporophyll than with those of any other recent genus. The apparently small size of the seeds and their relation to the ligular outgrowth, as well as the occurrence of separate bordered pits on the tracheides, suggest comparison with such a recent genus as *Cunninghamia*, though the structure of the scales is more like that of Araucarian sporophylls. The combination of features which are now distributed among different genera is to be expected in extinct types belonging to evolutionary stages anterior to the divergence of generic characters along independent lines. The occurrence in certain fossil woods of a mixture of Abietinean and Araucarian characters is regarded by Professor JEFFREY as evidence in favour of the thesis which he vigorously maintains, that the Abietineæ are older and more primitive than the Araucarieæ. In itself such combination affords general support to the view that the Abietineæ are a more specialised and a more recently evolved family than the Araucarieæ. We are not concerned at the moment with the general problem of the relative position of different sections of the Coniferales in an evolutionary series, but we would draw attention to the necessity of a careful and impartial examination of the foundations on which Professor JEFFREY bases his contention. We believe that the teaching of comparative morphology and palæobotany supports the view that in the Araucarieæ we have the oldest and most primitive members of the Coniferales.

Strobilites Milleri sp. nov. (Pl. I. fig. 13.)

The fossil represented in fig. 13 is very obscurely preserved on a piece of limestone in the MILLER collection, said to have been found at Helmsdale. Whether or not it was obtained actually at Helmsdale it is certain that the specimen is from the Upper Jurassic rocks of the Sutherland coast. It is associated with an impression of *Sagenopteris Phillipsi* (Brongn.) and a few other plant fragments. MILLER's fig. 150 (*Testimony of the Rocks*, p. 493) possibly represents this specimen, though it is far from accurate; no description accompanies the illustration.

A slender axis 8·5 cm. long bears numerous broadly oval bodies, 6 mm. long and 5 mm. broad, which appear to be spirally disposed. These sessile appendages we believe to be seeds. Each shows a more or less distinct differentiation into an inner portion limited by a slightly raised rim and an outer flat border which is much reduced in breadth at the apex. It may be that the inner portion is the impression of the hard woody shell of the seed, while the border represents a fleshy outer covering. Another possible interpretation is that each oval body is a seed in intimate association with a fertile bract. The preservation is, unfortunately, very imperfect, and a careful examination of the specimen was necessary to enable the artist to produce the drawing reproduced in fig. 13. It is but fair to add that Mr BROCK's drawing is a faithful rendering of the original.

Among previously described fossils bearing a fairly close resemblance to the Helmsdale species, some Rhætic specimens from Scania, described by NATHORST as *Stachyotaxus elegans*,* are worthy of special consideration. This Rhætic species is founded on shoots bearing two-ranked linear leaves very like those of *Taxites Jeffreyi*, while on other shoots of the same plant the leaves are much smaller and more or less closely appressed, a combination of vegetative characters which finds a close parallel in some recent species of *Dacrydium* and *Podocarpus*. The fertile shoots of *Stachyotaxus* reach a length of 12 cm. and bear spirally disposed bracts or carpellary leaves having two seeds, each of which is enclosed at the base by a cup-like cupule or epimatium. NATHORST thinks it probable that some of the bracts bore only one seed. He compares *Stachyotaxus elegans* and another species, *S. septentrionalis* (Agardh), with the recent species *Podocarpus spicata*, and believes that they are allied to *Dacrydium*. Miss GIBBS,† in a recently published paper on the Podocarps, agrees with NATHORST's view as to an affinity between *Stachyotaxus* and *Dacrydium*. A much more imperfect specimen from the Rhætic beds of Persia is referred by SCHENK ‡ to *Stachyotaxus septentrionalis*.

A comparison of the Sutherland fossil with the female spike of *Podocarpus spicata* § lends some support to the view that both *Strobilites Milleri* and *Stachyotaxus* are fertile shoots of conifers more closely allied to the Podocarpoideæ than to any other existing conifers.

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* NATHORST (08), pl. ii.

† GIBBS (12), p. 529.

‡ SCHENK (87), p. 9, fig. 2.

§ PILGER (03), p. 66, fig. 11.

The specimen described by Heer from Lower Cretaceous strata of Greenland as *Phyllocladites rotundifolius*[*] bears a close resemblance to *Strobilites Milleri*, but a more accurate drawing, published by Nathorst,[†] of Heer's type-specimen, which is referred by him to the genus *Drepanolepis*, largely destroys the impression of affinity to our fossil suggested by Heer's figures. The organs described by the latter author as seeds are regarded by Nathorst as the thickened bases of sickle-shaped, leaf-like organs. Reference may also be made to a fossil figured by Dunker[‡] from the Quadersandstein of Germany as a fruit-spike possibly belonging to the Dicotyledonous genus *Credneria*, which presents a fairly close resemblance to the Scotch specimen.

Strobilites Milleri, though too imperfectly preserved to be diagnosed with any degree of certainty, may perhaps be best described as a lax spike of sessile seeds agreeing closely in habit and in size with a megastrobilus of *Podocarpus spicata*.

We have adopted the non-committal designation *Strobilites*[§] in preference to *Stachyotaxus*, as the data are insufficient to justify the use of the latter name.

Cedroxylon Hornei sp. nov. (Pl. II. figs. 22-25; text-fig. 5, B–F.)

This species is founded on a piece of stem, 5 cm. in diameter, from Helmsdale on the Sutherland coast, which was sent to one of us by Dr Horne from the collection of the Scotch Geological Survey. The specimen consists of a portion of the wood with three small knots on the exposed and irregularly fractured surface. In a transverse section 2 cm. in breadth from the centre to the edge at the broadest part, rings of growth are very clearly shown (fig. 25); these vary considerably in breadth; in some of the rings there is a gradual decrease in the diameter of the tracheides extending through several rows, while in places the transition from spring to summer wood is much more abrupt and only three or four rows of tracheides are affected. Occasionally a band of narrower tracheides extends over only part of the circumference. The transverse section as a whole affords a striking illustration of spasmodic breaks and irregularities in the succession of seasonal periods, and furnishes clear evidence of climatic changes affecting the cambial activity. Similar irregularities in the breadth of the rings of growth and the occurrence of partial rings are described by Dr Barber in a Wealden species, *Cupressinoxylon vectense*.[||] This author gives several references to similar instances of cambial vagaries in other types of coniferous wood.[¶] The pith consists of more or less spherical cells with intercellular spaces, and the perimedullary zone is composed of rather smaller elements. The wood consists almost exclusively of tracheides, but there are some parenchymatous xylem elements in vertical series (text-fig. 5, B). The bordered pits, approximately 20μ in diameter, are usually in single rows, frequently separate (fig. 22), but occasionally

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[*] Heer (75), p. 124, pl. xxxv. fig. 17.

[†] Nathorst (97), p. 43, pl. vi. figs. 24, 25.

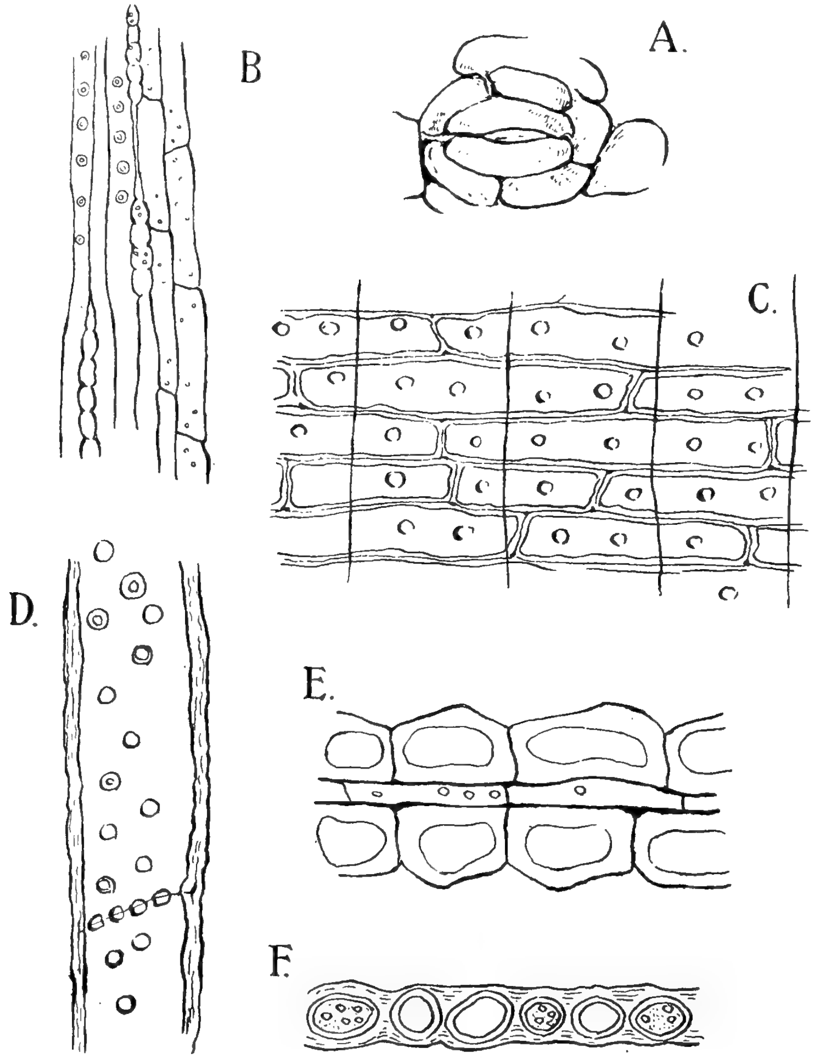
[‡] Dunker (56), pl. xxxv. fig. 1.

[§] Schimper and Mougeot (44), p. 31.

[||] Barber (98).

[¶] See also Seward (96).

in contact and flattened (figs. 23, 24). Double rows of opposite pits are not infrequent (fig. 23), and on some tracheides there is an alternation of double and single pits (fig. 22). A few pits occur in single rows, both separate and in contact but not flattened, on the tangential walls of summer elements (text-fig. 5, B.). The medullary rays vary from 1 cell to 26 cells in depth, though for the most part they are about 8–12 cells deep and always one row in breadth. There are two to four, most frequently two, simple or faintly bordered and approximately circular pits (text-fig. 5, C) on each field;* in a few places we have detected small pits on the horizontal walls of the medullary-ray cells (text-fig. 5, E) and on the tangential walls (text-fig. 5, F).†



TEXT-FIGURE 5.—A, Stoma of *Brachyphyllum eathiense* sp. nov.; B–F, *Cedroxylon Hornei* sp. nov.

The xylem-parenchyma appears to be confined to the region of the summer

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[*] We use this term for the area limited above and below by the walls of the medullary-ray cell and laterally by the vertical walls of the tracheides [" Kreuzfeld," GOTHAN (05)].

[†] *Cf.* GOTHAN (05), p. 43, fig. 76.

tracheides; the slightly oblique transverse walls are pitted, and partially bordered pits are scattered over the vertical walls (text-fig. 5, D).

The value of anatomical features as criteria for the determination of fossil coniferous wood is exceedingly difficult to estimate, and even in the case of well-preserved material it is often impossible to speak with confidence as to generic position. In recent years considerable additions have been made to our knowledge of the anatomy of both recent and fossil conifers, particularly in regard to such diagnostic characters as the pitting of the medullary-ray cells, the distribution of xylem-parenchyma, the amount of variation in regard to the arrangement of pits on the walls of the tracheides, and other characters. The investigations of Dr GOTHAN of Berlin, of Professor JEFFREY and his school, and of Professor LIGNIER are especially noteworthy; whatever views may be held as to the theoretical opinions based on structural features, the work accomplished by these observers has added considerably to the scientific possibilities of this difficult branch of palæobotanical research.

The features exhibited by the Helmsdale wood suggest comparison with the genus *Cupressinoxylon* of GOEPPERT and with *Cedroxylon* Kraus, as emended by GOTHAN.* The arrangement of the bordered pits on the tracheide-walls is of the type met with in both these genera,† but in the Abietineous pitting, that is, the occurrence of small pits on the vertical as well as on the horizontal walls of the medullary-ray cells, the Scotch wood agrees with the genera *Cedroxylon* and *Pityoxylon* and not with *Cupressinoxylon*. From the latter genus our specimen is distinguished by the absence of resin-canals, and it agrees with *Cedroxylon* in the limitation of the xylem-parenchyma to the summer wood. In the Arctic species of *Cedroxylon* described by GOTHAN from King Charles Land the frequent occurrence of double *alternate* rows of bordered pits, as in Araucarian wood, is a distinguishing feature probably of specific rank. There is a slight tendency towards this arrangement in *Cedroxylon Hornei* (fig. 22). The name *Cedroxylon* does not necessarily imply generic identity with *Cedrus*, but denotes affinity to such genera as *Cedrus*, *Pseudolarix*, and *Tsuga*.‡

Among other records of *Cedroxylon*, reference may be made to *Cedroxylon barremianum* Fliche § from the Lower Cretaceous rocks of the Haute-Marne, France; *Cedroxylon blevilleuse* Lign. from the Gault of Normandy; ‖ and to some imperfectly preserved specimens described by Drs STOPES and FUJII as *C. Matsumuræ* and *C. Yendoi* from the Upper Cretaceous rocks of Japan.¶ In LIGNIER's species the pits on the tracheides are relatively large, 13–20μ in diameter, in this respect agreeing with those of the Helmsdale species (20μ); there is also the same stellate type of pitting on some of the tracheides as that shown in fig. 22. The two species *C.*

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* GOTHAN (05), p. 102.

† BARBER (98); GOTHAN (08), pp. 23, 26.

‡ JEFFREY (11), p. 25.

§ FLICHE (00), p. 16, pl. ii. fig. 1.

‖ LIGNIER (07), pp. 263–267; pl. xviii. figs. 15–17, 21–23; pl. xxii. fig. 72; pl. xxiii. fig. 87.

¶ STOPES and FUJII (10), pp. 42–44; pl. iv. figs. 20–23; pl. iv. figs. 24–26.

cedroides Goth. and *C. transiens* Goth., described by GOTHAN* from King Charles Land, probably of Upper Jurassic age, show perhaps the closest analogy to *Cedroxylon Hornei.*

GINKGOALES.

Ginkgo digitata (Brongn.) forma *Huttoni.*

The only example of the genus *Ginkgo* hitherto recorded from the Kimeridgian strata of Scotland is an imperfect leaf-impression referred to HEER's species *G. sibirica.*† Among the fossils collected on the coast of Sutherland by Professor NATHORST in 1883 is a fairly good example of a *Ginkgo* leaf with broad cuneate segments, of the form frequently spoken of as *Ginkgo Huttoni* (Sternb.). Through the courtesy of Professor NATHORST a drawing was made of the specimen in the Stockholm museum: this drawing is reproduced in text-fig. 6.

TEXT-FIGURE 6.—*Ginkgo digitata* (Brongn.) forma *Huttoni.* From a specimen in the Palæobotanical Museum, Stockholm. Nat. size. [Block lent by the Syndics of the Cambridge University Press.]

CONCLUSION.

The fossils described in this paper, though unfortunately for the most part fragmentary and imperfectly preserved, enable us to extend the list of species of Scottish Jurassic plants. There can be no doubt that further search both among the petrified blocks on the beach at Helmsdale and on the shores of Eathie Bay, will lead to the discovery of additional information as to the structure of Kimeridgian plants, and one of our aims in writing these pages is to stimulate further research into the composition of a comparatively rich and by no means exhausted flora.

The list of Jurassic plants recorded from Scotland, published by one of us in a paper communicated to the Royal Society of Edinburgh in 1910,‡ may be supplemented by the following species :—

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* GOTHAN (08), pp. 23, 26.

† SEWARD (11), p. 679, text-fig. 9, A.

‡ SEWARD (11).

? PTERIDOPHYTA or GYMNOSPERMÆ.

Thinnfeldia scotica sp. nov.

GYMNOSPERMÆ. (CONIFERALES.)

? **Araucariinæ.**

Brachyphyllum eathiense sp. nov.
Conites Juddi sp. nov.

Abietineæ.

Cedroxylon Hornei sp. nov.

Conifers of uncertain position.

Taxites Jeffreyi Sew.
Masculostrobus Woodwardi sp. nov.

GINKGOALES.

Ginkgo digitata (Brongn.) forma *Huttoni.*

CYCADOPHYTA.

Bennettitales.

Williamsonia scotica Sew.*

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* SEWARD (12).

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EXPLANATION OF PLATES.

PLATE I.

Fig. 1. *Thinnfeldia scotica* sp. nov. Nat. size. (Professor NATHORST's collection, Stockholm.)

Figs. 2–4. *Brachyphyllum eathiense* sp. nov. Sections of leaves. *t*, transfusion tracheides; *p*, palisade cells. Fig. 2, × 50; fig. 3, × 15; fig. 4, × 35.

Fig. 5. *Taxites Jeffreyi* Sew. Section of leaf, × 100.

Figs. 6–8. *Masculostrobus Woodwardi* sp. nov. Fig. 6, nat. size; fig. 7, × 4; fig. 8, × 36. *a* (?), sporogenous cells.

Figs. 9–12. *Conites Juddi* sp. nov. forma γ. For explanation see text, pp. 876–878. Fig. 9, × 14; fig. 10, × 4; fig. 11, × 10; fig. 12, × 14.

Fig. 13. *Strobilites Milleri* sp. nov. Nat. size.

PLATE II.

Figs. 14–16. *Conites Juddi* sp. nov. forma γ. Fig. 14, × 7; fig. 15, × 25; fig. 16, × 30.

Figs. 17–21. *Conites Juddi* sp. nov. forma δ. Figs. 17, 18, 20, 21 enlarged photographs of cone-scales B, C, D, A, fig. 19. Fig. 19, × 1¾; figs. 17, 18, 21, × 5; fig. 20, × 6.

Figs. 22–25. *Cedroxylon Hornei* sp. nov. Figs. 22–24, × 250; fig. 25, × 40.

ns. Roy. Soc. Edin^{r} Vol. XLVIII.

A. C. SEWARD: JURASSIC PLANTS FROM CROMARTY AND SUTHERLAND—PLATE I.


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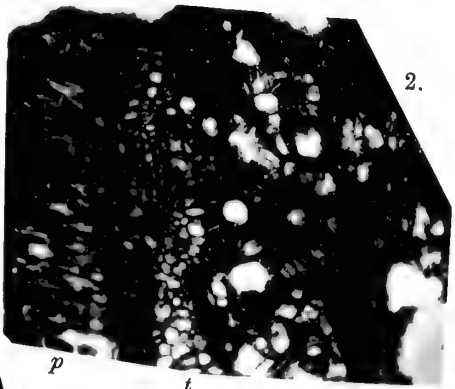
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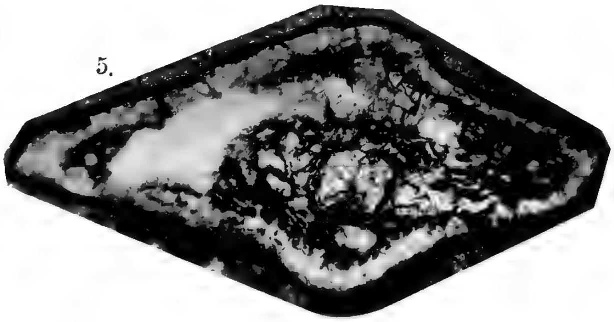
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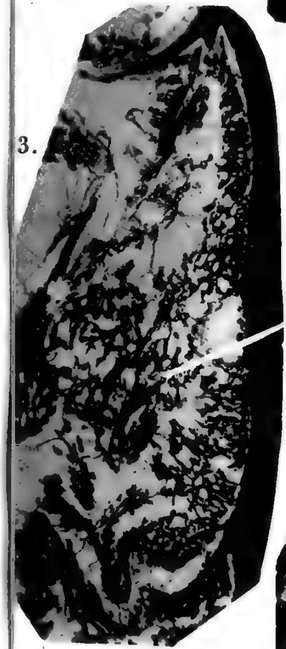
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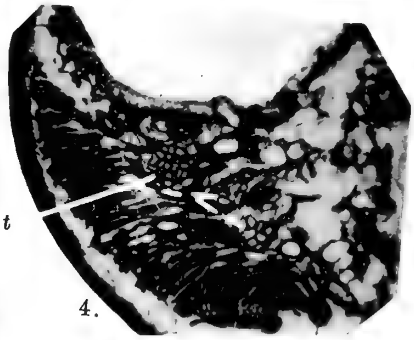
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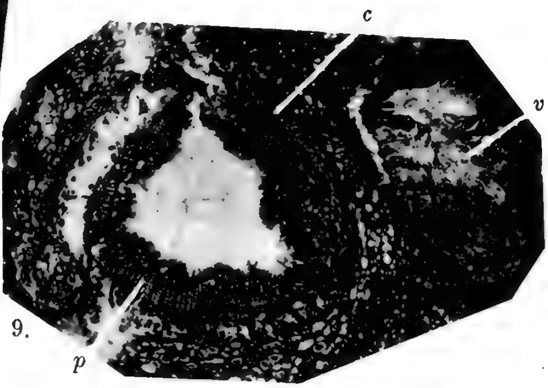
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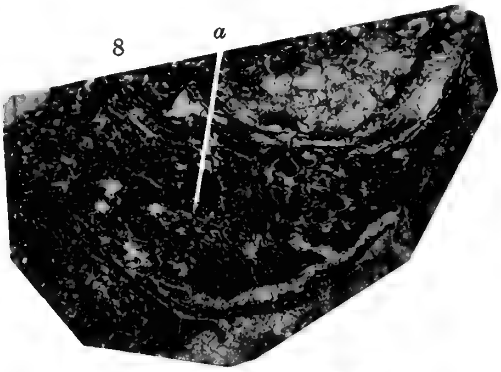
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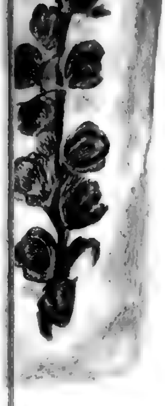
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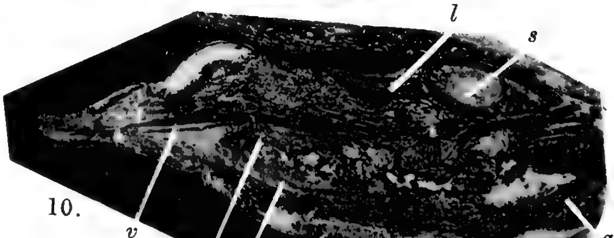
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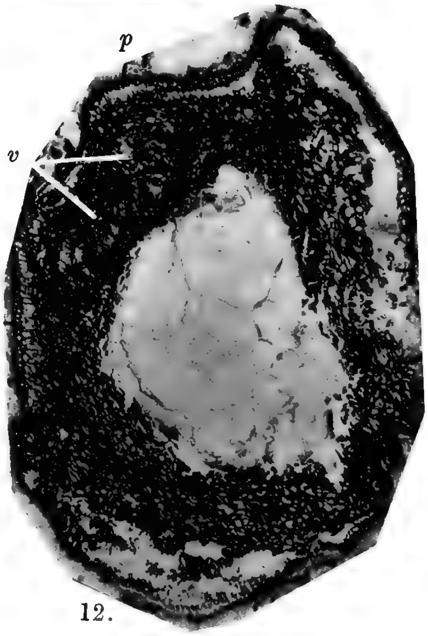
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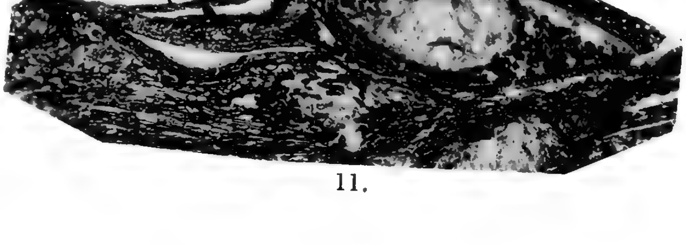
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s, Photo.

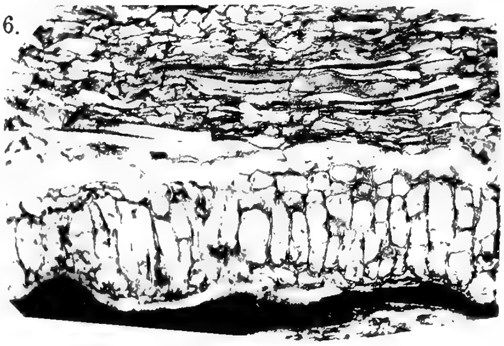
M'Farlane & Erskine, Edin.

Thinnfeldia (1); Brachyphyllum (2–4); Taxites (5);
Masculostrobus (6–8); Conites (9–12); Strobilites (13).

BRITISH MUSEUM
NATURAL HISTORY

A. C. Seward: Jurassic Plants from Cromarty and Sutherland—Plate II.

14.



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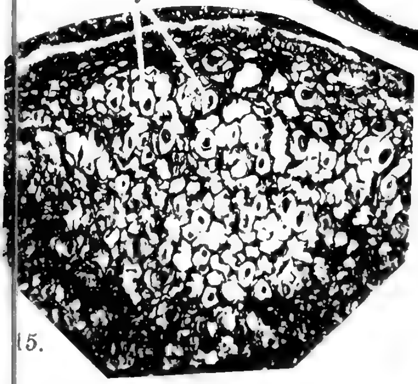

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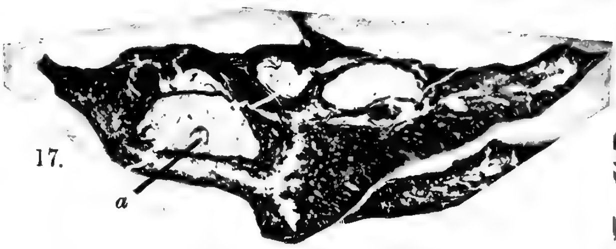

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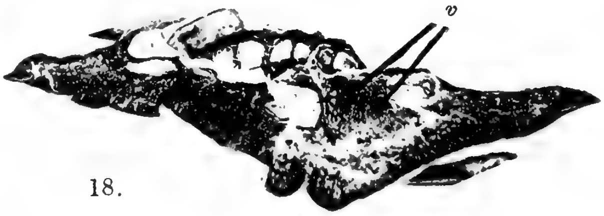

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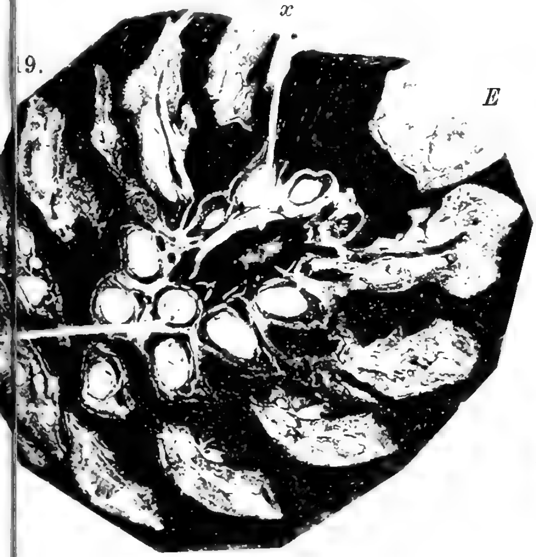

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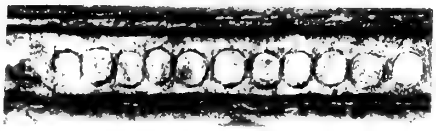

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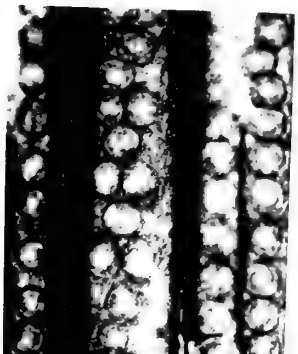

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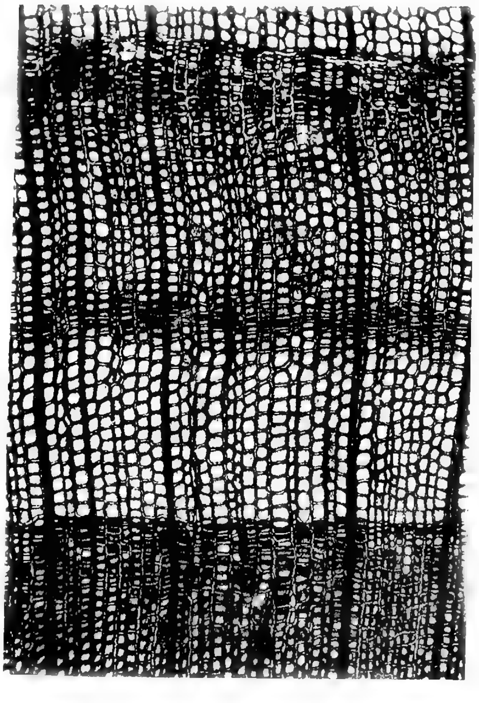

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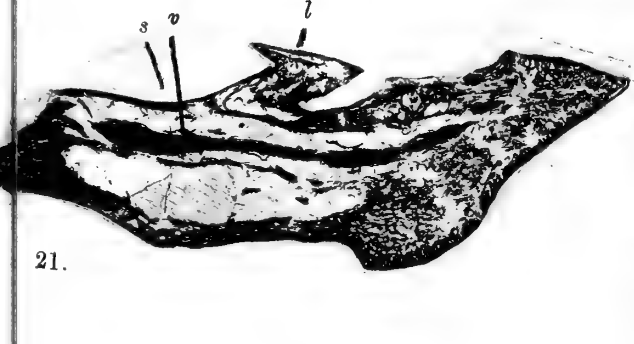

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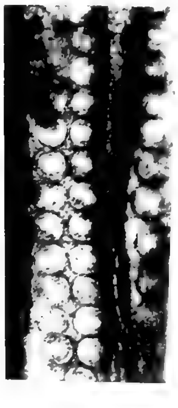

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M'Farlane & Erskine, Edin.

Conites (14–21); Cedroxylon (22–25).

BRITISH MUSEUM NATURAL HISTORY

XXXIII.—**The Right Whale of the North Atlantic,** *Balæna biscayensis*: **its Skeleton described and compared with that of the Greenland Right Whale,** *Balæna mysticetus*. By Principal **Sir Wm. Turner,** K.C.B., D.C.L., F.R.S., President of the Society, Knight of the Royal Prussian Order Pour le Mérite. (With Three Plates, and Figures in Text.)

(Read December 2, 1912. MS. received December 3, 1912. Issued separately March 24, 1913.)

CONTENTS.

Historical Introduction.

From the thirteenth to the seventeenth century a successful whale fishery was prosecuted in the Bay of Biscay and in the North Atlantic by seamen from the Basque ports of France and the north of Spain. So daring was their enterprise that they pursued their avocation northward to Iceland and even westward to Newfoundland and the adjoining shores of the American continent. The reputation of the Basque sailors as skilful whaling fishermen was so widely recognised that, when the whaling companies in England and Holland were started in the early years of the seventeenth century, Biscayan seamen were employed as the harpooners to strike the whales, and as coopers to construct the casks to contain the blubber. Up to that time the knowledge of the specific differences amongst the large whalebone whales was most imperfect, and it is not unlikely that both Right Whales and Fin Whales were captured as opportunity offered, though the former, from the greater length of whalebone and the thickness of blubber, were more prized. In 1611 an English whaling company sent for the first time an expedition to Spitzbergen, and from the instructions given to its commander, Thomas Edge, it would seem that two kinds of Right Whales had even then been noticed, the one larger and more valuable from the oil which it yielded and the length of the baleen, now known as the Greenland Right Whale, *Balæna mysticetus*, and the other a smaller whale, called the "Sarda." A whale captured off the coast of Iceland by the French and Spanish seamen, locally named "Sletbag," was probably the same as the Right Whale the "Sarda." With the development of the whale fishery in the Arctic Ocean, it became more evident that the Greenland Right Whale was distinct from the smaller animal which had previously been the object of pursuit. In 1671 F. Martens gave[*] the name "Nordcaper" to Baleen Whales captured near the North Cape; they differed from those which frequented the Spitzbergen seas in being smaller, with less blubber, shorter whalebone, more active and more dangerous to kill. The name Nordcaper continued to be employed as equivalent to the Baleine de Sarde of the French naturalists, and Bonnaterre and Lacépède, adopting *nordcaper*[†] as a specific name, distinguished it from *Balæna mysticetus*, La Baleine franche, or the Greenland Right Whale.

Owing to diminution in numbers, the pursuit of this whale terminated at the end of the eighteenth century, and many naturalists believed that its continued capture during the centuries had led to its extinction. G. Cuvier[‡] threw doubts, however, on the existence of the Nordcaper as a distinct species, and believed that, driven northward for refuge to the ice of the Arctic Sea, it was the same as the Greenland Whale; F. Cuvier[§] agreed also with his brother in this belief. In a memoir published in 1820,[||] Peter Camper recognised them as distinct species with different habitats, the *mysticetus* frequenting the whole extent of the icy Arctic, and the Nordcaper not living in such high latitudes, but in the seas of Iceland and Norway from the North Cape up to the Arctic zone.

In 1861 Eschricht and Reinhardt[¶] published a splendid memoir on the Greenland Right Whale, *B. mysticetus*, which contained an analytical description of its geographical distribution and of its osteology, and which fully established by facts and arguments its specific difference from the Nordcaper. Additional interest was given to this question by the report that two whales, mother and young, had been seen, in January 1854, off the harbour of San Sebastian in the Gulf of Gascony, that the young one had been captured and its skeleton preserved in the Museum in Pampeluna. On hearing of this capture, Eschricht visited Pampeluna, and in a letter to van Beneden,[**] written in September 1858, he stated that the whale was the same as the Sletbag of the Icelanders, the *Balæna biscayensis*, as he now named the species. He purchased the bones for the Copenhagen Museum, and submitted a memoir to the French Academy[††] in which he stated that it was not a *mysticetus*, but was allied to the *Balæna* of the Cape, which like the Nordcaper frequented temperate seas. Eschricht did not live to publish a description of this skeleton, but the authorities of the Museum granted permission to Professor Gasco of Naples to examine, make drawings, and write[‡‡] an account of the skeleton, in which he confirmed the opinion of Eschricht that it was *Balæna*

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[*] *Journal d'un Voyage au Spitzberguen*, Amsterdam, 1732.

[†] Lacépède, *Histoire nat. des Cétacées*, Paris, l'an xii. de la République (1804). *B. nordcaper*, La machoire inférieure très-arrondie; très-haute et très-large; le corps alongé; la queue alongée.

[‡] *Recherches sur les Ossemens fossiles*, v., Paris, 1825.

[§] *Hist. nat. des Cétacés*, Paris, 1836.

[||] *Observations anatomiques sur la structure intérieure de plusieurs espèces de Cétacés*, with Atlas of 53 plates, Paris, 1820.

[¶] *Kong. Danske Vidensk.*, v., 1861. Translated in Ray Soc. Publications, London, 1866.

[**] "Hist. nat. de la *Balæna biscayensis*," *Mém. couron. Acad. Roy. Belgique*, 1886.

[††] *Comptes rendus*, p. 294, 1860; *Ann. des Sc. nat.*, 5th series, t. i., 1864.

[‡‡] *Ann. del Museo Civico di Storici nat. di Genova*, vol. xiv., 1879.

biscayensis. A drawing of the whale which had been made by Dr Monodero was reproduced by van Beneden,[*] whilst measurements were recorded by Fischer, the author of instructive memoirs on the Cetacea of the south-west of France.[†]

In February 1877 an important capture of a female Right Whale took place in the Gulf of Taranto, South Italy. Professor Capellini examined it, and published a description[‡] with a coloured drawing by Hueber of the animal, and also figured some of the bones. He gave it the name *Balæna tarentina*, and regarded it as closely resembling *B. australis.* In the following year Gasco published a more detailed account of this specimen,[§] which he named *B. biscayensis.* He reproduced a coloured drawing by Marrullier, and, as the skeleton had been acquired by the Museum in Naples, he was able to figure many of the bones. In 1889 Professor de la Paz Graells[||] gave an account of the whales which frequent the coasts of Spain, and noted the skeletons in some of the provincial museums. He saw in the Institute of Secondary Instruction, San Sebastian, the skeleton of a *B. biscayensis* which had been taken apparently in February 1878 near Guetaria, in the Bay of Biscay. He figured the skeleton and some of the individual bones. He also referred to the skeleton of another specimen in the Museum, Santiago, caught about 1880 off the coast of Galicia.[¶]

In 1891 Professor Pouchet, from a comparison of two photographs, one of which was that of a Right Whale taken at Algiers in 1886,[**] a part of the skeleton of which is in the Museum of Natural History, Paris, whilst the other was a photograph of a whale caught off Cape Cod, Massachusetts, concluded that they were of the same species, *B. biscayensis.* The specimen from Algiers supplied a second example of the capture of this whale in the Mediterranean.

In 1893 Professor Guldberg stated[††] that from 1889 to 1891 Norwegian captains had caught Right Whales, which were Nordcapers, off the coast of Iceland. In 1889 he received at the Museum in Christiania a skull, and in 1891 a skeleton, and specimens had also been presented to Copenhagen and Bergen. It is obvious, therefore, that *Balæna biscayensis* had not been exterminated, and that isolated examples had been caught during the nineteenth century in seas as remote from each other as those of Iceland and the Gulf of Taranto in South Italy.

We may now inquire into the occurrence of the Nordcaper in Scottish waters. Some years ago the late Mr Thomas Southwell called attention to this matter.[‡‡]

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[*] *Ostéographie des Cétacés*, by van Beneden and Gervais, plate vii.

[†] *Ann. des Sciences nat.*, vol. xv., 1871 ; *Actes de la Soc. Linnéenne de Bordeaux*, vol. xxxv., 1881.

[‡] *Mem. dell' Accad. delle Scien. di Bologna*, vol. vii., 1877.

[§] *Atti della R. Accad. delle Scien.*, Napoli, vol. vii. 1878.

[||] *Mem. de la R. Acad. des Ciencias*, Madrid, vol. xiii., 1889.

[¶] In the course of his inquiry, Signor Graells made the interesting observation that the shields of the municipalities of the coast towns, Bermeo, Lequeitio, Castrourdiale, Ondarroa and Plencia in Viscayo, showed their early association with the whale fishery, as Basque fishermen giving chase to whales with boats and harpoons are represented.

[**] *Comptes rendus de la Soc. de Biologie*, Paris, 1891.

[††] "Zur Kenntniss des Nordkapers," *Zool. Jahrbuch*, vii.; also in *Biol. Centralblatt*, Leipzig, xxiii., 1903.

[‡‡] *Proc. Nat. Hist. Soc.*, Glasgow, 1881 ; also in his work on Seals and Whales, 1881, and in *Ann. Scot. Nat. Hist.*, January 1907.

He stated that in 1806 an old Right Whale, with its sucker which was killed, came into Peterhead Bay; also that in 1872 Captain David Gray saw one sporting off the Headland of that bay. They were at the time believed to be Greenland Right Whales which had wandered south, but our present knowledge that this animal does not leave the icy north justifies the inference that they were specimens of *Balæna biscayensis.* The recent establishment by the Norwegians of fishing stations in Shetland, Harris in the Hebrides, and on the west of Ireland has thrown much additional light on the species of large whales which frequent the seas to the north and west of Scotland. In addition to the Great Fin Whales, *Balænoptera musculus*, *B. borealis*, *B. sibbaldi*, several specimens of the Sperm Whale, the Humpback (*Megaptera boops*), and *Balæna biscayensis* have been taken. Mr Southwell recorded the capture of a Nordcaper[*] in July 1903 in lat. 61° N., about 50 miles west of Shetland. Mr R. C. Haldane[†] recorded six specimens of the same species, four bulls and two cows, as having been brought to the whaling station at Buneveneader, Harris, in 1906. The same naturalist further reported that in the years 1907 to 1909 sixty-eight examples of *B. biscayensis*, thirty-four bulls and thirty-four cows, many of the latter of which were with young, were taken, and of these sixty-six were at the Harris Station, and two, a bull and a cow, at the Alexandra Station in Shetland. Mr D. G. Lillie has recorded[‡] the capture in 1908 of four bulls and a cow from the fishing station at Inishkea, in the west of Ireland, but no specimen of this whale was taken at the Bellmullet Station in 1911.[§] Professor R. Collett has summarised[||] the takes of this whale by the Norwegians from April 1889 to 1908 as about eighty animals, the sexes being in almost equal numbers. As the fishing was conducted around Iceland, the Faroe Islands, and to the west of the Hebrides, his statistics include the specimens referred to in Mr Haldane's narrative to the same date. Collett[¶] reproduced four figures to show the external characters of this whale.[**]

Buneveneader, on West Loch Tarbet, is favourably situated as a station to which whales may be taken when captured during their migration northwards in the early summer. As regards the Nordcaper, the course which it usually makes is west of the Flannan Islands and St Kilda on the way to Iceland. Mr Eagle Clarke, the energetic Keeper of the Natural History Department of the Royal Scottish Museum, came into communication with Mr Carl F. Herlofson, the Manager of the Company at this station, and found him most willing to assist the Museum in adding to its collection specimens of the larger Cetacea frequenting the North Atlantic. Mr Herlofson presented to the Museum in 1911 a splendid skull of an old male Sperm Whale, and subsequently one of *Megaptera boops.* In the summer of 1912 the almost complete skeleton of *Balæna biscayensis* arrived, which, by the permission of the authorities of

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[*] *Ann. and Mag. Nat. Hist.*, vol. xvi., 1905.

[†] "Whaling in Scotland," *Ann. Scot. Nat. Hist.*, January 1907.

[‡] *Proc. Zool. Soc.*, London, October 1910.

[§] *Report*, British Assoc. Ad. Sc., Dundee, 1912.

[||] *Proc. Zool. Soc.*, London, vol. i., 1909.

[¶] *Proc. Roy. Soc.*, London, 1909.

[**] F. Freund described, *Deutsche Arbeit*, xi. p. 417, 1911–12, the use of the harpoon gun in the whale fishery off the Faroe Islands. *B. biscayensis* was seldom seen.

the Museum, I have examined, and an account of which I now submit to the Society, with illustrative figures. The animal was captured in 1910, west of St Kilda. Mr Herlofson gave every facility for the preservation of the bones, and under the supervision of Mr Arthur J. Edwards, one of the assistants in the Museum, they were carefully packed and despatched by steamer to be forwarded to Edinburgh. I have also to express my personal indebtedness to Mr Herlofson for presenting through me to the Anatomical Museum of the University the skull of an adult male *B. biscayensis*, caught 20 miles north-east of St Kilda in June 1912. The characters of this skull are also included in the description of the skull of the complete skeleton. The tympano-petrous bones accompanied the skull.

Specific Name and Geographical Distribution.

In the preceding section it is stated that the Right Whale frequenting the European waters of the North Atlantic was known locally as Nordcaper, Sarda or Sarde, Sletbag, and Biscay Whale. Its proper zoological designation should now be considered. The name *Balæna biscayensis* was given by Eschricht and was adopted at the time by van Beneden, Fischer, Gray, Flower and many other cetologists. In an important monograph recently published,* F. W. True has revived the name *Balæna glacialis*, introduced into cetological literature by Klein † and the Abbé Bonnaterre,‡ and has applied it to designate the Nordcaper or *B. biscayensis*; in the employment of this name he has been followed by Professor Collett.§ In connection with the term *glacialis*, it should be kept in mind that during the eighteenth century the specific distinction between the Nordcaper and the Mysticete was imperfectly understood, though it had been recognised that the Mysticete frequented the icy seas of Spitzbergen and Greenland, whilst the Nordcaper was found in the more temperate waters to the south. Fischer speaks of Klein and Bonnaterre as compilers, and he indeed doubts if they had ever seen a whale.‖ If the term *glacialis* is to be retained as the specific name of a Right Whale, it would be a more appropriate synonym of the Greenland Right Whale, which is a denizen of ice-bound waters; on the other hand, it would be a complete misnomer for the Nordcaper, which, to use the words of van Beneden, is the Right Whale of the Gulf Stream, as it would mislead and give a most erroneous idea of its habitat.

It was to the patient labours of Eschricht that a scientific demonstration of the geographical distribution, external characters, and to some extent the anatomy of the Right Whales were put on a sound basis; and so long as a special name is given to the Nordcaper or Right Whale of the temperate waters of the North Atlantic, it is due to

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* "The Whalebone Whale of the Western North Atlantic," *Smithsonian Contributions*, Washington, 1904.

† *Historia piscium naturalis*, 1740.

‡ *Tableau encyclopédique et méthodique: Cétologie*, pp. 3 and 4, Paris, 1789.

§ *Proc. Zool. Soc.*, London, 1909.

‖ Bonnaterre evidently relied on the descriptions by Anderson and Horrebows in their histories of Iceland for an account of the mode of fishing of this whale, though the latter disputed the accuracy of Anderson's statements. Bonnaterre's specific characters are as follows: "Le Nord Caper. *B. glacialis*, B. maxillis subæqualibus; inferiore rotundâ, in medio latiore; dorso impinni, albicante."

ESCHRICHT that his name *biscayensis* should be preserved, and in this connection, therefore, it is employed in this memoir.

Early, however, in the nineteenth century it was recognised that in the American waters of the North Atlantic, as well as in the temperate seas of the southern hemisphere, Right Whales were found smaller in size, and with shorter whalebone than is present in *mysticetus.* DESMOULINS* described in 1822 by the name *Balæna australis* a whale which frequented the seas around the Cape of Good Hope. Right Whales had been captured near New Zealand, and as far south as Kerguelen Island, also in the seas of Japan and Korea, to which local names, as *B. antipodarum* and *japanensis*, had been applied. FISCHER described a fœtus of *B. australis* caught in 1831 near Tristan da Cunha in the South Atlantic.† ESCHRICHT and REINHARDT referred to whales regularly caught off the coast of New England as probably the same species as the Nordcaper.

In the year 1865 Professor COPE commenced his series of memoirs on the Cetacea caught off the coasts of the United States by describing the skeleton of the Black Whale in the Museum of the Academy of Sciences, Philadelphia,‡ and he named the species *Balæna cisarctica.* The skeleton, including the intervertebral cartilages, was 37 feet long, the skull of which measured 8 feet 5 inches. In a memoir published in 1883, J. B. HOLDER described § three specimens: a male 40 feet 4 inches long, caught at Charleston in 1880; a female 48 feet long, off the coast of New Jersey in 1882; and a third, sex unknown, 35 feet long, on Long Island, New York. F. W. TRUE, in his important memoir, continued the data collected by HOLDER, supplied additional facts and opinions, reviewed and summarised the evidence bearing on the Right Whale which frequented opposite coasts of the North Atlantic, and came to the conclusion that *B. biscayensis* and *B. cisarctica* were the same species.

Many naturalists are of opinion that the Right Whale of the southern hemisphere should not be regarded as a species distinct from the Right Whale of the North Atlantic, and as the name *B. australis* given by DESMOULINS to the southern species preceded ESCHRICHT'S name *B. biscayensis*, it has been held that it should be the specific name for the Right Whale which frequents the temperate waters of both hemispheres. It should, however, be remembered that the Right Whale of the Bay of Biscay and the North Atlantic had been known, captured, and many of its characters recognised long before the southern Right Whale had been seen by zoologists.

Half a century ago, largely under the influence of the late Dr J. E. GRAY, it would have been thought impossible for the same species of whale to have lived both north and south of the Equator, and specific names were multiplied to indicate distinct species living not only in opposite hemispheres, but in different seas in the same hemisphere, even though they corresponded in their generic characters. For example, the beaked whale *Ziphius cavirostris*, obtained by CUVIER in the Mediterranean in 1804, was regarded by zoologists as both specifically and even generically distinct from certain

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* *Dict. Class. d'Hist. Nat.*, ii., 1822.

† *Actes de la Soc. Linnéenne de Bordeaux*, xxvii., Nov. 1868.

‡ *Proc. Acad. Nat. Sc.*, Philadelphia, 1865.

§ *Bull. American Museum*, New York, vol. i. No. 4, 1883.

other beaked whales found in the southern hemisphere. In a memoir on the skull of *Ziphius cavirostris* from Shetland,* I compared it with the descriptions of beaked whales from the south of the Equator named by GRAY *Petrorhynchus capensis*, by BURMEISTER *Epiodon australis*, and by VAN BENEDEN *Ziphius indicus*, and I came to the conclusion that they were only southern forms of the *Ziphius cavirostris* obtained by CUVIER in the Mediterranean and by myself from Shetland. In my *Challenger Report* on the bones of the Cetacea † I described the skull of a beaked whale from the Chatham Islands, which Sir JAMES HECTOR had originally named *Epiodon chathamiensis*. I compared it with the Shetland skull, and came to the conclusion that they were of the same species, though one had lived in the far north and the other many degrees south of the Equator. I also noted that, since my first memoir on *Ziphius* was published in 1872, VAN BENEDEN and HECTOR had accepted the view that the southern as well as the European crania of *Ziphius* were all examples of one species. I do not know if this whale has been caught in the tropics, but in my examination of the ear-bones collected by the *Challenger* and brought by the dredge from the floor of the ocean, I identified a tympanic bone obtained at 2275 fathoms in lat. 29° 35′ S. as identical in characters with that of the *Ziphius cavirostris* from Shetland.‡

A wide geographical distribution prevails with Sperm Whales (*Physeter macrocephalus*). They are caught in the temperate seas of New Zealand, also as far north as Shetland and the Faroe Islands,§ they are regularly hunted in the intermediate tropical seas, and no evidence of specific distinction exists between them whatever be their habitat. To all appearance, the great Sperm Whales are descended from a common ancestry. When oceans communicate directly or indirectly with each other, an opportunity is given to the Cetacea to make an extensive migration, which for them, as for other migratory animals, seems to be mainly determined by the amount and nature of the food-supply, which in the Right Whales consists of plankton organisms, mostly minute crustacea, and in many other Cetacea of either cephalopods or small fish.‖ Differences in habitat therefore do not necessarily imply specific difference, and on this ground no sufficient reason exists why the smaller Right Whale of the European and American coasts of the North Atlantic should not be the same species as the *Balæna australis* of the southern hemisphere. No adequate evidence has been given to prove the presence of this whale, so characteristic of temperate waters, in the seas of the tropics.

In the concluding volume of the *Reports* ¶ of the Challenger Expedition, Sir JOHN MURRAY has collected and analysed the results obtained from the sounding, dredging and trawling stations. He has shown that numerous species of Invertebrata, identical in character, were found in both the Arctic and Antarctic Oceans, and that a similarity of species existed in certain invertebrates from the temperate zones of the seas north and

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* *Trans. Roy. Soc. Edin.*, vol. xxvi., 1872.

† *Zoology*, part iv., 1880.

‡ See plate ii. figs. 9, 10, in my *Challenger Report* on the Bones of Cetacea, part iv., 1880.

§ *Proc. Roy. Soc. Edin.*, vol. xxiv., 1903.

‖ The Killer Whale, *Orca gladiator*, is a flesh-eating cetacean, for it attacks and devours seals and porpoises.

¶ *Summary of Results*, 2nd part, 1895.

south of the tropics, though these species were not represented in the waters of the tropics. A few species of fish were also obtained from opposite hemispheres which possessed a specific similarity.

Although the great whale of the Arctic Ocean, *Balæna mysticetus*, has not been found in the Antarctic, the characteristic Right Whale of the temperate zone is present in the waters of both hemispheres, though not found in the intermediate tropics. If the conditions of temperature and food-supply in the tropical zone had in previous times permitted these whales to migrate across the equator, as is now the case with the great Sperm Whale, these Right Whales would probably have had, like *Physeter*, a common ancestry; but if conditions such as now exist had prevailed in bygone times, throughout the stages of evolution of the Balænidæ, it is difficult to believe that a migration across the intermediate tropical zone could have taken place. Of the Right Whales, therefore, in each of the northern and southern temperate areas one may speculate that an independent descent in each area from, it may be a more primitive form, may possibly indicate the course of their evolution.

COLOUR—BALEEN—SIZE.

Colour.—It is customary in the description of the external characters of the Nordcaper to state that it is black on the back, the sides, and the belly. The authority for this colouring is apparently the drawing by MONODERO of the young San Sebastian specimen (1854), which was reproduced by VAN BENEDEN.* Similarly, CAPELLINI's reproduction of HUEBER's drawing of the Taranto specimen is also black. GASCO, in his figure of the Taranto whale, represented it of a uniform blackish colour, but made the head proportionally less than in CAPELLINI's figure. GULDBERG described the deep black colour of the entire body, though, on the authority of Captain BERG, individuals shewed white spots here and there on the black surface. COLLETT stated that the Nordcaper was usually all black, though in some 10 per cent. the belly was more or less white, well defined against the black; at times the white patch was constricted in the middle, and spotted with black. He figured the ventral surface of a female in which these characters were well marked. Mr EDWARDS has kindly given me the opportunity of reproducing a photograph by Mr HERLOFSON of the belly of one of the Nordcapers brought into his station (fig. 16). A broad white patch extended from the ventral surface of the throat as far back as the pectoral limbs, immediately behind which it was intersected by a black band, and was then continued white to the region of the anus. Obviously, therefore, a white belly more or less extensive and marked with black spots or bands may sometimes occur.

One of the noticeable external characters of this whale was the presence on the snout and the front of the lower jaw of a wart-like growth, called by whaling seamen the "bonnet." It was figured in CAPELLINI's memoir on the Taranto whale, and recently in COLLETT's memoir. It consisted of a mass of crustaceous Epizoa belonging to the genus Cyamus.

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* *Ostéographie des Cétacés*, by VAN BENEDEN and GERVAIS, fig. 1, pl. vii.

Lütken and **Sars** have identified the species as usually *Cyamus ovalis*,* a form of whale louse. Mr **Edwards** told me that in a specimen which he saw, the growth formed a moving mass 12 inches in diameter and 2 inches deep, so strongly attached to the snout that he had to employ pliers to remove it. **Guldberg** stated that these Epizoa may be scattered over the body generally, and **Edwards** found them on the skin around the anus and female parts.

Baleen.—The triangular baleen plates were black in colour, though **Collett** stated that sometimes the most anterior were white; their bristles were black, and fine as silk. As in *mysticetus*, their bases were narrow in conformity with the palatal area from which they grew. The maximum length recorded was a little more than 7 feet, which is about one-half that of the longest plates in *mysticetus*. Specimens of the plates of *biscayensis* in the Royal Scottish Museum ranged from 4 feet to a little more than 7 feet in length, and from 6¾ to 9 inches in width at the base; and **Guldberg** gave 7 feet 1 inch as the length in an Iceland specimen. **Scoresby** gave 13·7 inches as the maximum length in *B. mysticetus*, but from 10 to 12 inches is more usual.

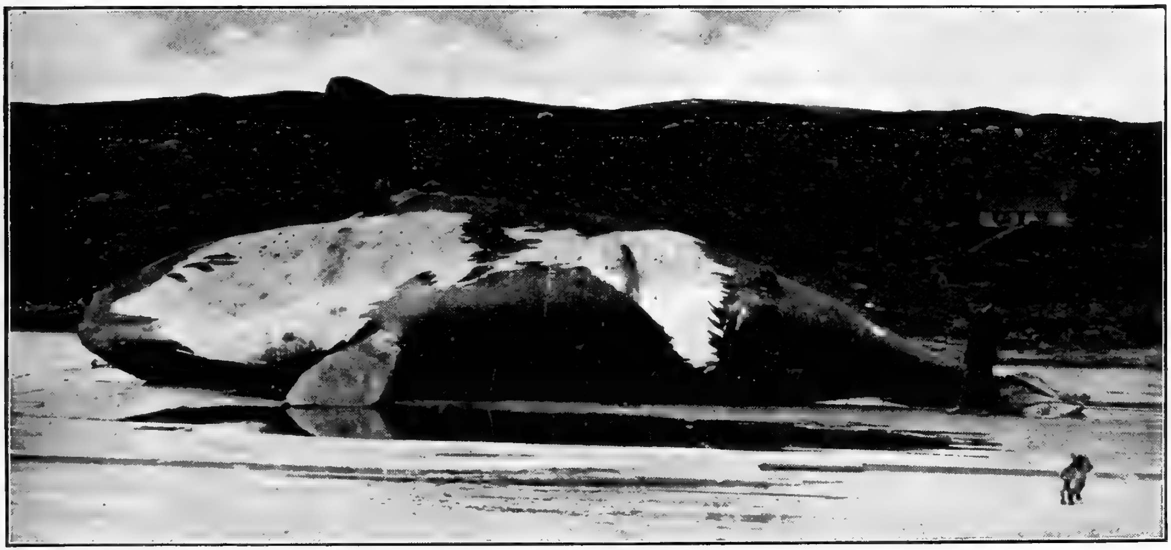

Fig. 16.—Ventral surface.

Size.—The young specimen caught at San Sebastian in 1854 was said to be 24 feet 9½ inches long, and another specimen from Guetaria was 34 feet 3 inches. That at Taranto, a female, was 39 feet 4 inches (12 metres). **Guldberg** gave the length of a female as 42 feet, and that of other specimens from Iceland as ranging up to 51 feet 8 inches, the smallest of which were not full-grown; he also reproduced three photographs of a male lying on the beach at Dyrefjord in Iceland. The success in recent years of the Norwegian whalemen has enabled many additional measurements to be made. **Haldane** stated that, of 67 specimens of both sexes, the bulls ranged from 43 to 51 feet,

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* **Lütken** has given in *Vidensk. Selsk. Skr.*, Copenhagen, 1873, an elaborate account of the species of Cyamus which infest whales.

the average being 45·9 feet; the cows ranged from 44 to 51 feet, with an average of 46·9 feet; the cows therefore exceeded in average length the bulls, but the maximum in each sex seemed to be about 51 feet. COLLETT'S measurements, which included those noted by HALDANE, ranged in 44 specimens from 36 to 48 feet in 24 bulls; from 31 feet (9·45 m.) to 50 feet (15·2 m.) in 20 cows, the average length in the females being a little more than in the males.

SCORESBY, in his classical work on the Arctic Regions, stated that of 322 individuals of *B. mysticetus,* in the capture of which he was personally concerned, not one exceeded 60 feet, though he had been told of one 67 feet long, and another as much as 70 feet; but of six which he measured, four, apparently adults, ranged from 50 to 58 feet. In the animal 58 feet long the head was 19 feet, therefore about one-third the total length of the animal.

In *B. biscayensis* again, observers agree that the head bears a smaller proportion to the total length of the animal, about one-fourth. In being smaller, therefore, than *mysticetus,* as well as the head being proportionately less, *biscayensis* shows specific characters which distinguish it from the Right Whale of the Greenland seas. The large skull of *B. biscayensis* in the University Museum of Anatomy was from an animal whose length was stated by Mr HERLOFSON to be 51 feet. The skeletons, the skull included, of eleven American specimens of the North Atlantic Right Whale recorded by TRUE, are stated to have ranged from 30 to 53 feet in length.

SKELETON.

The material at my disposal for purposes of study consisted of the skull and almost complete skeleton in the Royal Scottish Museum and a separate skull in the Anatomical Museum of the University, also three tympano-petrous bones. I have been aided in making the measurements by Mr ROBERT REID, assistant in the Royal Scottish Museum, and by Mr ERNEST J. HENDERSON, Assistant Conservator to the Anatomical Museum of the University, and I am indebted to the latter for the photographs of the bones from which most of the illustrations have been prepared.

SKULL.

In outline the skulls possessed the highly arched facial region characteristic of a Balæna. In Table I. measurements are given of the two skulls, and in the same table are included the measurements of two skulls of the Greenland Whale, *B. mysticetus,* in the Anatomical Museum of the University.* (See Plates I., II.)

The *occipital* bone in *B. biscayensis* formed a large proportion of the wall of the cranium. It mounted to the vertex and articulated with the thin edge of the frontal which separated it from the nasals. The vertical and transverse diameters of the squama were almost equal; the posterior surface was convex and raised into a mesial vertical ridge in its upper part, but on each side it showed a shallow concavity which extended to the side of each condyl. The foramen magnum was almost circular. The

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* *Marine Mammals in the Anatomical Museum of the University of Edinburgh,* pp. 21, 22, 1912.

condyls were separated behind by a marked interval, but were only an inch asunder in front. The exoccipital extended outwards from the condyl to the squamous temporal.

The *frontal* contributed only a narrow edge to the vertex, but broadened on each side and ended in a strong bar which formed at its outer end the upper border of the orbit with the pre- and post-orbital processes, the latter of which was the larger. The malar and lachrymal bones had not been preserved in the skull from the skeleton, and the boundary of the orbit was incomplete. (See p. 919 for orbit in separate skull.)

The *parietal* did not reach the vertex, and articulated by its upper border with the lateral border of the occipital squama. It was seen on the side of the cranium locked between the frontal and squamous temporal.

The *squamous temporal* was a massive bone nearly equal in vertical and transverse diameter, which gave breadth to the posterior part of the cranium. It ended externally in two blunt processes, the anterior of which was a little behind the orbital part of the frontal, whilst the posterior and most depending process provided the shallow glenoid concavity, one foot 2 inches in diameter, for the temporo-mandibular joint. The petrous temporal on the under surface of the cranium was locked between the squamous temporal and exoccipital.

TABLE I.

Measurements of Skulls of Balænidæ.

	B. biscayensis.				*B. mysticetus.*			
	R. S. M.		U. An. Mus.		U. An. Mus.		U. An. Mus.	
	ft.	in.	ft.	in.	ft.	in.	ft.	in.
Length, condylo-premaxillary, in straight line,	12	6½	13	9	11	5	8	0
,, ,, over vertex curve,	15	0	16	0	13	2	...	
,, from glenoid to tip of premaxillary,	11	5½	12	7	10	3	7	4
,, of superior maxilla,	10	5	11	3½	9	8	...	
,, of premaxilla,	11	1	11	7¼	10	2½	...	
,, of rostrum in straight line,	9	6	10	2	8	7½	...	
,, from tip of premax. to middle of upper orbital border,	11	3	12	4	10	1	7	3
Breadth in squamoso-occipital region in straight line,	7	7½	8	2½	5	7	4	2
,, in frontal region between post-orbitals in straight line,	8	2½	8	10	5	7	4	2½
,, base of rostrum in straight line,	2	11	3	1	1	9	..	
Occipital bone, greatest breadth,	3	6	3	11	3	1½	2	8
,, ,, height from foramen magnum,	3	2½	3	3	2	5	1	10
,, ,, ,, from back of condyl,	3	10	3	9	2	9	...	
,, ,, ,, of foramen magnum,	0	5	0	6	0	5¾	0	4
,, ,, breadth of foramen magnum,	0	5	0	5½	0	4¼	...	
Between pre- and post-orbital processes,	0	7½	0	8	0	6	0	5½
Nasal bone, length mesially,	1	1	1	0	1	0¼	...	
,, ,, greatest breadth of each nasal,	0	6	0	7¾	0	5¼	...	
Anterior nares, greatest breadth,	1	3	1	5	0	10	...	
,, ,, long diameter,	2	3½	2	5	2	1½	...	
Posterior nares, vertical diameter,	0	8¼	...		0	5½	0	2
,, ,, transverse diameter,	1	1	...		0	8	0	8
Hard palate, length along curve,	12	10	...		11	3	...	
,, ,, greatest breadth,	2	6	2	8	1	8	...	
Mandible, length of outer surface of ramus,	13	2½	13	6	...		...	
,, chord of arc of ramus,	11	8½	12	5	...		7	9½
,, girth in front of condyl,	3	1½	3	7	...		2	2¼
,, vertical depth, 3 feet in front of condyl,	1	3½	1	4½	...		0	8½
,, ,, 4 feet behind free end,	0	11	0	11	...		...	
,, diameter of condyl,	1	2	1	2	...		...	

The facial part of the skull formed the rostrum, or beak, highly arched from behind forwards. The *superior maxilla* articulated at its nasal end with the frontal; it widened laterally into a triangular plate which passed downwards and outwards parallel to and in front of the strong bar of the frontal. The plate did not overlap the outer surface of the frontal, but was prolonged below its deeper surface, and ended externally in a pointed apex 6 inches internal to the pre-orbital process of the frontal. Near the base of the plate the bone was pierced by five large foramina for the transmission of vessels and nerves to the beak. The superior maxilla formed the outer border of the rostrum to within 6 inches from the tip; it diminished in breadth from behind forwards, and its anterior end was about an inch broad; its upper surface was longitudinally grooved in the greater part of its extent. The base of the beak was not, as in the Odontoceti, definitely marked by a notch, but was indicated approximately by the most posterior of the large vascular foramina; it was about 3 feet broad.

The *premaxillæ* extended from the frontal at the vertex to the tip of the beak; they were arched from behind forwards, and convex from side to side. In breadth each bone attained a diameter of from 8 to 9 inches, and as they were longer and broader than the superior maxillæ they formed the more noticeable constituents of the beak. A horizontal line drawn from the edge of the glenoid cavity to the tip of the beak formed the chord of the arc of the beak, and a perpendicular drawn from it to the outer border of the highest part of the arch of the superior maxilla measured 3½ feet.

The *nasal* bones were locked between and articulated with the premaxillæ and the frontal. Their long axis was almost horizontal, the upper surface was flattened, the under surface entered into the roof of the nose, the thickened posterior border was in line with the upper ends of the superior and pre-maxillæ, the anterior border was slightly concave and had a short projection at its mesial angle.

The *anterior nares* opened forwards in front of the nasals, their antero-posterior diameter was somewhat more than 2 feet, and their greatest breadth a little in front of the nasals was more than 1 foot; each side was formed by the inner surface of the premaxilla. On looking into the nares an ethmoido-turbinal was seen on each side, the anterior border of which was about 1½ foot behind the anterior border of the nasal. The vomer was not a mesial plate at the anterior nares, but was spout-like in form; its two lateral borders articulated with the premaxillæ, and its mesial groove lodged a thick band which represented a mesethmoid.

The *hard palate* had a strong mesial keel formed by the vomer, which was visible between the palatal surfaces of the superior maxillæ to within about 4 feet from the tip of the beak. The keel divided the palate into two equal lateral halves, each of which, concave from side to side and from before backwards, contained foramina for vessels and nerves to supply the palatal mucous membrane and the baleen plates.* The hard palate along the curve was nearly 13 feet long, and its greatest breadth, measured in a straight

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* For an account of the structure and vascularity of whalebone, see my memoir on *Balænoptera sibbaldi* in *Trans. Roy. Soc. Edin.*, vol. xxvi., 1870.

line across the mesial ridge, was about 2 feet 6 inches. The pair of palate bones formed the hinder part of the hard palate; they articulated with each other mesially, and both the anterior and the outer borders articulated with the superior maxilla. The pterygoids were seen behind the palates and the posterior surface of each was hollowed into a sinus-like chamber.

The *posterior nares* had a transverse diameter about one-third greater than the vertical. The sharp posterior mesial border of the vomer, which did not extend so far back as the opening, was seen; it articulated below with the mesial borders of the palate bones, and in this region separated the nasal chambers from each other.

The *Mandible* consisted of two distinct rami not fused at the symphysis. The rami arched strongly outwards, and they enclosed a buccal chamber of large dimensions for the lodgment of the tongue, whilst the high arching of the palate permitted the vertical growth of the long baleen plates in this cetacean. The outer surface of the ramus was convex; the inner, almost a plane surface, had a large dental foramen, the edge of which projected upwards in front of the condyl, also other smaller foramina for vessels and nerves; the upper and lower borders were narrow. A horizontal line drawn from the condyl to the tip of the arched ramus gave the chord of the arc, and a perpendicular from it to the upper border of the bone measured 1 foot 9 inches. The condyl was smooth and was defined by a neck; the coronoid process was not developed. The rami were free and pointed at their anterior ends, which had doubtless been connected together by fibrous bands.

Hyoid bone.—The body, great cornua (thyro-hyals), small cornua (cerato-hyals) were fused together and formed a bone, convex on the ventral, concave on the superior surface (fig. 17). It measured between the tips of the great cornua 2 feet 4 inches along the convex surface, and 1 foot 11½ inches in a straight line. The great cornu was somewhat cylindriform, 1 foot 1¼ inch in girth. The small cornua projected for 1½ inch from the anterior border close to the mesial plane, and were only one inch asunder. The stylo-hyals had not been preserved.

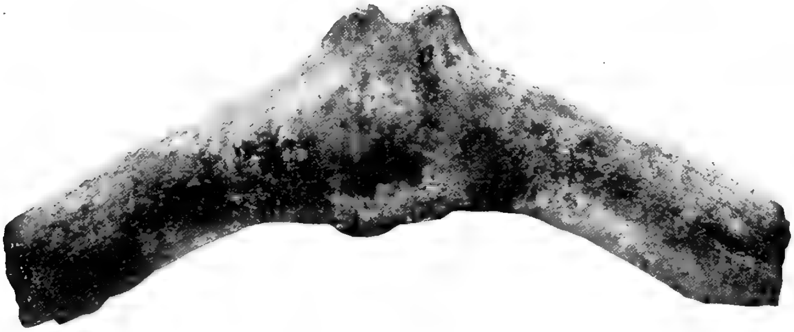

FIG. 17.—Hyoid bone.

In the general form and construction of its skull *B. biscayensis* corresponded with *B. mysticetus*, but owing to the much longer baleen plates in the latter the head was higher and the mouth was deeper and wider. In comparing the measurements of the two species in Table I., it should be kept in mind that the skulls of the Biscay Whale were adult; those of *mysticetus* were immature—the one with the mandible was from a young skeleton, about 25 feet long, and therefore not quite half the length of the adult, whilst the other, with a skull 11½ feet long and without the mandible, was from an older though not an adult animal, perhaps about 40 feet long.*

In *biscayensis* the smaller adult skull was 12 feet 6½ inches long, and its breadth in the fronto-orbital region was 8 feet 2½ inches, the breadth being about two-thirds the length, whilst in the larger *mysticetus* the breadth, 5 feet 7 inches, was about half the length, 11 feet 5 inches, which doubtless is a specific difference. The occipital squama differed in the two species; in *biscayensis* the greatest breadth of the posterior surface was somewhat more than the height measured from the foramen magnum, whilst in *mysticetus* the breadth was yet greater than the height. The character of the posterior surface of the squama was also different: in *biscayensis* the mesial vertical ridge, narrow below, expanded laterally about the upper half, but was bounded on each side by a broad concavity; whilst in *mysticetus* the mesial ridge expanded in the upper part to form an almond-shaped convexity which occupied a considerable proportion of the squama and left room for a relatively narrow lateral concavity. In *biscayensis* the breadth of the skull in the squamoso-occipital region was less than in the fronto-orbital, and the post-orbital process projected beyond the anterior process of the squamous temporal; in *mysticetus* these diameters were practically the same, and the squamous temporal, pre- and post-orbitals, and the external apex of the superior maxilla were almost in the same antero-posterior vertical plane. In *biscayensis* the nasal bones were somewhat broader in relation to their length, their posterior border was transverse to their long axis and not indented, and the anterior nares were wider than in *mysticetus*; whilst in the latter the posterior border was pointed and indented, and two processes from the frontal extended forwards between the nasal bones for 3 inches.

Figures of the skulls of European examples of the North Atlantic Right Whale had previously been given by GASCO for the Taranto specimen; by DE LA PAZ GRAELLS for the specimen in the Cabinet of Secondary Education at San Sebastian, who also figured the mandible of one preserved in the Institute at Gijon in Asturias.

The external characters of the American Right Whale from New Jersey have been figured by HOLDER, as well as the skulls of the Charleston and New York specimens; TRUE in Plates 42 to 46 figured the skulls of the New York and Charleston examples, also COPE's type specimen of *B. cisarctica*, and the head of one caught off Cape Cod in April 1895. VAN BENEDEN figured in Plates I. and II. of the *Ostéographie* the skull and skeleton of *B. australis* in the Paris Museum of Natural History, and in

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* These crania are catalogued in my *Marine Mammals in the Anat. Mus. of the University*, pp. 21, 22, London, 1912. As the skeleton of the smaller mysticete was suspended in the Museum at a considerable height, difficulty occurred in making complete measurements.

Plate III. the bones of the so-called *B. antipodarum* in the same Museum; he did not reproduce the skull of *B. biscayensis*, for, as is shown in Plate VII., he had access to only a few bones of the skeleton.

Tympano-petrous Bones.—From the study of these bones in the Cetacea[*] it is obvious that importance is to be attached to their size, form and markings in estimating specific characters. The *Tympanic bone* in *Balæna mysticetus* was massive; in the adult it was from 5 to 6 inches long, from 3 to 4 inches broad, and between 4 and 5 inches in vertical diameter. The outer surface was divided into two unequal convex portions, the posterior of which was much the larger, by a long, wide and deep oblique groove; from its upper border a lip-like process, bounded behind by a groove, projected for the attachment of the malleus; the lower part of the outer surface showed a shallow concavity and ended inferiorly in a strong keel, which extended the length of the bone (Plate III. fig. 11). The inner surface was convex and striated with vertical grooves; its upper border was almost horizontal, moderately thick as compared with the same border in Balænoptera, and was rounded into the tympanic cavity, its anterior end was slightly notched for the Eustachian tube (Plate III. fig. 13).

The description of the tympanic in *B. biscayensis* is based on the examination of three specimens, which in their general form have the characters of Balæna and not of Balænoptera. They varied in length from $5\frac{3}{8}$ to $5\frac{5}{8}$ inches, in breadth from $3\frac{3}{8}$ to $3\frac{1}{2}$ inches, in vertical diameter from $4\frac{3}{8}$ to $4\frac{1}{2}$ inches; in all, the height was greater than the breadth. *B. biscayensis* differed from *mysticetus* in the anterior division on the outer surface being more rounded, in the lip-like process from the upper border being defined behind by a deep notch and not by a short groove, in the posterior border being more rounded and less ridge-like than in *mysticetus*, in the anterior border being more gently continued into the keel and the junction not being almost rectangular as in *mysticetus*, in the latter of which the keel was prolonged further forward (fig. 10). The striated part of the inner surface was more flattened in *biscayensis*, its upper border was thinner and more oblique, and it terminated anteriorly in a distinctly deeper Eustachian notch than in *mysticetus* (fig. 12).

When compared with two tympanics of *B. australis* a striking resemblance in general form with *biscayensis* was observed. Also in the details of the outer surface, in the deep notch defining the posterior border of the lip-like process, in the rounding off of the posterior border into the keel, in the obliquity of the upper border of the inner surface, and in the depth of the Eustachian notch *B. biscayensis* and *australis* closely corresponded, though the striated part of the inner surface in *australis* was not so flattened as in *biscayensis*, and its upper border was relatively thin (fig. 14). In all the essential characters, therefore, the tympanics of these animals were practically alike. In the genus Balæna the height of the tympanic was materially greater than the breadth, whilst in Balænoptera these dimensions were almost equal.

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[*] I may refer to my recently published volume, *Marine Mammals in the Anatomical Museum of the University of Edinburgh*, London, 1912, for observations on and figures of the tympanic bones in many species of the Cetacea.

The *Petrous bone* was fused in two places with the tympanic in *B. mysticetus*, *biscayensis* and *australis*: the more anterior was in front of the great oblique groove at the upper border of the anterior division of the outer surface; the more posterior was fused with the upper part of the inner surface close to the opening into the tympanum. The *periotic* proper constituted a small proportion of the petrous, and was situated opposite and internal to the opening into the tympanum. It was formed of hard dense bone, and in *B. mysticetus* measured $2\frac{3}{8}$ inches by $1\frac{3}{8}$ inch; in *biscayensis* $2\frac{3}{4}$ by $1\frac{3}{4}$; in *australis* $2\frac{7}{8}$ by $1\frac{7}{8}$. The three species closely resembled each other in the characters of the periotic proper: the inner or cranial surface was jagged and marked by the canals or foramina for the auditory vessels and nerves; the outer or tympanic surface showed the fenestra ovalis for the stapes. The inferior surface of the petrous was relatively smooth; the superior surface was more spongy in character and articulated with the cranial wall. In *mysticetus* the so-called mastoid was 6 inches long, in *biscayensis* $4\frac{1}{2}$ inches, and in *australis* $8\frac{1}{2}$ inches.

Two of the *Tympanic ossicles* were present in more than one specimen. The Malleus was fused with the lip-like process of the tympanic, the Incus articulated with the malleus, the Stapes was absent.

The tympanic ossicles of the Taranto *biscayensis* were figured by CAPELLINI and GASCO in their respective memoirs on this animal, and the malleus and incus from one of my crania are figured in Plate III. fig. 15.

VERTEBRAL COLUMN.

I arranged the bones of the spine in groups with the bodies in contact with each other. The vertebral plates, with few exceptions, were either wholly or partially fused with their bodies; the intervertebral discs were fused with the cervicals, but were otherwise absent. The length of the spine from the atlas to the terminal caudal, in a straight line, was 26 feet 8 inches. Had the discs been in place the length would probably have been from 30 to 31 feet. The condition of ossification showed that the whale had reached maturity. The vertebral formula was $C_7D_{14}LCd_{35} = 56$. The vertebræ were weighty in relation to their size, as also in *Balæna mysticetus*.

Cervical Region.—The seven cervical vertebræ with their discs were fused into a mass of bone, in which the constituent vertebræ could readily be recognised, though the fusion of the anterior six with each other was much more complete than that of the 6th with the 7th, for in these two the osseous union was limited to their inferior or ventral surfaces, where an osseous outgrowth united the two bodies (Plate II. fig. 6). The length of the cervical mass, measured on the ventral aspect, was 13 inches, the greatest width between the tips of the transverse processes of the atlas was 2 feet 3 inches. The anterior surface of the atlas possessed two separate articular concavities for the occipital condyls, the diameter between their outer borders was 14 inches, and the vertical diameter of each was 11 inches. The spinal foramen was $5\frac{1}{4}$ inches broad and 7 inches vertically. The spines of the anterior six cervicals were fused together, also the laminæ from the 1st to the 3rd, but the laminæ of the 4th to the 6th were free. The laminæ of the axis formed a plate 6½ inches broad (fig. 6). The spine and laminæ of the 7th cervical were not fused with the 6th.

The transverse processes had several interesting features. In the Atlas a massive process, not perforated, represented the diapophysis or superior transverse process of the vertebra (fig. 7). It was fused near its outer end with a corresponding process of the axis, which arose by two roots, of which the anterior joined the above process of the atlas, whilst the posterior was fused with the superior transverse process of the 3rd vertebra; the roots were distinct at their origin, and bounded an ovoid foramen 2 inches in diameter. The superior transverse process of the 3rd was also fused with one from the 4th cervical. That from the 5th was partially fused with one from the 6th, and in these cases an elongated ovoid foramen intervened, where the fusion was incomplete. The superior transverse process of the 7th was not fused and was broad at its outer end.

In the Atlas the inferior transverse process or parapophysis, 4½ inches long, was situated 2 inches below the flattened superior process. That from the Axis projected for 4 inches from the body. The corresponding inferior processes from the 3rd and 4th vertebræ were not symmetrical on opposite sides. The right side of the 3rd possessed a slender inferior process 4 inches long, which was fused at its outer end with the corresponding process of the axis. From the right side of the body of the 4th a tubercle about an inch long represented the inferior transverse process; the 3rd and 4th cervicals had no corresponding inferior processes on the left side, and the 5th, 6th, and 7th had none on either side of the body. The outer ends of both the diapophyses and parapophyses were free, and in no vertebra did they join to form a large lateral foramen, on the side of the cervical spine, which, in the adult Balænopteridæ, were occupied by the arterial meshwork of the rete mirabile.*

Dorsal Region.—Fourteen vertebræ possessed costal articular surfaces. Those on the 1st dorsal were relatively thin at the free end of each transverse process. The 2nd and 3rd dorsals had similar articular surfaces. In the 4th to the 10th the transverse process was thickened and articular at its free end, and in addition a distinct costal articular surface was present on each side of the body near its posterior border. The 11th to the 14th had no costal surfaces on the sides of the body, the 11th and 12th transverse processes, broad, flat, and long, had each a costal articulation at its outer end; in the 13th and 14th dorsals the transverse processes, also articular, were long and narrow, and thickened at the end. The spines of the dorsal vertebræ were as a rule large plates flattened laterally and truncated at the free end, but the 1st to the 3rd were somewhat pointed. The anterior articular processes were strong and directed forwards and upwards. The ventral surface of the body from the 7th to the 12th had an antero-posterior mesial ridge.

As regards dimensions, the dorsal vertebræ increased in size from before backwards.

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* See my memoir on *Balænoptera sibbaldi* (*op. cit.*), 1870.

The height of the 1st from the ventral surface to the free end of the spine was one foot 9 inches, that of the 14th was 2 feet 4½ inches; the breadth of the 1st between the free ends of the transverse processes was 2 feet 4½ inches, that of the 14th was 3 feet 3¼ inches. The transverse diameter of the body of the 1st was 10½ inches, that of the 14th was 12 inches; the vertical diameter of the body of the 1st was 9 inches, that of the 14th was 9½ inches. The length collectively of the bodies of the dorsal vertebræ, measured in a straight line, was 7 feet.

Lumbo-caudal Region.—Thirty-five vertebræ were present between the last dorsal and the terminal caudal. Of these, I regard the 22nd to the 33rd, both inclusive, twelve in number, as *Lumbar*, although the 33rd had an indication of an articulation for a chevron bone at the posterior border of its ventral surface. The lumbars were the largest vertebræ (fig. 8), and if we take the 7th as a type of the series, its height from the ventral surface to the free end of the spine was 2 feet 5 inches, and its breadth between the free ends of the transverse processes was 3 feet 5½ inches; the transverse diameter of the body was 12½ inches, and its vertical diameter was 11 inches. The spines in the series were flattened laterally and usually truncated at the free ends, but in the 11th and 12th they tapered a little. The transverse processes, flattened from above downwards, projected in the middle part of the region about 15 inches from the body. The anterior articular processes, strong and flattened laterally, projected forwards and upwards. The ventral surfaces of the bodies from the 3rd to the 11th had a mesial antero-posterior ridge. The length of the collective lumbar bodies, measured in a straight line, was 8 feet 2 inches.

The *Caudal* vertebræ were twenty-three in number. The anterior eleven possessed spines, and eight of these had also transverse processes, which like the spines diminished in projection and size from before backwards. The vertebræ which followed the above, representing only the bodies, were flattened on the anterior and posterior surfaces, were circular in outline, and the largest resembled in form curling-stones without a handle (Plate II. fig. 9). They gradually diminished in size, the most anterior was 10 inches in diameter, the last two were fused with each other, the penultimate was 2½ inches by 2¼ inches, the last was a nodule 1½ inch broad at its base, but tapered to a point behind; from its appearance and size no other bone had been posterior to it. The 5th and the succeeding caudals with transverse processes were pierced by a vertical foramen at the root of each process, whilst in those still more posterior each side of the body was perforated by a vertical canal as far as the third from the end. The length of the caudal bodies, measured in a straight line, was 10 feet 4 inches.

Chevron Bones.—Judging from the articular surfaces visible on the ventral aspect of the bodies of the caudal vertebræ, eleven or twelve chevron bones had been present, and of these ten had been preserved. In eight the two originally distinct lateral plates had fused together to form a mesial ventral spine, which enclosed the caudal vascular canal. The upper ends of these plates were thickened and articulated with their respective vertebræ, so that each chevron belonged to two vertebræ with the intervertebral cartilage. The larger chevrons were massive and ranged in dimensions from 11 to $9\frac{3}{4}$ inches in vertical diameter and from $7\frac{1}{2}$ to $6\frac{1}{2}$ in transverse diameter across the basal articulation. The smallest chevron was $5\frac{1}{4}$ by $6\frac{1}{4}$ inches (fig. 18). In two bones the lateral plates were not fused together mesially and there was no spine; in the larger each plate was 6 inches by 4 inches; in the smaller, $3\frac{1}{2}$ inches by 3 inches.

FIG. 18.—Chevron bones.

In this skeleton the number of vertebræ corresponded with those recorded in the European skeletons of this whale which GASCO, in the specimen from Taranto, and GULDBERG, in two from Iceland, had examined and described. In these the cervicals numbered seven, and the dorsals fourteen, except perhaps in that captured at San Sebastian in 1854, where the number of dorsals was said by GASCO to be thirteen.* The skeletons of *B. cisarctica* chronicled by TRUE from the American coast also had fourteen dorsals. With these numbers the skeleton now described is in accordance. Twelve is the customary number for the lumbar vertebræ, and twenty-three, or in one specimen twenty-four, for the caudals. In the skeleton described in this memoir, the vertebra which I have regarded as the 12th lumbar had a partial articulation at the posterior border of its ventral surface for a chevron bone. Some might be disposed to regard it as the 1st caudal, which would reduce the lumbars to eleven bones, and would add this vertebra to the caudal series. The formula of the adult spine of the North Atlantic Right Whale is $C_7D_{14}L_{12}Cd_{23}=56$. GASCO has figured the block of cervical vertebræ of the immature Taranto *biscayensis*, as well as representatives of the other groups of vertebræ in which the vertebral plates were not ossified to the bodies.

We are now in a position to examine the proportion of each region of the spine to its entire length, and of the length of the skull to that of the vertebral column. The block of *cervical vertebræ*, 13 inches long, represented the thickness of both the bodies of the vertebræ and their ossified intermediate discs. On an estimate that the entire spine

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* One dorsal had probably not been preserved.

with its intervertebral cartilages was about 30½ feet long, it was 28 times longer than the cervical spine. As the individual vertebræ of the neck were immobile on each other, movement in this region was restricted to the occipito-atloid articulations and to the joints between the 7th cervical and the 1st dorsal vertebra. The head therefore, large and weighty, was articulated by a movable joint at the anterior end of the spine to a compact mass of bone formed of the seven cervical vertebræ and ossified discs.

The length collectively of the bodies of the *dorsal vertebræ* was 7 feet, to which 18 inches may be added as the probable thickness of their intervertebral cartilages, together about 102 inches. The entire spine was from 30 to 31 feet long, about 3½ times longer, therefore, than the dorsal vertebræ plus their cartilages. The dorsal region was characterised by the mobility of the vertebræ on each other and by that of the ribs on the vertebræ during respiration.

The length collectively of the bodies of the *lumbar vertebræ* was 8 feet 2 inches, the thickness of their intervertebral cartilages was probably 19 inches, together 117 inches. The entire spine was about 3 times longer than the lumbar vertebræ with their cartilages.

The collective length of the bodies of the *caudal vertebræ* was 10 feet 4 inches, that of their intervening cartilages was possibly 12 inches, together 136 inches. The entire column was about 2¾ times longer than the caudal region. The length of the entire lumbo-caudal region was 253 inches. The bones of this region have attached to them the powerful muscles concerned in the movements of the hinder part of the body of the whale, more especially in the working of its broad tail, so that more than one-half the length of the spine takes a part in locomotion, and enables a speed of 8 to 10 or even a greater number of miles an hour to be obtained.

In the specimen with the spinal column, the skull proper, in a straight line from the occipital condyl to the tip of the premaxilla, was 12 feet 6½ inches long. As the free ends of the mandible apparently projected slightly beyond the premaxillæ, the skull was longer by a few inches, and may be at least 13 feet (156 inches). The entire vertebral column was about 2⅓ times longer than the skull.

The skeleton, including the skull, mandible, and intervertebral discs of this adult male was probably about 44 feet long, and if one were to add a foot as representing the thickness of the soft parts at the mandibular and caudal ends, the estimated length of this specimen was about 45 feet, so that the proportion of the head was somewhat more than one-fourth the entire length of the animal.

In *Balæna mysticetus* the vertebral column usually contained 55 vertebræ, though 56, or only 54, have been noted. They are grouped as follows: $C_7D_{13}LCd_{35}$ or $_{36}$. The cervicals, as in *biscayensis* and *australis*,* are fused together as a large block. ESCHRICHT and REINHARDT have shown that in the new-born *mysticetus* and in the fœtus the cervicals form one undivided mass of cartilage, so that the fusion is funda-

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* I have described the cervicals of *B. australis* from New Zealand in my *Challenger Report* on the Bones of the Cetacea, *Reports, Zoology*, part iv., 1880.

mental. It constitutes, therefore, a marked difference from the Fin Whales, in which these vertebræ are distinct from each other in the fœtus.* I know of no observations on these vertebræ in the fœtus of the other species of Balæna, though doubtless they corresponded in their development with *mysticetus*.

As the dorsal vertebræ were provided with costal articulations, their number corresponded with that of the pairs of ribs. The customary number in *mysticetus* was 13, though Eschricht and Reinhardt saw a rudimentary 14th rib in a fœtus, and in a young individual only 12 pairs of ribs were present. In the adult *biscayensis* described in this memoir 14 dorsals were seen, which corresponded with the number already referred to on page 907 in other skeletons, so that both in its dorsal vertebræ and in the pairs of ribs this whale differed from *mysticetus*.

I have stated on page 907 that the precise separation between the lumbar and caudal regions is associated with the position of the most anterior chevron bone, and I have regarded that vertebra as the 1st caudal, the ventral surface of the body of which articulated with both the 1st and 2nd chevrons, whilst the vertebra immediately anterior, which articulated with only half the 1st chevron, is regarded as the 12th lumbar. In their great memoir on the Greenland Right Whale Eschricht and Reinhardt had previously reached the same conclusion, for they said that the 1st caudal can only be distinguished from the last lumbar by both its anterior and posterior borders on the ventral surface of the body being provided with articular facets for chevron bones. The lumbo-caudal formula in *mysticetus* is $L_{13}Cd_{22}$, in *biscayensis* $L_{12}Cd_{23}$. Here also is a specific difference, though not of the same importance as the difference in the number of dorsal vertebræ and ribs in the two species, for the caudals in the same species are subject to variations in number in some individuals. In the seven skeletons tabulated by True of the vertebræ in the American Right Whale, six had the formula L_{11}, and in five the caudals ranged from 23 to 25, the complete formula being $C_7D_{14}L_{11}Cd_{23\text{ to }25}$, in all 55 to 57 vertebræ. In the number and grouping of its vertebræ this whale (*B. cisarctica* of Cope) corresponded essentially with *B. biscayensis*.

In *B. biscayensis* and *B. australis* the head has been regarded as one-fourth the total length of the animal, though in this specimen of *biscayensis* the skull was between one-third and one-fourth of the computed total length. On the other hand, in *B. mysticetus* the head is described as one-third of the total length.

Ribs.

Fourteen pairs of Ribs were present, which corresponded in number with the dorsal vertebræ. All the ribs articulated with the dorsal spine, either to the transverse processes only, or to both the bodies and the transverse processes. Only the 1st pair articulated with the sternum, as is customary in the whalebone whales, and the others

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* I found this to be the case in an advanced fœtus of a *Balænoptera sibbaldi* dissected in 1869–1870. The fœtus is described in *Trans. Roy. Soc. Edin.*, 1870.

came to a free end ventrally. They formed a series of arches which entered into the construction of the sides of the thorax. As they varied so greatly in length, I give in Table II. the length of the right ribs measured along the outer convex surface from the vertebral end to the ventral end, as well as the chord of the arc between its two extremities; the measurements give the dimensions in feet and inches.

TABLE II.

	1st Rib.	2nd Rib.	3rd Rib.	4th Rib.	5th Rib.	6th Rib.	7th Rib.
Length of Rib	4 8¼	6 8¾	7 10	9 8½	10 1	10 2	10 1
Chord of Arc	3 9	4 8½	5 4½	5 7	6 1	6 1	5 9

	8th Rib.	9th Rib.	10th Rib.	11th Rib.	12th Rib.	13th Rib.	14th Rib.
Length of Rib	9 8	9 1½	8 7½	8 0	6 11	5 4½	2 0½
Chord of Arc	5 10	5 7¾	5 8	5 6¾	5 5	4 6	2 0

The right 1st rib was 7 inches broad at the sternal end, the vertebral end was attenuated and articulated with the transverse process of the 1st dorsal, the surfaces were flattened and the margins were rounded. The left was about 3 inches shorter than the right. The ribs increased in length and in curvature from the 1st to the 6th, and then diminished gradually to the 14th, which was almost straight and was the shortest member of the series. The 2nd and 3rd articulated with only the transverse processes of their respective vertebræ. The 4th to the 10th inclusive had each developed a neck which extended inwards beyond the surface of articulation for the transverse process, and reached the side of the body of its vertebra, to which it had been articulated; it constituted the proper head of the rib; whilst the articular surface for the transverse process represented the tubercle of the rib. The 11th to the 14th had each only one articular surface for the transverse process of its vertebra. No rib possessed two heads in the proper sense of the word, *i.e.* was provided with two necks springing from a common shaft, each of which ended in an articular head to reach its appropriate vertebra. The shafts of the 2nd to the 4th ribs were somewhat flattened, that of the 2nd was about 6 inches at its broadest part. Behind the 4th the shafts were more rounded and afterwards more slender. The 12th and 13th had the shafts twisted, and they and the 14th were pointed at the tip.

GASCO figured several ribs of the Taranto whale. GRAELLS represented in Plate III. of his memoir a profile and dorsal view of the skeleton of the *B. biscayensis* in the Cabinet of the Institute in San Sebastian.

Sternum.

The Sternum or breast-bone consisted, as in the Baleen Whales generally, of a single plate-like segment,* with which the 1st pair of ribs had articulated. The base or anterior border was deeply notched and the outline was cordiform, the posterior border was prolonged into a blunted apex, each lateral border was thickened in its anterior half and formed an articular surface for the 1st rib. The ventral surface was a little convex, and the superior or thoracic surface was concave. The greatest breadth at the base was 21½ inches, the length from the apex to the cordiform notch was 13 inches, and to the most projecting part of the anterior border 18¼ inches (fig. 19A). The cordiform sternum in *biscayensis* has been figured by Gasco and Guldberg, whose drawings have been reproduced by True. In *mysticetus* the sternum has been carefully described by Sir John Struthers.† In one specimen the base showed a shallow cordiform concavity, in the other the base was pointed. The latter bone, presented by him to the University Anatomical Museum, was 27 inches long by 20 inches at its broadest part; it had only one costal articulation on each side, and its posterior end was attenuated (fig. 19B).

Fig. 19A.—Sternum *B. biscayensis.*

Fig. 19B.—Sternum *B. mysticetus.*

The sternum of *B. biscayensis* has been figured by Capellini, Gasco, Guldberg and True; that of *B. mysticetus* by Eschricht and Reinhardt, Struthers and True.

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* I figured many years ago the sternum of a fœtal *Balænoptera sibbaldi* which had a small supplementary second segment (*Journ. Anat. and Phys.*, vol. iv., 1870, and *Marine Mammals, op. cit.*, 1912).

† *Journ. Anat. and Phys.*, vol. xxix., 1895. Fig. 19B is from one of his specimens.

Thorax.

The bony walls consisted of 14 dorsal vertebræ, 14 pairs of ribs, and the single segment of the sternum. Owing to the marked curvatures of the great majority of the ribs, the side walls of the chest arched outwards so as to enclose in a great chamber the heart, the pair of lungs, and other subordinate viscera. From the relatively feeble curve of the 1st pair of ribs, the thoracic inlet was laterally compressed and somewhat ovoid in form (fig. 20, D1). Through their sternal attachment they could be fixed in inspiration by the action of the intercostal and other muscles attached to them. Starting from the first pair, the intercostals attached to the ribs behind could elevate and rotate outwards their respective bones, so as enormously to increase the thoracic cavity laterally and dorsi-ventrally, whilst the diminution of the arch of the diaphragm would increase its capacity in the antero-posterior direction. The absence of a fixed attachment to bone of their ventral ends enabled these ribs on opposite sides to be drawn much further asunder than was their relative position during expiration, which also would materially contribute to the increase in size laterally of the thoracic cavity. If in man, where seven pairs of ribs articulate ventrally with the sternum, the expansion of the lungs and of the thoracic capacity is three or even four times greater at the end than at the beginning of a full inspiration, there can be little doubt that in the large Cetacea with a single-segmented sternum the expansion of the lungs and chest-wall will be proportionally larger. It is through the thoracic construction, therefore, that the great whales during inspiration are enabled so to distend the air-cells

Fig. 20.—1st and 6th dorsi-costal segments.

of the lungs prior to diving, that they can remain below the surface of the sea for 5 to 10 minutes, or even 20 minutes or longer when feeding, as was observed by SCORESBY. The same authority also related that when struck by the harpoon they can descend to a depth of 400 fathoms, and under special circumstances to 700 to 800 fathoms.

An idea may be formed of the capacity of the thorax in the state which corresponds with complete expiration by articulating to a dorsal vertebra the first pair of ribs which belong to it, and by adapting the sternum between their ventral ends (fig. 20). The 1st dorsi-costal segment was 3 feet 5 inches in its greatest transverse diameter, and 3 feet 3½ inches in its dorsi-ventral diameter. These measurements gradually increased to the 6th segment, in which the ribs had the maximum length and curve, when the transverse diameter was 7 feet 4 inches and the dorsi-ventral 5 feet 6 inches (fig. 20, D6). Further back the length and curve gradually diminished, and in the 14th segment the ribs were so short and had so feeble a curve that they exercised practically no influence on the dimensions of the thorax. In *biscayensis* as in *mysticetus* the thorax in its general form was barrel-shaped, due to the wide curve of the majority of the ribs, which contrasted with the form of the skeleton in the Fin Whales (Balænopteridæ), in which the side walls were more flattened. HOLDER, who figured the entire skeleton of the New York Right Whale, saw 14 pairs of ribs in it and in the other skeletons described in his memoir. Another specific distinction between *biscayensis* and *mysticetus* is therefore to be recognised. The ribs of *B. australis* have been figured by VAN BENEDEN.

PECTORAL LIMB.

Scapula.—A large plate-like bone which measured 4 feet 1½ inch in length between the anterior and posterior angles, and 3 feet ½ inch in glenoido-vertebral

FIG. 21.—Right scapula, dorsum.

breadth. The glenoid cavity was shallow and measured 12½ inches in height by 11 in breadth. The outer surface of the bone was marked by a faint ridge close to the anterior border which indicated a rudimentary spine; the acromion, 9½ inches long, sprang from the bone at the anterior end of this ridge, its surfaces were flattened, 5 inches broad, and the free end was truncated (fig. 21). The inner surface was flattened. The anterior border was slightly concave, the posterior or glenoid border was concavo-convex, and the vertebral border was strongly convex. The anterior angle was more pointed than the posterior; the bone was 2½ inches thick at these angles, and the vertebral border in places was 2 inches thick. The coracoid process was feebly indicated. The scapula has been figured by Capellini, Gasco, Graells, Holder and True. In *B. mysticetus* the coracoid is a distinct process.

Humerus.—Short in relation to its bulk. Head large, articular surface smooth and convex, tuberosity large and projecting externally; neck a shallow constriction. The bone was one foot 9 inches long, the girth around the head and tuberosity 3 feet 9 inches. The shaft was short and 2 feet 2 inches in girth. The breadth at the lower end was one foot 2 inches. The radial and ulnar articular surfaces were distinct and separated from each other by a ridge; the radial surface was 8 inches and the ulnar 5 inches wide. The epiphyses were fused with the shaft (fig. 22).

Radius.—A bone with flattened surfaces; the outer border was almost straight, the interosseous (inner) border was concave. Its length was one foot 10½ inches, its breadth at humeral end 10 inches, at carpal end 14 inches, the girth in the middle of the shaft was one foot 8 inches. The upper epiphysis was fused with the shaft, the carpal epiphysis was ossified and partially fused with the shaft (fig. 22).

Ulna.—The surfaces of the bone were more flattened in the lower than in the upper half, the inner border was markedly concave, the interosseous (outer) border was sinuous. The length was one foot 6½ inches, the girth in the middle of the shaft was 11¾ inches. The humeral articular surface was 5¼ inches wide, and a short thick olecranon process projected at its inner end; the upper epiphysis was fused with the shaft. The carpal end was 12 inches wide, and its epiphysis, though ossified, was only partially fused with the shaft (fig. 22). In *B. mysticetus* the olecranon was prominent and associated with the humeral articulation, and the bones of the forearm were longer than the humerus.

Manus.—The Hand was pentadactylous and consisted of carpus, metacarpus and phalanges (fig. 22). The carpus was for the most part a mass of cartilage about 2 feet in breadth and one foot in vertical diameter; its ossification was limited and unsymmetrical in the two limbs. In one carpus only two bones were detected, in the other only one bone was seen. On the surface of the cartilage indented lines were present which mapped it into areas, not at all times distinctly defined. The study of the manus was greatly assisted by photographs taken by Mr Arthur Edwards after he had removed the integument. In the proximal part of the cartilage a distinct area was seen immediately opposite the interval between radius and ulna; in one carpus a rough nodule of bone, $5\frac{1}{2}$ by $3\frac{1}{2}$ inches in diameter, was imbedded in but did not reach the surface of the cartilage, in the other the cartilaginous area was defined, but it had no ossification, it represented the carpal intermedium. To its ulnar side an unossified area represented the ulnare, and from it a cartilaginous projection constituted the pisiform, *p*.

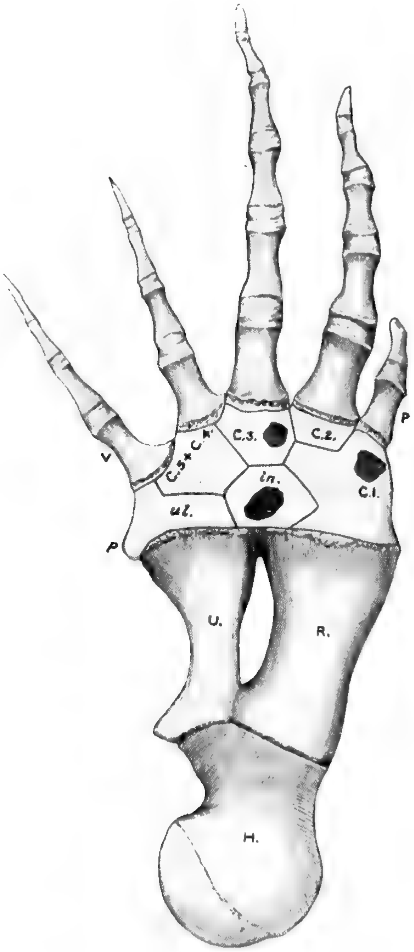
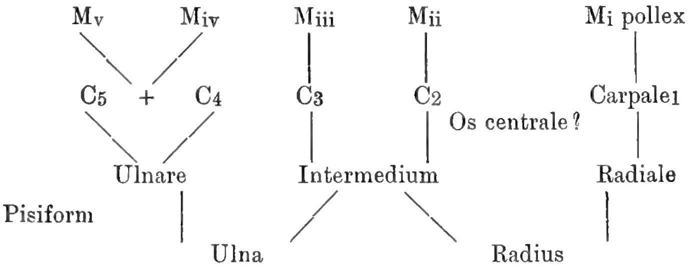


FIG. 22.—Pectoral limb, *B. biscayensis.*

On the radial side of the intermedium was a mass of cartilage imperfectly mapped into areas, the proximal part of which represented the radiale; the distal part was jointed to the metacarpal of the pollex, P, and in one carpus a rough nodule of bone $5\frac{1}{2}$ by 4 inches occupied it which was doubtless distal carpale$_1$, but in the other carpus it was not ossified. A prolongation of the cartilage between the intermedium and carpale$_2$ was possibly a potential os centrale.

The distal part of the carpal cartilage was also mapped into areas: one associated with Metacarpal$_{ii}$ represented carpale$_2$, another with M$_{iii}$ carpale$_3$, another and larger with M$_{iv}$ and M$_v$ represented carpalia$_{4+5}$. In one carpus the distal carpalia were unossified, in the other a nodule of bone 3 by 2½ inches was concealed in the cartilaginous distal carpale$_3$.*

CARPO-METACARPAL FORMULA.



In the human hand, where the metacarpals are enveloped by the common integument of the palm, and the phalanges, constituting the skeletons of the free digits, have a separate covering of skin for each digit, it is customary to regard the metacarpals as belonging to the palm and to dissociate them from the digits proper. In the Cetacea, again, both metacarpals and phalanges have a common tegumental covering, and each digit consists of both its metacarpal and phalangeal elements. The formula may be represented as follows:

Minimus.	Annularis.	Medius.	Index.	Pollex.
Ph_3	Ph_3	Ph_3 or 5	Ph_4 or 3	Ph_2 or 1
|	|	|	|	|
M	M	M	M	M

The two hands were not uniform in the number of phalanges in the pollex, index, and medius. The length of the metacarpo-phalangeals was obtained by placing the bones of each digit in order, allowing intervals between them to represent the thickness of the intermediate joints, the size of the intervals being estimated from the scale on the photographs of the digits taken by Mr EDWARDS. The metacarpo-phalangeals of the pollex measured 11 inches; index 2 feet 9 inches; medius 3 feet 5¼ inches; annularis 2 feet 3½ inches; minimus 2 feet. The pollex therefore was the shortest and the medius was much the longest digit.

As regards the length and general bulk of the metacarpals, M_{ii} was the biggest, and the others in order as follows: M_{iii}, M_{iv}, M_v, M_i. The ends of the bones were more expanded than the shafts, they were rough, and no separate epiphyses were seen. The phalanges in each digit diminished in size from the first to the terminal, and the free end of the last was usually attenuated. The metacarpals and some of the phalanges at the proximal ends showed indications of an epiphysis almost completely fused with the shaft of the bone.

GASCO figured the skeleton of the pectoral limb in the Taranto specimen; the bones

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* I may refer to my memoirs in *Proc. Roy. Soc. Edin.*, vol. xxix. p. 687 and vol. xxx. p. 508, also to my book on *Marine Mammals* (*op. cit.*), for figures and descriptions of the manus in the Odontoceti.

of the shaft corresponded in form with those in my specimen, the carpal cartilage was not mapped by him into areas, no centres of ossification were observed, though a pisiform cartilage was seen. HOLDER figured the manus of the New York *B. cisarctica* with a pisiform, and with eight ossific nodules, four in the proximal and four in the distal carpal row. It is not said if this was seen in the manus before maceration, so that possibly the number and arrangement may be due to the articulator. VAN BENEDEN figured the carpus of *B. australis* in the Paris Museum, the radiale, intermedium and ulnare in the proximal row, three carpalia in the distal row which represented C_2, C_3, and C_4, also a pisiform. In the skeleton of the so-called *B. antipodarum* the three bones of the proximal row were figured, two distal carpalia which represented C^3 and C_4, also a pisiform.

ESCHRICHT and REINHARDT figured in *B. mysticetus* four carpal elements and in addition a pisiform. In Sir JOHN STRUTHERS's specimens* a similar arrangement was figured. It would seem as if three of these represented the three bones of the proximal row, though they varied as to the presence of ossific nodules. The fourth evidently belonged to the distal row, and was more especially associated with the second and third digits, so that it probably represented distal carpalia$_{2+3}$.

PELVIC BONES.

A pair of Pelvic Bones accompanied the skeleton, and, in addition, a right bone from another skeleton of the same species was received from Mr HERLOFSON by the Royal Scottish Museum. Each of the paired bones was $14\frac{1}{4}$ inches long in a straight line, but it was curved, convex on the one, and concave on the other surface. It consisted of a central body from which a long process projected towards the spine, another long process was directed ventrally, whilst a third process was so short that it might be included in the body. The body with the short process was triangular in form and 4 inches broad. The ventral process, 7 inches long, was somewhat twisted and ended bluntly. The superior process, 6 inches long, tapered to its free end. On the concave surface a somewhat ovoid area, $2\frac{1}{4}$ by $1\frac{1}{2}$ inches in diameter, was situated immediately below the short process, it represented an acetabulum for articulation with the femur; though now roughened, it had at one time doubtless been covered by cartilage (fig. 23, A, B). The femur had, however, not been preserved.

The single os pelvis from another skeleton was the right bone.† It differed somewhat from the above; the ventral process was $7\frac{3}{4}$ inches long, thicker and straighter. The superior process, $3\frac{1}{2}$ inches long, was rudimentary, slender and pointed at the free end. Its origin from the body was marked by a bony bar, which seemed as if a fracture, subsequently united, might have occurred in early life. The concave surface of the body with its short process had an area 3 inches by $1\frac{1}{2}$ inch which resembled

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* *Journ. Anat. and Phys.*, vol. xxix., 1895.

† This specimen has been presented to the University Anatomical Museum.

the surface on each of the paired bones which formed the acetabulum, but no femur had been preserved (fig. 23, C).

Gasco, in his memoir on the Taranto whale, figured the concave surface of one of the pelvic bones and showed the articular area for the femur, though that bone had not been preserved. Guldberg, in his memoir on the Nordcaper, gave three figures of a pelvic bone which generally resembled those above described. He was, however, so fortunate as to obtain a specimen in which the rudimentary femur was in articulation with the os pelvis and the capsular ligament of the joint was in place. Further, the cartilaginous tibia was also present and the articular surface at the lower end of the femur for the tibia was visible.

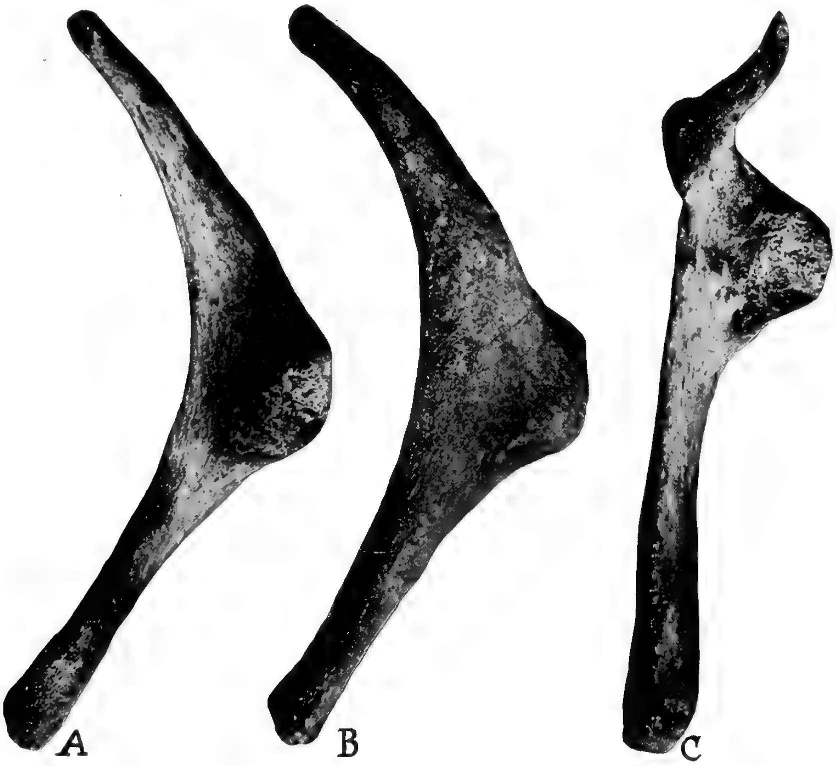

Fig. 23.—Pelvic bones.

Reinhardt in 1843 was the first to recognise the rudimentary femur and tibia in a new-born Right Whale, *Balæna mysticetus*, and some years later Eschricht and he observed them in a half-grown and in a full-grown specimen. The most complete description of the os pelvis and rudimentary hind limb in this whale was given by Sir John Struthers,* from its examination in five animals. In their general form the pelvic bones in *B. mysticetus* resembled those in *biscayensis*, though they were somewhat stronger in the former species. From his description and illustrative figures, the ventral process at its lower end (*o* in Struthers's figures) was for the attachment of the interpelvic ligament connecting the two bones ventrally, as well as for that of the

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* *Journ. Anat. and Phys.*, vol. xv., 1881.

crus penis in the male, whilst the shaft of this process gave origin to the compressor urethræ muscle. The superior process (*b* or beak in STRUTHERS's figures) seemed to be shorter and more slender than in *biscayensis*; doubtless in both species it was connected to the spine by a ligament. He also figures the femur and the cartilaginous tibia. As the femur and tibia in this skeleton of *biscayensis* had not been preserved, a comparison of the rudimentary hind limb with that in *mysticetus* could not be made, though from GULDBERG's figures it had corresponding characters in both species of Right Whale.

OS PENIS.

The Os Penis had been obtained. It was 12¾ inches long, and somewhat cylindriform in shape. The deep end was swollen, 8 inches in girth, and from it the bone tapered to the opposite end, which was 5¼ inches in girth (fig. 24). The presence of a bone in the penis of a Right Whale had not previously attracted attention. It was not quite as long as the corresponding bone in the walrus, and its texture was not so dense.

FIG. 24.—Os penis.

ORBIT.

The separate skull in the Anatomical Museum, as may be seen from the measurements in Table I., is of larger dimensions than the skull on the skeleton. As its Orbit was entire, I have been able, therefore, to complete the description of this region. The upper border was formed by the outer or orbital bar of the *frontal* bone, thick and rounded, which ended in front in the pre-orbital process, and behind in the somewhat larger post-orbital. The antero-posterior diameter of the orbit was 8 inches, and its vertical diameter was 8½ inches. Its lower border was formed by the curved *malar* bone, which articulated behind with the anterior blunt process of the squamous-temporal, and in front with the outer end of the pointed process of the superior maxilla. The temporal end of the malar was truncated and 4 inches in diameter; a disc of fibrous tissue was interposed between it and the corresponding articular surface of the temporal. The maxillary end, 4½ inches in its greatest diameter, was irregular in shape and formed an elongated process which passed upwards behind the pointed process of the superior maxilla; a disc of fibrous tissue about half an inch thick was interposed between it and the articular surface of the maxilla. The malar bone, measured along the convexity, was 16 inches between its articular ends; it was generally concave in its long axis, with the inner surface flattened and the outer surface vertically convex; its girth was $8\frac{7}{8}$ inches (fig. 25).*

The *Lachrymal* bone was a plate $13\frac{1}{2}$ inches long, interposed between the external or orbital bar of the frontal and the apex of the triangular plate of the superior maxilla, which lies parallel to and immediately in front of the orbital bar of the frontal. Its attachment was so slight that it could easily be drawn out of its place, when it was seen to be flattened, thin and friable; it was $1\frac{3}{4}$ inch broad in its upper third, narrowing materially at its lower end; the outer border, which appeared in the narrow cleft between the frontal and superior maxilla, was thickened and moderately strong; the inner border was thin and papyraceous.

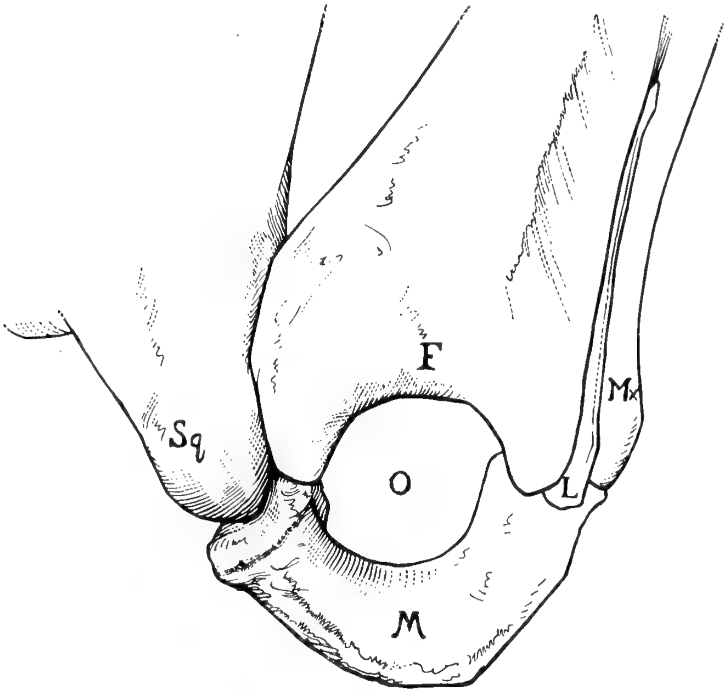

FIG. 25.—Orbit.

SUMMARY.

The specific differences between *Balæna biscayensis* and *B. mysticetus* may be summarised as follows:—

The adult *biscayensis* was neither so long, nor with so great a girth, nor did its head bear so large a proportion to the total length of the animal as in *mysticetus*. The blades of baleen were not so long; the mouth was not so large in proportion; the colour was more uniformly black, though a small percentage of the animals examined had large white patches on the ventral surface; the "bonnet" was distinct at the end of the snout.

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* If this figure is compared with that of the orbit of a young *Balæna japonica* in REINHARDT'S memoir on ESCHRICHT'S collection, *Vidensk. Selsk. Skr.*, 5 Række, Copenhagen, 1869, their close resemblance may be noted.

The skull of *biscayensis* was in breadth about two-thirds of its length, that of *mysticetus* about one-half. In *biscayensis* the height and breadth of the occipital squama approximated, in *mysticetus* the breadth was materially greater than the height, and the posterior surface of the squama differed in character in the two species. The fronto-orbital diameter was broader than the squamoso-occipital in *biscayensis*, whilst in *mysticetus* they were about equal. The nasals in *biscayensis* were broader relatively to the length, and their posterior border was almost transverse, whilst in *mysticetus* two processes from the frontal passed between them. The anterior nares were also broader in *biscayensis* than in *mysticetus*.

The tympanic bones were very distinctive, the most noticeable features being the presence in *biscayensis* of a deep notch on the outer surface behind the lip-like process, and a much deeper notch at the anterior or Eustachian end of the upper border of the inner surface than in *mysticetus*.

The vertebral formula in *biscayensis* was $C_7D_{14}L_{12}Cd_{23} = 56$; in *mysticetus* $C_7D_{13}L_{12}Cd_{23} = 55$, the important difference being the additional dorsal vertebra in the former, which is associated with the presence in it of 14 pairs of ribs, whilst *mysticetus* has only 13 pairs.

The sternum was notched at its base, or anterior border, more deeply in some specimens of *biscayensis* than in others, whilst in *mysticetus* the notch, when sometimes present, was shallow.

The scapula had only a rudimentary coracoid in *biscayensis*, whilst in *mysticetus* it was a distinct process.

The ulna in *biscayensis* did not possess so prominent an olecranon process as in *mysticetus*.

The manus corresponded generally in both species. The carpal elements were so imperfectly ossified in *biscayensis* that only two bones were present in one carpus, whilst the other had only a single bone. Notwithstanding the imperfect ossification the division of the cartilage into more or less definite areas was recognised, the customary three elements formed along with the pisiform the proximal row, and four apparently were in the distal row. In *mysticetus* four carpal elements and a pisiform have been described, but observations are still needed to enable a full comparison with *biscayensis* to be made.

The pelvic bones resembled those in *mysticetus*, though they were not so thick as in that species and were somewhat more curved. Both species possessed a rudimentary osseous femur and a cartilaginous tibia.

EXPLANATION OF PLATES AND FIGURES IN TEXT.

PLATE I.

Fig. 1. Profile of Skull with Mandible of adult *Balæna biscayensis.* O, orbit; *g*, glenoid fossa—page 900.

Fig. 2. Occipital squama, squamoso-frontal region, nasal region and dorsum of beak of the same skull. The figure includes the tip of the premaxillæ—page 900.

Fig. 3. Hard palate, squamoso-glenoid, fronto-orbital and maxillary regions of the same skull; *g*, the glenoid fossa—page 900.

PLATE II.

Fig. 4. Back of Cranium of *B. biscayensis*—pages 898, 902.

Fig. 5. Back of Cranium and naso-rostral region of *B. mysticetus.* The tip of the beak is not included—page 902.

Fig. 6. Lateral view of block of Cervical Vertebræ of *B. biscayensis*—page 904.

Fig. 7. Anterior surface of Atlas of the same—page 905.

Fig. 8. Characteristic Lumbar Vertebra, the 7th, of the same—page 906.

Fig. 9. The thirteen terminal Caudal Vertebræ of the same—page 906.

PLATE III.

Fig. 10. Outer surface, left Tympanic, *B. biscayensis*—page 903.

Fig. 11. Outer surface, left Tympanic, *B. mysticetus*—page 903.

Fig. 12. Inner surface, left Tympanic, *B. biscayensis*—page 903.

Fig. 13. Inner surface, left Tympanic, *B. mysticetus*—page 903.

Fig. 14. Inner surface, left Tympanic, *B. australis*—page 903.

Fig. 15. Malleus (M) and Incus (I) of *B. biscayensis*, × 2—page 904.

[The figures in this Plate and fig. 25 in the text are from drawings from nature by Mr JAMES T. MURRAY.]

FIGURES IN TEXT.

Fig. 16. Ventral surface of *Balæna biscayensis*, page 897, from a photograph of Mr HERLOFSON'S.

Fig. 17. Convex surface of hyoid bone of the same,—page 901.

Fig. 18. The largest and the smallest chevron bones of the same, reduced to show their relative size—page 907.

Fig. 19. Figures of the sternum, A, of *biscayensis*, and B, of *mysticetus*—page 911.

Fig. 20. Figures in section of the vertebro-costal arches of *B. biscayensis*, D_6, through the 6th dorsal and the 6th pair of ribs; D_1 through the 1st dorsal and the 1st pair of ribs. S, the position of the sternum,—page 912.

Fig. 21. Dorsal surface of the right scapula of *B. biscayensis*—page 913.

Fig. 22. Dorsal surface of the skeleton of the pectoral limb. H, humerus; R, radius; U, ulna; *in*, intermedium; *ul*, ulnare; radiale not differentiated; *p*, pisiform; C_1, Carpale_1; C_2, Carpale_2; C_3, Carpale_3; C_{4+5} Carpalia_{4+5} conjoined; P, pollex; V, minimus. This figure is constructed from the bones of the shaft; partly from the carpal bones and those of the digits themselves, and partly from Mr EDWARDS's photographs. The osseous nodules found in the carpus in the two hands are figured as if in the same carpus—page 915.

Fig. 23. Three Pelvic bones. A, the concave, and B, the convex surface of the bones from the described skeleton. C, the concave surface of a right pelvic bone from another skeleton. On each concave surface the acetabular area is to be seen—page 918.

Fig. 24. Os Penis from the described skeleton—page 919.

Fig. 25. The right orbital region of the large separate skull of *B. biscayensis.* O, orbit; F, orbital border of frontal; Sq, squamoso-temporal; Mx, superior maxilla; L, lachrymal; M, malar—page 920.

Sir William Turner on *Balæna biscayensis.*—Plate I.

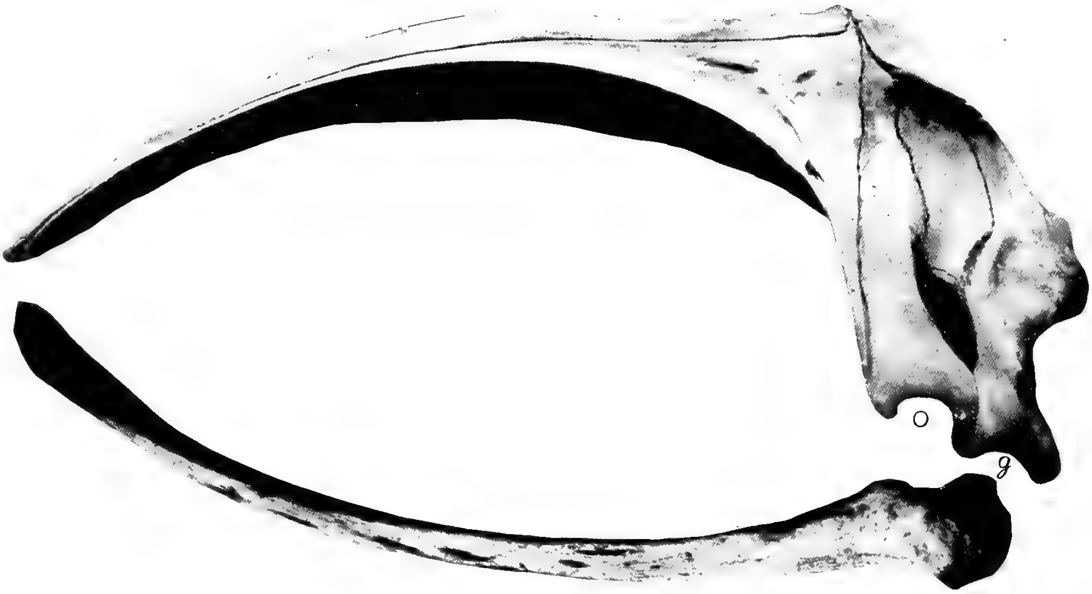

Fig. 1.

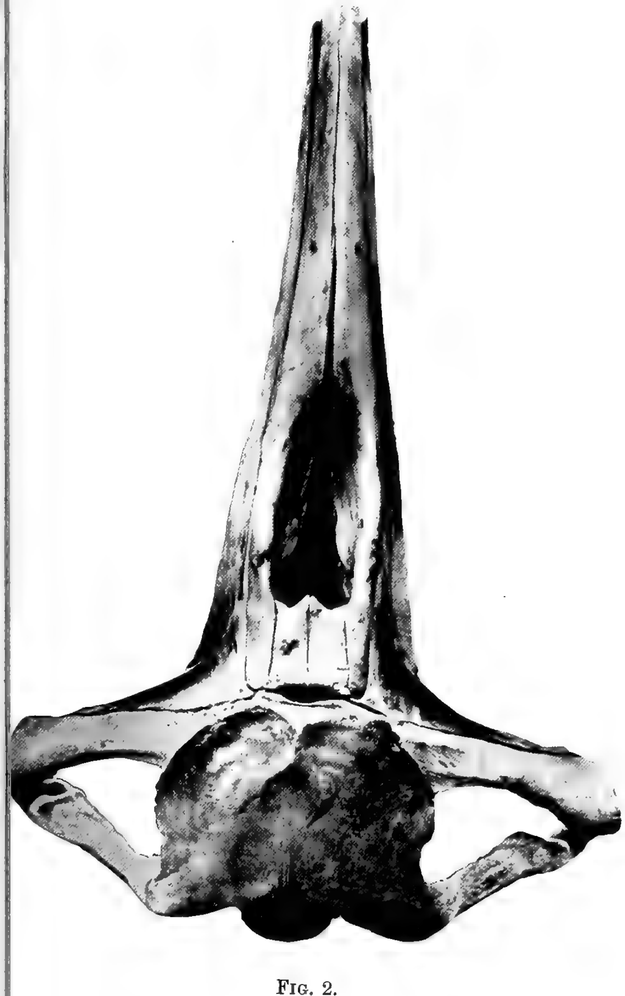

Fig. 2.

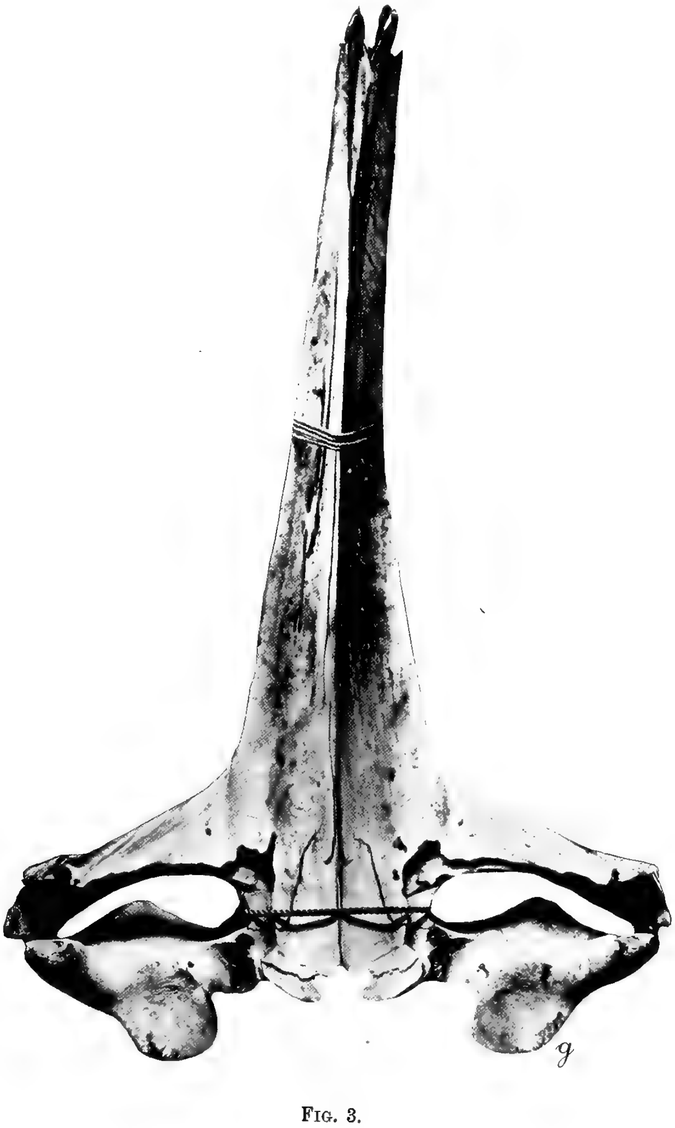

Fig. 3.

BRITISH MUSEUM
NATURAL HISTORY

FIG. 6.

FIG. 8.

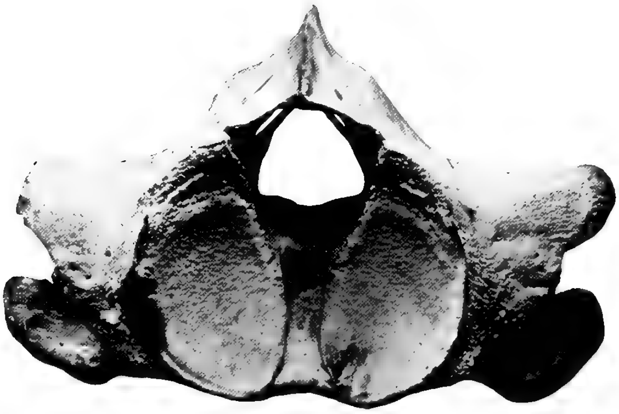

FIG. 7.

FIG. 9.

FIG. 5.—*B. mysticetus.*

FIG. 4.

BRITISH MUSEUM NATURAL HISTORY

Sir William Turner on *Balæna biscayensis.*—Plate III.

Fig. 11.—*B. mysticetus.*

Fig. 10.—*B. biscayensis.*

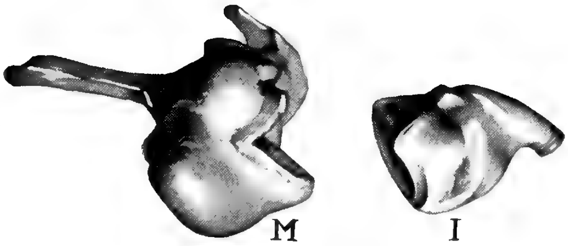

Fig. 15.—*B. biscayensis.*

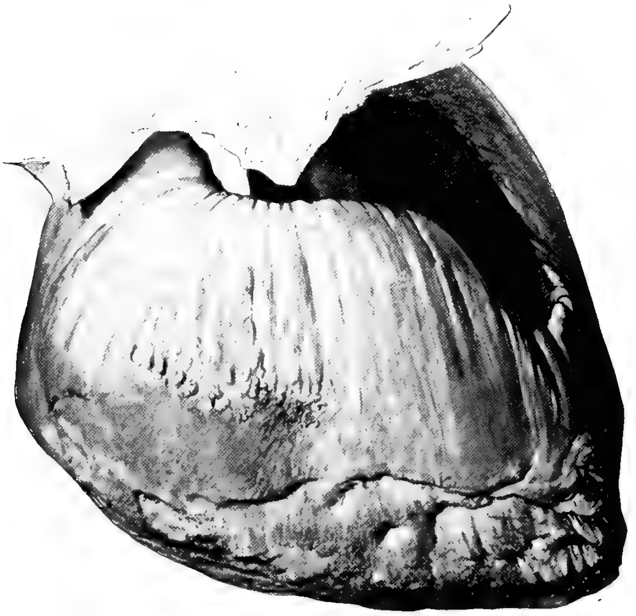

Fig. 14.—*B. australis.*

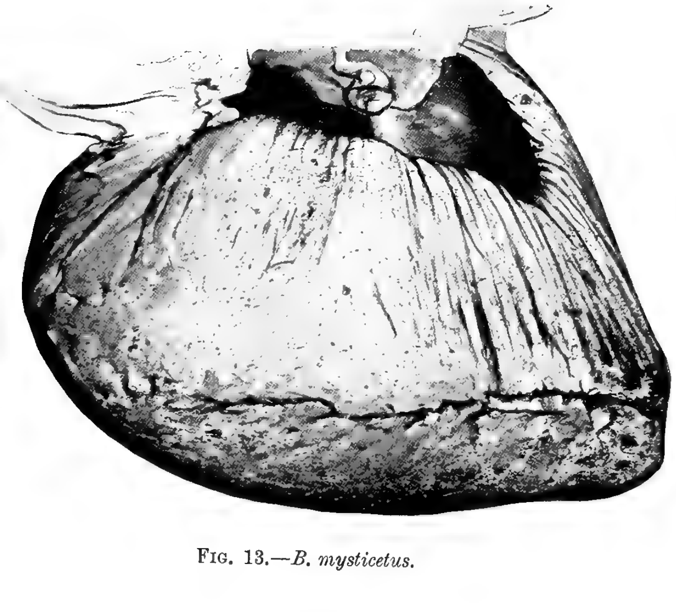

Fig. 13.—*B. mysticetus.*

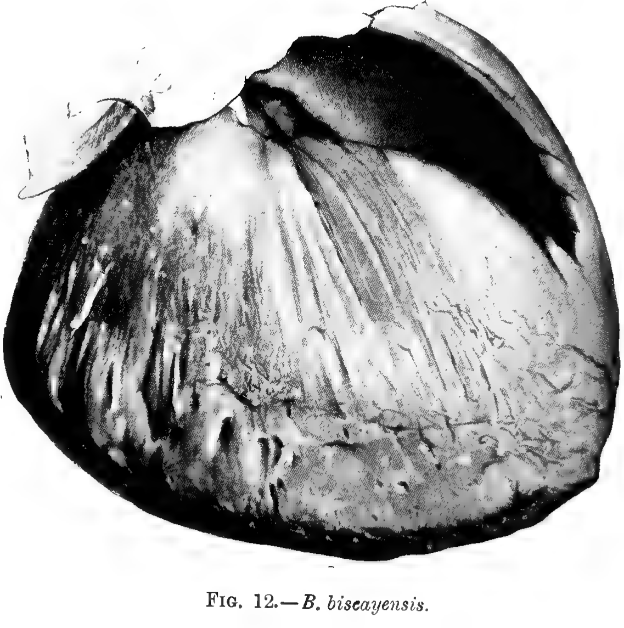

Fig. 12.—*B. biscayensis.*

BRITISH MUSEUM NATURAL HISTORY

XXXIV.—The Geology of South-Eastern Kincardineshire. By Robert Campbell, M.A., D.Sc., Lecturer in Petrology in the University of Edinburgh. *Communicated by* Professor James Geikie, D.C.L., LL.D., F.R.S. (With Three Plates.)

(Read June 17, 1912. MS. received February 12, 1913. Issued separately April 3, 1913.)

CONTENTS.

I. Previous Literature.

In 1804, Lieutenant-Colonel Imrie * communicated to the Royal Society of Edinburgh a paper entitled "A Description of the Strata which occur in ascending order from the Plains of Kincardineshire to the Summit of Mount Battoc, one of the most elevated points in the Eastern District of the Grampian Mountains." He pointed out that, in a short stretch of six miles in the North Esk section, "we pass from the secondary horizontal strata of the newest formation to the vertical, contorted primary strata of the oldest date, and terminate with granite, the primitive rock in the conception of many geologists." The section, as subsequent research has shown, bristles with difficulties, but Imrie, unlike so many of his fellow-geologists of the fighting days of the early part of last century, deliberately sets himself to give "a statement of the facts presented by nature, leaving to others to draw their conclusions in relation to their own speculations, which they imagine the facts to warrant." The alternation of sandstone, grits, and conglomerates among the "secondary" rocks and the steepening of their dip as they are traced towards the Highlands; the jaspers, grits, shales, and limestones of the "primary" rocks, and the "rather unusual manner in which the

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* *Trans. Roy. Soc. Edin.*, vol. vi. p. 3, 1812.

secondary and older strata meet each other"; the numerous east-and-west dykes of whin and porphyry intruded into the secondary strata; and the porphyry dykes in the mica schist area trending in a direction at right angles to the strike of the schists, are in turn clearly described and their positions noted on the admirable sketch-map which accompanies the memoir. While the paper as a whole is a splendid record of close observation, the account given of the whin dyke near the House of the Burn may be singled out as a brilliant piece of descriptive geology. In a second paper,* read to the Wernerian Society in 1810, IMRIE described the thick conglomerates between Fowls Heugh and Stonehaven. He noted the occurrence of pebbles of jasper, porphyries, granites, gneiss, quartz, etc., and pointed out that "quartz" (quartzite) and porphyries predominate. He recorded also the presence of a vertical bed of "greenstone" at Stonehaven harbour and a "clay porphyry" at Cowie.

Of the many short sketches of local geology embodied in the *New Statistical Account of Scotland*, vol. xi.—Forfar and Kincardine—two, namely those on the parishes of Fordoun and St Cyrus, are of considerable historical interest. In his account of the geology of Fordoun, written in 1837, the eminent geologist Professor (afterwards Principal) JAMES DAVID FORBES † compared the "transition clay slate" series at the Clattering Bridge with the "primary" rocks of the North Esk section described by IMRIE. He noted the occurrence of a "clay porphyry" in the same relative position in each locality—in what we now know to be the line of the Highland Boundary fault; he suggested the correlation of the limestones in the North Esk, at Clattering Bridge, and at Mains of Drumtochty—a suggestion fully confirmed many years afterwards by the detailed mapping by Mr BARROW, who has designated them the Margie limestone; and further he recorded from the Clattering Bridge section a bed containing "red jasper in dots"—an observation which gives additional evidence of the occurrence of the Margie series of Mr BARROW at that locality. Professor FORBES's paper contains also an admirable account of the field relations of one of the east-and-west trap dykes, and he sees in the presence of this dyke "an adequate cause for the rapid rise of the sandstone strata" in the Ferdun burn.

The first record of fossils from Kincardineshire is given in the account of the geology of St Cyrus ‡ written in 1841 by JAMES MURRAY, the local schoolmaster. In an interesting footnote it is stated that fossils were first discovered in Canterland Den in the "present year" by Mr JAMES PETER of Canterland. These consisted of "broad tapering leaves, fragments of the stems, branches, and leaves of fuci, called *fucoides*, and rounded masses of oval or circular dots, resembling the compressed seeds of the strawberry, and supposed by Mr MILLAR to be the roe of an extinct species of gigantic lobster." The fossil last mentioned is undoubtedly *Parka decipiens*.

If we may judge from the absence of published papers, the geology of Kincardineshire must have been rather neglected during the next twenty years—a fact which is rather

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* *Mem. Wernerian Soc.*, vol. i. p. 453, 1811.

† *The New Statistical Account of Scotland*, vol. xi. *Kincardineshire*, p. 72, 1845.

‡ *Ibid.*, p. 274, 1845.

surprising when we consider the impetus given to the study of the Old Red Sandstone by the discoveries and writings of HUGH MILLER. The Forfarshire Old Red, on the other hand, was diligently exploited. Ultimately, however, the treasures of Canterland Den attracted the Forfarshire enthusiasts, and in 1861 the Rev. HUGH MITCHELL* of Craig published a list of the fossils obtained by him from that locality. Occasional references to the geology of Kincardineshire occur in POWRIE's papers on the Forfarshire Old Red, and in his account of the "Connection of the Lower, Middle, and Upper Old Red Sandstone of Scotland" he places all the Old Red Sandstone of Kincardineshire in the Lower division, including also the jasper, serpentine, and limestones of the "Highland Border rocks," which had been assigned more correctly by FORBES to the transition clay slate series.

A great advance was made in 1884 by the publication of the first edition of Sheets 66, 67, 57, and 57*a* of the one-inch-to-the-mile map by the Geological Survey. The maps embodied the results of detailed mapping by Messrs IRVINE and SKAE. The rocks on the foreshore between the North Esk and St Cyrus are mapped as Upper Old Red Sandstone; the contemporaneous character of most of the trap rocks is indicated and their boundaries on the whole accurately delineated. It is further shown that the Old Red Sandstone is separated from the metamorphic rocks of the Highlands by a great fault; and the mapping shows very clearly that the chief structural feature of the Old Red area is a continuation of the Strathmore syncline.

In his *Ancient Volcanoes of Great Britain,* published in 1897, Sir ARCHIBALD GEIKIE gives the first connected account of the volcanic history of the Kincardineshire Old Red Sandstone, and, in an interesting chapter dealing mainly with the coast section, describes admirably not only the volcanic rocks but also the remarkable conglomerates with which they are associated. He considers the Kincardineshire lavas as belonging to the "Montrose centre of eruption."

The revised edition of Sheets 57, 66, and 67, issued in the same year by the Geological Survey, contains valuable additions by Mr GEORGE BARROW, chief of which are the mapping of definite aureoles of contact minerals due to progressive metamorphism in the schistose rocks, and the recognition of a belt of Silurian [?] rocks intervening between the schists and the boundary fault of the Old Red Sandstone. Reference is made to the latter discovery in the *Ancient Volcanoes of Great Britain*† and in the *Silurian Rocks of Britain,*‡ published in 1899. A detailed account of the lithological characters and structural relations of the "Highland Border rocks" was communicated to the Geological Society of London by Mr BARROW§ in 1901. He has shown that between Cortachy and Stonehaven they appear as three lenticular strips. The lenticels between Cortachy and Clattering Bridge and to the north of Drumtochty Castle have been described in detail by Mr BARROW, who has shown that the rocks belong to two

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* *Quart. Journ. Geol. Soc.*, vol. xvii. p. 147, 1861.

† Vol. i. p. 201.

‡ *Mem. Geol. Survey: The Silurian Rocks of Britain*, vol. i., *Scotland*, p. 73.

§ *Quart. Journ. Geol. Soc.*, vol. lvii. p. 328.

divisions: (1) "the Jasper and Green-rock series," probably of Arenig age, and (2) "the Margie series" resting unconformably in the former. They are always separated from the schists by a thrust plane and from the Old Red Sandstone by the Highland boundary fault. Further reference to Mr BARROW's paper will be made in connection with the description of another area of Highland Border rocks near Stonehaven.

The present paper deals with the stratigraphy of the palæozoic rocks of that part of Kincardineshire which lies south of the Highland fault. As has been shown in a preliminary note,* they include:

(1) Upper Cambrian [?] (Highland border rocks).
(2) Upper Silurian (Downtonian).
(3) Lower and Upper Old Red Sandstone.

Evidence of contemporaneous volcanic activity is found in all the formations except the Upper Old Red Sandstone; and certain intrusive rocks are probably of Carboniferous age.

II. UPPER CAMBRIAN [?].

A narrow strip of Highland Border rocks occurs on the coast near Stonehaven, extending from a point on the foreshore opposite St Mary's Chapel, Cowie, to Garron Point. The predominating rock type is a crushed green igneous rock, which has undergone intense shearing and folding, and to a large extent has been converted into chlorite schist. Vesicular structure, however, can still be recognised in places, and "pillowy" structures are sufficiently well preserved to demonstrate the original igneous character of the rocks. The field evidence suggests that they are pillowy lavas or spilites, and this is borne out by microscopical examination of the least altered parts of the rock. All the slides examined are typical spilites, and several show characteristic variolitic structures.† The coarsely crystalline diabase types, presumably intrusive in character, described by Mr BARROW from the other lenticels, have not been found.

The Highland Border rocks at Stonehaven may be looked upon as consisting mainly of a succession of pillowy lavas, but here, as in nearly all described occurrences, they are accompanied by fine-grained siliceous sediments. In the present case these consist of cherts, jaspers, and black cherty shales rich in iron oxides. These occur chiefly as intercalations between successive flows, but to some extent they are found in lenticular masses, suggestive of their having originally filled spaces between adjacent pillows. The sediments in every case consist of silica and iron oxides with varying proportions of calcite. In none of the slides has any undoubtedly terrigenous material been detected. Some of the cherts resemble the radiolarian

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* *Geol. Mag.*, dec. 5, vol. viii. p. 63.

† A detailed account of the petrography of these and other igneous rocks of South-Eastern Kincardineshire will be given in another paper.

cherts of the Southern Uplands, and the presence of rounded bodies suggestive of the remains of radiolaria probably indicates that they have had a similar origin.

In August 1909, on the occasion of a visit to the Garron Point section in company with Dr B. N. PEACH and Dr W. T. GORDON, we spent some time in searching for fossils in the above-mentioned sediments. The rocks on the whole seemed to be less intensely sheared than the similar rocks in the North Esk and Drumtochty sections, and the cleavage planes to coincide approximately with the bedding planes. Hence the conditions seemed favourable for the preservation of fossils. Nor were we disappointed. After a few hours' work we discovered in the black cherty shales on the north side of Craigeven Bay what were undoubtedly organic remains, namely, a linguloid shell, a bivalve phyllocarid crustacean, and a worm tube. Realising the importance of the discovery, we reported it to Dr HORNE, then Assistant Director of the Geological Survey, and the assistance of Mr D. TAIT was obtained in making a detailed search in the fossiliferous beds. Mr TAIT collected a remarkable suite of fossils, which have thrown important light on the age of the rocks. Dr PEACH, in whose hands the fossils were placed for determination, has very kindly supplied the following note :—

"The collection includes several specimens of hingeless brachiopods belonging to the genera *Lingulella*, *Obolella*, *Acrotreta*, *Linnarssonia*, and *Siphonotreta* ; a few specimens of a bivalve phyllocarid allied to *Caryocaris* and *Lingulocaris* ; cases of a tubicolar worm, the structure of the tubes being like that of the modern *Ditrupa*.

"Without further study it may be premature to express a definite opinion about the horizon of these fossils. The genera represented are most commonly found in the lowest division of the Lower Silurian (Ordovician) system and the Upper Cambrian. The absence of graptolites, however, suggests that they may belong to the latter rather than to the Lower Silurian."

Dr WALCOTT, of the Smithsonian Institute, Washington, to whom a selection of the fossils was afterwards submitted, reports that he is inclined to agree with Dr PEACH's conclusion that the fauna is an Upper Cambrian one.

With the exception of radiolaria, which had been detected by Dr PEACH in the cherts at Gualin, near Loch Lomond, the other occurrences of these rocks along the Highland Border had not yielded any organic remains. Recently, however, Dr JEHU * has announced the discovery of fossils in the chert and black shale series at Aberfoyle. And in Dr JEHU's collection Dr PEACH has recognised *Lingulella*, *Obolus*, and the jaw of an annelid.

The chief interest in the discovery of fossils in the Highland Border rocks lies in the direct bearing which it has on the fascinating, if perplexing, problems presented by the tectonics of the Central and Eastern Highlands.

Are these rocks pre-Cambrian ? Their correlation as Lower Silurian is suggested by the lithological and structural resemblances between the Jasper and Green-rock and

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* *Nature*, vol. lxxxix. p. 347, 1912.

Margie series on the one side of the Central Valley and the rocks of Ordovician age on the other. The crushed spilitic lavas with their accompanying cherts and jaspers find their counterpart in the Arenig volcanic series of the Southern Uplands; the sediments of the Margie series, resting unconformably on the former group, and derived in part at least from it, may fairly be compared with certain higher horizons in the Ordovician of the South of Scotland. The palæontological evidence obtained at Stonehaven, on the other hand, favours the view that the Jasper and Green-rock series is Upper Cambrian. It is possible, however, as Dr PEACH * has pointed out, that the Highland Border rocks will ultimately be found to include representatives of both the Arenig and Upper Cambrian formations. But from our present point of view the distinction between Upper Cambrian and Ordovician as the position of the series as a whole is of minor importance. The vital question is: In the light of recent discoveries can they possibly be regarded as pre-Cambrian? Our lack of knowledge of the life of pre-Cambrian times may, it is true, forbid dogmatic assertion on this point; but it will be admitted, I think, by most geologists that the range of genera obtained at Stonehaven and Aberfoyle, taken together with the lithological resemblances cited above, affords very strong, if not conclusive, evidence against these rocks being pre-Cambrian.

III. THE STRUCTURAL RELATIONS OF THE [?] UPPER CAMBRIAN.

Along their northern boundary the Cambrian rocks are separated from the Dalradian Schists by an overthrust fault, which, during low tides, may readily be traced from the southern shore of Craigeven Bay to Garron Point. Its position is indicated by the occurrence of a dolomitic fault rock, creamy white on a fresh fracture, but weathering to a rusty brown colour. In Craigeven Bay the dolomite attains a maximum thickness of about 40 feet. Microscopic sections show that it is undoubtedly a fault rock, made up largely of carbonates, but containing here and there recognisable angular fragments of the spilitic lavas. Thin veins of similar rock are developed along some of the minor movement planes in the green rocks themselves. The overthrust character of the fault is well seen from the position of the dolomite bed on the cliff on the north side of Craigeven Bay, and again from the fault feature south of the Skatie Shore. The fault is not indicated in the first edition of the one-inch map of the Geological Survey, but has been inserted by Mr BARROW in the revised edition. It may be regarded as a continuation of the Highland Boundary fault.

The southern boundary of the Jasper and Green-rock series at Ruthery Head has hitherto been mapped as a fault separating the schistose rocks from the Old Red Sandstone. During the present research, however, evidence has been obtained which proves that the junction is really an unconformable one, and that the overlying beds are of Downtonian age.

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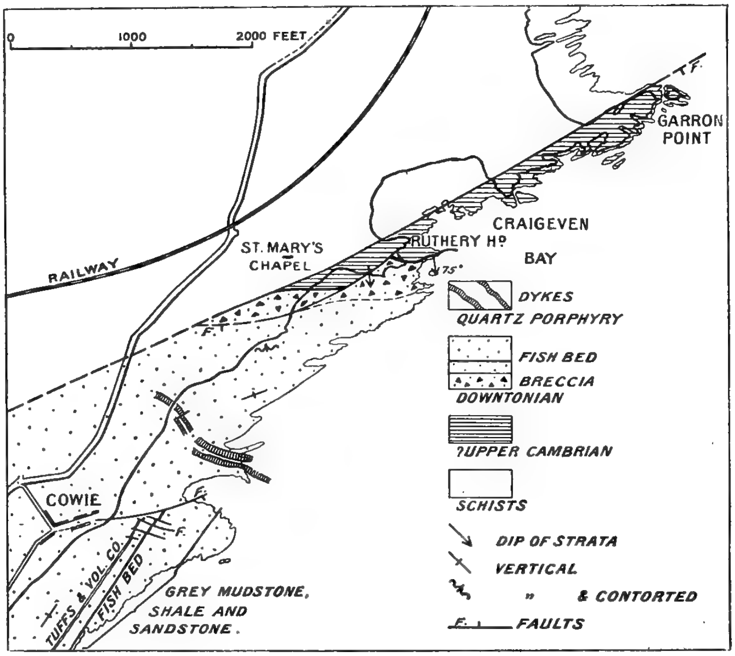
* Presidential Address to Section C, British Association, Dundee, 1912.

IV. The Unconformity between the Downtonian and [?] Upper Cambrian at Ruthery Head.

The nature of the junction between the Upper Cambrian and the Downtonian may be studied most satisfactorily in the cliff section at Ruthery Head and on the foreshore to the east of that headland. To the north extend the green Cambrian strata with their main structural planes, whether of cleavage or of bedding, in igneous and sedimentary rocks alike, dipping to the north-west; to the south lie the red Downtonian beds highly inclined towards the south-south-east. (See Sketch-map, and Plate I. figs. 1, 2, and 3.) It is not perhaps difficult to understand why the character of the boundary between the two sets of rocks should have been misunderstood, since there are many features in the section which suggest the presence of a powerful east-and-west fault. The Cambrian rocks for a considerable distance away from the junction have been stained red, and are in places very much shattered; the basement beds of the Downtonian consist of breccias made up to a large extent of reddened fragments of the underlying Jasper and Green-rock series; and the presence of numerous hitch faults tends still further to obscure the nature of the boundary. But, while it may be difficult, even after one has become familiar with the rock types, to distinguish the basement beds of the Downtonian from the reddened Cambrian rocks, it is always easy to recognise the character of the dominant structures in the respective types, and by means of these to trace the somewhat irregular course of the junction along the foreshore opposite Ruthery Head. The presence of intercalated beds of jasper in the



Text-Fig. 1.—Sketch-map of Geology of the Coast of Kincardineshire from Cowie to Garron Point.* (*R. Campbell.*)

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* Reproduced by permission from the *Geological Magazine*, dec. 5, vol. viii., 1911.

reddened spilites has also been found of great assistance in distinguishing these rocks from the overlying Downtonian.

Detailed examination of an exposure between two of the small hitch faults—such, for example, as that shown in Plate I. fig. 2—shows clearly that the junction is not a fault plane but an unconformity. It can be seen, moreover, that the younger rocks rest on a highly irregular eroded surface of the older.

An overthrust fault, which crosses Ruthery Head in north-easterly direction, shifts the outcrop of the lowest Downtonian breccias 160 yards to the south-west. From the fault the unconformity can be traced, although not so easily as in the section just described, along the foreshore in a westerly direction, until it is cut out again by the Highland fault near the mouth of the small stream which flows past St Mary's Chapel.

V. UPPER SILURIAN (DOWNTONIAN).

The rocks overlying the Upper Cambrian were formerly mapped as part of the Lower Old Red Sandstone formation. The palæontological evidence recently obtained, however, shows that the "Stonehaven Beds" must now be regarded as of Downtonian age. No marked discordance has been detected anywhere in the upward succession from Downtonian to Old Red Sandstone in this area; and since, in their lithological characters the former is of the nature of a transition series, it is not easy to fix the boundary between the two formations. In the description of the coast section given in my preliminary note, I took the massive conglomerate of Downie Point as the base of the Old Red Sandstone, but further study of the inland sections has led me to include with the basement conglomerates the brown micaceous pebbly sandstones at Stonehaven harbour along with the intervening tuffs and volcanic conglomerate. The sandstones contain numerous pebbles of quartzite, and herald the oncoming of the coarse "quartzite conglomerates" which form so characteristic a feature of the Lower Old Red Sandstone.

The succession of the Downtonian beds as seen in the coast section from the mouth of the Cowie Water to Ruthery Head is as follows (in descending order):—

	Feet.
7. Tuffs and tuffaceous sandstones	800
6. Grey sandstone and fossiliferous sandy shales and mudstones (with fish band)	600
5. Red sandstones	60
4. Volcanic conglomerate and tuffs	40
3. Grey and brown sandstones with thin red mudstones	1000
2. Purple sandstones	60
1. Basement breccias with intercalated sandy mudstones	200

The basement beds include a succession of breccias interstratified with finely bedded sandstones and sandy mudstones. The breccias consist in large part of angular and subangular fragments of the underlying rocks, but they contain also rounded pebbles of weathered granite and schists. The purple sandstones overlying the basement beds appear to consist mainly of finely comminuted debris of the rocks of the Upper Cambrian series.

Next in the succession comes a thick series of grey and brown ochreous sandstones with intercalations of pale red mudstones. The sandstones often contain much volcanic debris in the form of fragments of andesitic and felsitic rocks; clay galls, indicating contemporaneous erosion of clay beds, are abundant; and false-bedding is everywhere of common occurrence. Beautiful examples of sun-cracks have been noted in the mudstones. On the south side of the entrance to Cowie harbour a dip fault with downthrow to the south shifts the above series to the west, and on the foreshore between Cowie and Stonehaven Bay the brown and grey ochreous sandstones are overlain by a coarse volcanic conglomerate associated with a belt of tuffs and tuffaceous sandstones.

The volcanic conglomerate has a maximum thickness of about 30 feet, and may be traced as a conspicuous ridge on the foreshore extending in a south-south-westerly direction from Cowie pier. As it approaches the Cowie harbour fault it is traversed by a large number of small dip faults, each of which shifts the outcrop slightly to the eastward as the conglomerate is followed towards Cowie. Made up almost entirely of rounded boulders of hornblende andesites and rhyolites, the conglomerate is overlain by a belt of soft red andesitic tuffs with a maximum thickness of 27 feet, to which succeeds a thin bed of fine conglomerate with green tuffaceous matrix.

The next member in the succession is a massive red sandstone with occasional thin mudstone intercalations. It presents no feature of particular interest.

The red sandstone is overlain by about 600 feet of grey sandstone and sandy shales with green and grey mudstones. This group (No. 6) is the most important in the series, since, alike in its lithological characters and in its fossil contents, it shows the Silurian rather than Old Red Sandstone affinity of the succession. The predominant sediments are grey sandstones, occasionally rich in clay galls, and in places containing bands of calcareous nodules. At intervals there occur intercalations of green and grey sandy mudstones and shales, in which *Dictyocaris* is found in great abundance. The most noteworthy of the mudstone and shale groups occurs about 20 yards east of Cowie harbour. On visiting this section in August 1909, in company with Dr PEACH and Dr W. T. GORDON, we found not only *Dictyocaris*, but also *Eurypterus* sp. and fragmentary plant remains, and in a thin bed of reddish sandy mudstone, overlying the red sandstone (No. 5), Dr GORDON discovered several fish plates. Some of the fish fragments were suggestive of *Birkenia*. Dr GORDON and Dr PEACH joined me again during the following summer in order that we might try to get material sufficient to establish the horizon of this fish fauna, and considerable additions were made to the finds of the previous year.

The fishes were submitted to the late Dr R. H. TRAQUAIR, who undertook the description of new species. In a preliminary note contributed to the *Geological*

Magazine[*] he concluded that the fish remains from Cowie consisted of: (1) Cephalaspidian scutes belonging to a species as yet unnamed and undescribed; (2) fragments of thin, minutely tuberculated plates, which might also be Cephalaspidian, though their nature was problematical; (3) two median plates of a beautiful new *Cyathaspis*. After examination of additional material Dr TRAQUAIR[†] communicated another short paper to the British Association meetings at Dundee, in which he gave the following brief diagnosis of the new *Cyathaspis*:—

"*Cyathaspis Campbelli* (Traquair).—Shield, ovoid, concave, shallow, broadest part situated behind the point of greatest expanse; covered with stout ridges running in a longitudinal direction, but also tending to converge a little anteriorly and posteriorly. These ridges are also constantly interrupted, so as to give almost a tubercular appearance, the tubercles being comparatively distantly placed, much compressed, and crenulated."

Dictyocaris, unfortunately, must still be labelled "*incertæ sedis.*" From its resemblance to the living *Marchantia* it was thought it might possibly be a plant; but Dr D. H. SCOTT, to whom specimens were sent for determination, replied that in his opinion they were not vegetable. Dr SMITH WOODWARD thought they were unsatisfactory fragments of the dermal armour of Cephalaspidian and Pteraspidian fishes, and a larger collection of specimens was made and submitted to Dr TRAQUAIR along with the undoubted fish remains. Dr TRAQUAIR was of opinion that it was not likely that the fossil could represent the median layer of the Pteraspidian shield, although the resemblance was a suggestive one. There can be no doubt, however, that the Cowie specimens are identical with the *Dictyocaris* of SALTER, which occurs in the Upper Silurian of the Southern Uplands and in the Downtonian of England.

Apart from plant fragments and worm-tracks the remaining fossils in my collection belong to the Arthropoda. They include *Ceratiocaris* sp. (carapace, rostrum, and cercopod); *Archidesmus* sp., and a new genus of Myriapod; (?) larval form of insect; *Eurypterus*, sp. nov.; and fragments of scorpion. The arthropoda will be described by Dr PEACH, to whom I am indebted for the above provisional determination.

As long ago as 1881 Mr MACCONOCHIE collected for the Geological Survey from the "Stonehaven Beds" *Dictyocaris*, fragments of *Pterygotus*, *Eurypterus*, and (?) *Kampecaris*, and Dr HORNE has told me that in discussing these fossils at that time Dr PEACH expressed the opinion that they might be of Silurian age.

The highest beds in the Downtonian series (No. 7) consist of green and red tuffs and brown tuffaceous sandstone with occasional intercalations of pebbly bands and thin sandy mudstones. They are exposed in the foreshore at Stonehaven Bay, but can be examined only when the tides are low.

Inland, on account of the drift-covered character of the country, the succession cannot, of course, be studied in the same detail. In sections in the Carron Water and its tributaries, however, in railway cuttings, and in occasional quarries, evidence has

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[*] *Geol. Mag.*, dec. 5, vol. viii. p. 66, 1911.

[†] *Ibid.*, vol. ix. p. 511, 1912.

been obtained which has enabled me to map the Downtonian series for about seven miles to the west. The general strike of the series is parallel to the Highland fault, while the strata are highly inclined with dip to the south-south-east. Locally, as may be seen in the coast section, there is inversion, and the beds dip towards the fault. It is quite clear, however, that from the mouth of the Cowie Water to the basement breccia we are dealing with a descending succession. From the coast to the neighbourhood of Elfhill the Downtonian rocks form the lowest strata in the steeply inclined northern limb of the Strathmore syncline. Westwards from Elfhill there is a tendency to set up a steep-limbed anticline pitching out to the south-west against the Highland fault, and from Elfhill to the Carron Water just west of the farm of Waters the Downtonian series occupies the core of the anticline.

No very useful purpose would be served by describing in detail the various inland sections. The volcanic conglomerate with its associated tuffs (No. 4), and the fossiliferous green and grey mudstones of No. 5, have been traced at intervals for about six miles to the west of Stonehaven. They keep the same relative position, their lithological characters are constant, and *Dictyocaris* continues to be the characteristic fossil. Both zones may be recognised in the Carron Water between Carron Lodge and the bend of the river opposite Dunnottar church. Just west of the church the series is traversed by an important fault, which extends from Thornyhive Bay to the Highland fault near Fetteresso sawmill. The outcrop of the fossiliferous beds is shifted to the north-west. Reappearing in the Cheyne Burn near the sawmill, they may be traced westwards, and are found in the Burn of Graham a short distance below Bridge of Graham, on the Carron Water about half a mile west of Tewel, and again on the Carron Water at its junction with the Elfhill Burn. The volcanic conglomerates and tuffs are best seen in a splendid strike section in the Elfhill Burn. They are also exposed in the Burn of Graham.

From the section in the Carron west of Tewel Mr D. Tait obtained a fish spine, and, since there the green mudstones are associated with a reddish sandy mudstone, which, lithologically, is identical with the band which yielded the fishes at Cowie, it is hoped that careful search in this locality will yield further specimens belonging to the Cowie fish fauna. In a quarry near the schoolhouse of Tewel a curious mottled sandstone is in places richly charged with plant remains, none of which unfortunately are determinable.

VI. Evidence regarding the Age of the "Stonehaven Beds."

At an early stage in this research one of the points which appealed to me most strongly was the marked dissimilarity between the "Stonehaven Beds" and the usual facies of the Caledonian Old Red of Kincardineshire and Forfarshire. And when, afterwards, under the guidance of Dr Peach, I had visited typical sections of the Downtonian of Lanarkshire and the Pentland Hills, it became clear at once that, so far as lithological evidence went, the above series bore the impress of a Downtonian rather than a normal Old Red Sandstone type of sedimentation. In Kincardineshire, just as in the Southern Uplands, the Downtonian rocks form what is truly a transition series, in some respects exhibiting the characters of a typical Upper Silurian group of sediments, in others those of the Lower Old Red Sandstone. To the former belong the green and grey mudstones and the greywacké-like sandstones; to the latter, the coarse conglomerates and the false-bedded ochreous sandstones.

Consideration of the palæontological evidence cited above leads to a similar conclusion. Neither *Dictyocaris* nor *Ceratiocaris* has hitherto been met with in rocks younger than Upper Silurian, while both are common forms in the Downtonian elsewhere in Britain. The unique fishes of the Downtonian of the South of Scotland, it is true, have not so far been found; but, since the nature of the invertebrate fossils favours the reference of the "Stonehaven Beds" to that horizon, the occurrence of *Cyathaspis*, as Dr TRAQUAIR has pointed out, may be regarded as corroborative evidence.

Professor KIÆR [*] has recently announced the discovery of a Downtonian fauna in the sandstone series of the Kristiania area—a series described as Old Red Sandstone by MURCHISON in 1844, and so regarded by most Norwegian geologists since his time. The list of fossils given by Professor KIÆR in his preliminary report includes *Dictyocaris* (very abundant), *Ceratiocaris* sp., at least two new species of *Eurypterus*, *Pterygotus* sp., two new Cephalaspidomorph fishes, and three new genera of Anaspid fishes.

There is undoubtedly a striking similarity between the above assemblage of fossils and those found at Stonehaven. It is impossible, of course, to compare the eurypterids and fishes of the two areas until fuller descriptions are available, but in both cases there is a noteworthy abundance of the problematical *Dictyocaris* along with fragments of *Ceratiocaris.*

In short, the palæontological evidence and the character of the sedimentation together show conclusively that the "Stonehaven Beds" must be regarded as Downtonian, although not necessarily on the same horizon as that of the fossiliferous zones of the Downtonian rocks of the South of Scotland.

VII. COMPARISON OF THE KINCARDINESHIRE DOWNTONIAN WITH THE DOWNTONIAN OF THE SOUTHERN UPLANDS.

The palæontological evidence [†] obtained in the Southern Uplands indicates that the green and grey mudstones, the greywackés, and the fish band are marine. They have yielded species of eurypterids, which in the Wenlock series are associated with graptolites, in the Ludlow series with a *Lingula*; they contain, moreover, *Glauconome*, *Spirorbis*, crinoid stems, and sponges. The rock types resembling the Old Red Sandstone sediments, on the other hand, have been supposed to indicate fresh- or brackish-water

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[*] *Videnskapsselskapets Skrifter*, i. Mat.-Naturv. Klasse, 1911, No. 7.

[†] *Mem. Geol. Survey: Silurian Rocks of Britain*, vol. i. pp. 69, 603.

conditions. In Kincardineshire no evidence has been obtained so far which would point to marine sedimentation. No undoubtedly marine organism has been found, and the association of the eurypterids with plant remains, scorpion fragments, galley-worms, and a larval form of insect appears to show that the green and grey mudstones were laid down in close proximity to a land area, and, at the most, can imply only estuarine conditions; the interbedded ochreous sandstones with their characteristic false-bedding, and the development of sun-cracks in the red mudstones, point conclusively to deposition in shallow water. The coarse volcanic conglomerate, like those of the Old Red Sandstone, is in all likelihood a torrential flood gravel.

No contemporaneous volcanic rocks have been found in the Downtonian series of the Southern Uplands; the earliest lavas and tuffs invariably overlie the basement greywacké conglomerate of the Lower Old Red Sandstone. Sir ARCHIBALD GEIKIE * has correlated the initial outbreak of volcanic activity in "Lake Caledonia" with the coming on of the conditions which gave rise to the lowest of the massive quartzite conglomerates at Stonehaven. That volcanoes were active in this region at a much earlier period is seen from the development of tuff and volcanic conglomerates in the Downtonian sequence. The lowest volcanic conglomerate is about 2500 feet below the above-mentioned quartzite conglomerate. As we have already seen, the lowest zone of volcanic conglomerates and tuffs can be traced inland until it is lost against the Highland fault. There is abundant evidence also to show that the materials of all the associated sediments were derived from the Highland area. One must conclude, therefore, that early in Downtonian times (or perhaps in pre-Downtonian, but subsequent to the movements which folded the eastern schists) volcanic activity had already begun in the schist country to the north of the Highland fault.

In the Southern Uplands the Downtonian series passes down conformably into the Ludlow. The presence of quartzite conglomerates shows that the sediment, in part at least, was derived from the Highland area. At Stonehaven the Downtonian rests unconformably on rocks of a much lower horizon (probably Upper Cambrian), and there is in all probability a marked overlap as the Lower Old Red Sandstone formation is traced over the Highland area to the west. In Kincardineshire the Downtonian series passes up conformably into the Lower Old Red Sandstone; in the Southern Uplands it has been found that the two series are separated by an unconformity in the Pentland Hills and Ayrshire; while in Lanarkshire there is an "apparent conformability," the basal conglomerate of the Lower Old Red Sandstone series being made up everywhere mainly of boulders of greywacké derived from the rocks of the Silurian tableland to the south.

Consideration of the chief points in the above comparison leads to the following conclusions:—

(1) During early Downtonian times there was continuous subsidence of the southern part of the central valley and the area now occupied by the Southern

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* *Ancient Volcanoes of Great Britain*, vol. i. p. 303.

Uplands, while along the Highland Border and further northwards there was a movement of compression and elevation and consequent denudation. Such a theory affords a satisfactory explanation of the occurrence of boulders of Highland rocks in the Downtonian conglomerates of the Southern Uplands.

(2) The above movements of subsidence reached the Highland Border during late Downtonian times. This is shown by the fact that the Downtonian rocks of Kincardineshire, which include the highest beds in that group, rest unconformably on the Highland Border series.

(3) While this movement of subsidence went on continuously in the central valley, about the end of the Downtonian period movement of compression set in towards the south, resulting in the production of the land area of the Southern Uplands, of which the southern Downtonian rocks form a part.

(4) At the beginning of Lower Old Red Sandstone times the central valley was flanked to north and south by mountain ranges and itself formed a subsiding area on which the coarse sediments derived from the rapid denudation of these mountain masses were deposited.

(5) Finally, the earlier beginning of volcanic activity in the northern side of the midland valley may be correlated with the earlier development of movements of compression and elevation in that region.

VIII. LOWER OLD RED SANDSTONE.

The rocks of Lower Old Red Sandstone age, which occupy the greater part of south-eastern Kincardineshire, include coarse conglomerates, sandstones, and marls interbedded with lavas, tuffs, and volcanic conglomerates. The enormous thickness of the groups of contemporaneous volcanic rocks points to a prolonged period of volcanic activity, which, as we have seen above, had been initiated at least as far back as Downtonian times. Resting conformably on the Downtonian series, the Lower Old Red Sandstone is in turn overlain by rocks of Upper Old Red Sandstone age. The latter are found in Kincardineshire in a small area along the coast between East Mathers and the mouth of the North Esk, and the junction between the two series is everywhere a line of faulting. Near Arbroath, however, the Upper Old Red Sandstone rests unconformably on the Lower; and, as Dr HICKLING* has clearly shown, the latter series had undergone extensive folding and denudation before the deposition of the former.

In Kincardineshire, as elsewhere, one notable characteristic of this formation is the paucity of organic remains. A few additions to our knowledge of the fossiliferous localities have been made in the course of the present research, but the palæontological evidence is so meagre that it has been found of little value for stratigraphical purposes. Lithological evidence, on the other hand, obtained from conglomerates,

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* *Geol. Mag.*, dec. 5, vol. v. p. 396, 1908.

lavas, and tuffs, and, in particular, the recognition of a well-marked succession in the lavas, has aided materially in elucidating the structure of the area occupied by the Lower Old Red Sandstone.

The rapid variation in the character of the rocks in any given horizon makes it almost impossible to draw a sharp line of demarcation between one zone and another. For convenience in description, however, I have divided the Lower Old Red Sandstone series into five groups, arranged as under in descending order :—

E. The Strathmore Group.
D. The Garvock ,,
C. The Arbuthnott ,,
B. The Crawton ,,
A. The Dunnottar ,,

The approximate thickness of each group is as follows :—

	Maximum feet.	Minimum feet.
Dunnottar Group	6900	7500
Crawton ,, ...	1600	
Arbuthnott ,, ...	5000	3000
Garvock ,, ...	4000	3800
Strathmore ,, ...	1500 +	

The marked variation in the thickness of the three lowest groups is due in large measure to the varying development of the intercalated lava zones, and to the rapid lateral variation of the associated volcanic conglomerates.

The above figures confirm Sir ARCHIBALD GEIKIE'S* estimate of 20,000 feet as the maximum thickness of the Lower Old Red Sandstone of Lake Caledonia, included in which are the "Stonehaven Beds" (2760 feet), regarded in this paper as Downtonian.

A. *The Dunnottar Group.*

The Dunnottar group includes the part of the Lower Old Red Sandstone which lies between the base of the series and the top of the Tremuda Bay lavas. A brief description of the coast section from Stonehaven to Thornyhive Bay will perhaps serve to indicate the general aspect of this portion of the Old Red succession. Its chief characteristic is a magnificent development of coarse conglomerates with intercalated thin brown sandstones. In the conglomerates well-rounded quartzites are always the most conspicuous constituent. They are accompanied by other "Highland" rocks and by a varying proportion of granites of "newer granite" type, quartz porphyries, rhyolites, and acid andesites. Boulders derived from the Jasper and Green-rock series are present, as a rule,

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* *Text-book of Geology*, vol. ii. p. 1008, 1903.

in great abundance, but in the conglomerates underlying the Tremuda Bay lavas they are almost entirely wanting, their place being taken by an abnormally large number of rhyolites and acid andesites. Locally, too, and particularly in the conglomerate just south of Strathlethan Bay, boulders of a coarse grit resembling the "Haggis rock" of Caradoc age of the Southern Uplands are fairly numerous.

At four horizons the conglomerates are interbedded with contemporaneous volcanic rocks.

(*a*) At Stonehaven harbour the basement members of the group, brown micaceous pebbly sandstones, are separated from the coarse quartzite conglomerate of Downie Point by a considerable thickness of acid tuffs, with a few bands of coarse volcanic conglomerate.

Three lavas are indicated in the Geological Survey map as occurring in the vicinity of Stonehaven harbour, but I have been able to find only one crystalline igneous rock, and that an intrusive quartz dolerite.

(*b*) In Strathlethan Bay the Downie Point conglomerate underlies a series of soft tuffs and tuffaceous sandstone, with which again are associated volcanic conglomerates. Here, too, we find the lowest lava flow of Old Red Sandstone age in Kincardineshire—an augite andesite. It forms the small island of Carlin Crag, but is truncated by a fault and does not appear in the cliff section.

(*c*) After a long interval, represented by a great thickness of conglomerates, another zone of acid tuffs is found in Old Hall Bay, just south of Dunnottar Castle.

(*d*) At Tremuda Bay the highest members of the Dunnottar group include a series of at least six flows of olivine basalt of a coarsely crystalline, doleritic type, each of which consists of a massive central portion with well-marked scoriaceous upper and under surfaces. The second shows good columnar structure. The slaggy upper surfaces occasionally enclose "veins" of sandstone. The bottom lava has flowed over a bed of soft mud, portions of which have been caught up in the lower scoriaceous surface. At the north side of Thornyhive Bay the lavas are truncated by the important fault already alluded to, and the top of the series is not seen.

The lava near the lighthouse at Todhead Point is a doleritic basalt of the same type as the above, and, along with the underlying conglomerates, may perhaps be considered as belonging to the Dunnottar group. It shows a very slaggy upper surface with the characteristic sandstone veinings, and has been described and figured by Sir ARCHIBALD GEIKIE.*

Inland sections are sufficiently numerous to show that, along the steeply inclined northern limb of the Strathmore syncline, the Dunnottar group maintains the same general characters which it exhibits in the coast section. Quartzite conglomerates predominate, but at intervals there occur acid tuffs and volcanic conglomerates. On the south-eastern slope of Carmont Hill, near Square's Knap, a vesicular augite andesite is associated with a coarse volcanic conglomerate, and, although the lava is not quite of

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* *Ancient Volcanoes of Great Britain*, vol. i. p. 303.

the same type as the andesite of Carlin Crag, it seems fairly certain that it is on the same volcanic horizon as the Strathlethan Bay zone.

The only fossils obtained from the Dunnottar group are specimens of *Parka* sp., collected from a grey sandstone associated with the tuffs at Strathlethan Bay.

From Stonehaven harbour to the middle of Old Hall Bay the general direction of strike is east-north-east and west-south-west, while the strata are vertical or very highly inclined. In the section on the foreshore in the southern half of Old Hall Bay the angle of dip falls very rapidly, until at the extreme south corner it averages about 35°. South of the next important headland, Maiden Kaim, the beds swing round the great synclinal fold of Strathmore, the strike changing to north-west and south-east, and the average angle of dip falling to 25°.

B. *The Crawton Group.*

The Crawton group is characterised by a marked increase in the proportion of volcanic rocks, quartzite conglomerates no longer predominating as in the underlying series. Detailed mapping has shown that it presents markedly different suites of lavas on the two sides of the Strathmore syncline. The area occupied by the northern limb of the fold contains a fine development of acid andesites; along the southern limb there occurs a remarkable group of porphyritic basalts.

(*a*) *The Crawton Basalts and Associated Rocks.*—The predominating type of lava in this series is a basalt with large tabular phenocrysts of plagioclase, which closely resembles the well-known Carnethy "porphyry" of the Pentland Hills.* We shall refer to it as the Crawton type of basalt. The most southerly exposure of the Crawton basalts is seen on the shore about a mile south of Gourdon, where they are striking seawards in a north-west and south-east direction. Swinging round somewhat abruptly near Nether Knox, they return to the north-north-east and south-south-west direction of strike—the general strike of the synclinal fold. They may be followed along the higher slopes of Gourdon Hill, and ultimately crop out in the Water of Bervie near Pitcarry Mills. There they are truncated by a fault, the line of which is marked by a thick fault breccia forming a prominent wall-like feature on the left bank of the river. Reappearing on the north side of the above fault near Mill of Bervie, the Crawton basalts form the lower of the two prominent rock features of Bervie Brow. As they are followed northwards it is found that, just west of Grange and again a short distance east of Wardend, the continuity of their outcrop is interrupted by two faults, which have the effect of shifting it successively further to the east. Good exposures of the basalts are seen in the old quarries in Whistleberry Wood, and the group may be followed in a northerly direction for about a mile and a half until it is again traversed by a dislocation—the Braidon Bay fault—which shifts the outcrop out to sea on the downthrow side. The direction of strike, however, again changes as the beds begin to

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* *Mem. Geol. Survey*, "The Neighbourhood of Edinburgh," p. 32, 1910.

swing round the synclinal fold, and the characteristic Crawton basalts reappear on the coast section at the village of Crawton, where they attain their maximum thickness. From Crawton their outcrop may be followed in a north-north-westerly direction parallel to the coast to Gallowton, when, interrupted by a fault, it bends abruptly round to the east, and the group comes back to the coast at Thornyhive Bay. On the northern limb of the syncline the Crawton basalts appear in the Glaslaw Burn, and may be traced towards the south-south-west in bare rocky knolls in the fields almost as far as Upper Criggie.

On the shore section near the village of Crawton it can be seen that the Crawton type of basalt occurs in three successive flows, each with a slaggy upper and under surface, and a massive, columnar central portion. The parallel arrangement of the tabular felspars imparts to the rock a marked platy structure. The lowest flow shows a somewhat unusual type of weathering. On a gently sloping rock platform, which has been carved out in the massive portion of the flow between low- and high-water marks, the sea has worked out a regular series of pot-holes, each of which coincides in position with the centre of one of the hexagonal basalt columns. Apparently some agency acting along the joints has hardened the margins of the columns, while the centres have been left an easy prey to the eroding action of the sea. In many places the vesicular surfaces of the Crawton lavas show the characteristic sandstone-veinings. But perhaps the most striking feature of the group is the evidence which it everywhere gives of contemporaneous erosion. This is particularly well seen at the top of the highest flow at Crawton. The overlying conglomerates are seen to rest on an irregular eroded surface of the lava (Plate I. fig. 4). Sometimes the slaggy top of the latter has been entirely removed, and the pockets of conglomerate rest directly on the massive central portion. The eroded hollows coincide in position with prominent joint fissures, which are seen to narrow as they are traced downwards, and to be occupied by successively finer and finer pebbly sandstones, until they end off in minute cracks filled with very fine silt. Obviously the lavas had cooled and consolidated before the advent of the currents which carried out the work of erosion. Although the overlying conglomerates contain occasional large slaggy boulders of the Crawton basalt, still the proportion of such boulders is remarkably small, and certainly does not suggest that the conglomerates have been derived by wave action from an old shore cliff of Crawton lava. To this point we shall return later. Meanwhile, it may be noted that the restriction of the Crawton basalts to one definite horizon, coupled with their occurrence as boulders in the overlying conglomerates, has been of great service in mapping the latter.

Associated with the basalts of the Crawton type are other basalts which will be described in detail in another paper. The most widespread is a type, sparingly porphyritic with olivine and augite, which overlies the normal group from Crowhillock, Kinneff, to Gallowton. Occasionally, too, there are small intercalations of coarsely crystalline non-porphyritic basalts—for example, at Bervie Brow and Whistleberry; and in the Glaslaw Burn section the highest flow is a basalt with porphyritic plagioclase, olivine, and augite. These associated lavas also exhibit evidence of having undergone contemporaneous erosion.

Between the porphyritic basalts and the base of the Crawton group there intervenes a series of volcanic conglomerates, tuffs, and "Highland" conglomerates,* with one small intercalation of basic andesites or basalts near Whistleberry Castle.

The tuffs and volcanic conglomerates attain their maximum development between Bervie Bay and Whistleberry. In that tract, indeed, the "Highland" conglomerates play quite a minor part. The tuffs are built up essentially of angular and subangular fragments of hornblende and biotite andesites and felsites, the andesites always predominating. Locally they contain in abundance angular pieces of a green rock which resembles the spilitic lavas of the Upper Cambrian series. They are frequently calcareous, and weather with characteristic honeycombed and furrowed surfaces. Like the tuffs, the volcanic conglomerates consist mainly of the debris of hornblende and biotite andesites. A noteworthy feature is the large size of the well-rounded boulders of hornblende andesite—a section across one in a conglomerate near Shieldhill measured 9 feet × 10 feet. The relative proportion of boulders and matrix is variable, but the latter, which has much the same composition as the associated tuffs, is always more abundant than in the "Highland" conglomerates. The latter are characterised as usual by the almost bewildering variation in their composition as any one particular bed is traced from point to point. As a rule they contain a fair proportion of volcanic rocks belonging to Old Red Sandstone types. But the feature which, despite the extraordinary variety of the constituents, always arrests attention, and which serves to distinguish the "Highland" conglomerates of this group from all the others, is the abundance of boulders derived from the Upper Cambrian series. The green spilitic lavas are often so numerous as to impart a general greenish hue to whole belts of the conglomerate. The occurrence of "Haggis rock" boulders is also noteworthy. At many points, and particularly in the vicinity of Shieldhill, excellent examples of contemporaneous erosion can be seen where these conglomerates rest on an uneven surface of tuffs and volcanic conglomerates.

To the north and south of the Bervie-Whistleberry tract there is a marked change in the character of the sediments between the Crawton basalts and the base of the group. The tuffs and volcanic conglomerates play a smaller and smaller part in the succession as they are traced in either direction from the above centre, and their place is taken by conglomerates in which "Highland" rocks predominate and by brown tuffaceous sandstones. The lowest conglomerates in the neighbourhood of Todhead Point contain a big proportion of basic lavas, derived perhaps from the contemporaneous erosion of the underlying Tremuda Bay series of basalts. At a higher horizon, and separated from the above by a bed of acid tuff, a somewhat remarkable conglomerate

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* Throughout this paper the term "Highland conglomerate" is used to designate a conglomerate in which the majority of the boulders belong to rock types occurring in the Highland area. Similarly, quartzite conglomerate and volcanic conglomerate denote conglomerates whose predominating pebbles are respectively quartzites and volcanic rocks.

forms the cliffs below Hallhill. It contains large scattered boulders in a tuffaceous matrix. One rounded boulder of acid andesite measures in section 14 feet × 9 feet; quite near it is another of green schistose grit measuring 7 feet × 5 feet × 3 feet. Two points are noteworthy —the exceptionally large amount of matrix, and the occurrence together of unusually big boulders of "Highland" rocks and acid andesites. Detailed descriptions of this and other conglomerates must be reserved for another paper. The following general results, however, have been arrived at from a preliminary study of the conglomerates of this group:—(1) the predominance of volcanic conglomerates in the Bervie-Whistleberry tract, with a gradual transition northwards and southwards to non-volcanic conglomerates; (2) the abundance in all the "Highland" conglomerates of boulders derived from the "green rocks" and jaspers of Upper Cambrian age; (3) the maximum development of "newer granites" in the neighbourhood of Bervie Bay.

The lava flow near Whistleberry Castle is of particular interest, since it shows, better perhaps than can be seen elsewhere in Kincardineshire, very characteristic "sandstone veining." Through practically its whole thickness it is traversed by sandstone veins and by large irregular patches of finely bedded sediments (see Pl. I. fig. 5). It recalls the examples from the Turnberry shore described by Sir ARCHIBALD GEIKIE.*

In the sediments underlying the Crawton lavas there is also a noteworthy development of minor intrusions in the form of decomposed lamprophyres, which occur sometimes in thin sills, sometimes in narrow dykes, too small to be shown on the $\frac{1}{2}$-inch map. They are restricted to this horizon.

(*b*) *The Burn of Guinea Andesites and Associated Rocks.*—We have seen above that the Crawton basalts may be traced along the northern limb of the syncline as far as Upper Criggie. Further to the west is found another volcanic group occupying approximately the same horizon, but showing an altogether different assemblage of lavas. Basalts are represented by two, or at most three, small flows, and these markedly different from the Crawton type. The predominating types are acid andesites.

Appearing first near Temple of Fiddes—about a mile west of Upper Criggie—this volcanic zone may be followed a short distance beyond Collieston. Then for about two miles the solid geology is completely obscured by a great thickness of drift. Just west of Drumlithie similar lavas again begin to make their appearance, and, continuing with an east-and-west strike, they cross the Bervie Water beyond Hawkhill. Again for a short distance they are concealed under a thick deposit of boulder clay, but, swinging round the Elfhill anticline, they return to the Bervie Water at the Horse Pot. Then for about a mile they are hidden under drift. They reappear, however, on the northern limb of the anticline, in the Burn of Guinea, and again circling round a synclinal fold which succeeds the anticline, they are finally lost against the Highland fault. North of the fault, however, in the extreme west of the area, a series of lavas, exposed in the Kirkton Burn and other stream sections, and mapped as intrusive porphyrites on the

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* *Ancient Volcanoes of Great Britain*, vol. i. p. 333.

Geological Survey map, belong to types which are identical with the Burn of Guinea hornblende andesites. It is extremely likely that these belong also to this horizon.

At the bottom of this volcanic zone occurs a group of dacites extending from East Kinmonth to the Water of Bervie, and forming for a considerable distance the northern bank of a remarkable dry valley. I was unable to find any exposure showing the nature of their contact with the adjacent strata, and I had doubts as to whether they might not be intrusive. But since they show everywhere very fine fluxion structure, and since dacite boulders almost identical in character make their appearance in the overlying conglomerates, they are in all probability lavas.

The lavas coloured on the map as hornblende and augite andesites include normal hornblende-biotite andesites with phenocrysts of plagioclase, hornblende, and biotite, and compact non-porphyritic types which are somewhat more basic in character, but which, on microscopic examination, are seen to contain occasional patches of magnetite, which may represent resorbed hornblende and biotite.

The basalts which are found intercalated with the above series between the Bervie Water and Drumlithie include a doleritic type, and a black compact hypocrystalline type with porphyritic olivine.

The widespread occurrence of boulders of the hornblende-biotite andesites in the overlying conglomerate shows that this volcanic group underwent extensive contemporaneous denudation, and a very fine example of an eroded lava surface with the overlying conglomerate is seen in a small quarry at Harlingtongue.

Owing to the paucity of exposures, but little can be made out regarding the sediments associated with the above lavas. On the Bervie Water at Burn of Guinea farm there is a fine section of a coarse "Highland" conglomerate with boulders of quartzite, granite, granophyre, quartz porphyry, and schists. Conglomerates of the same type occur in the Pilketty Burn and in Kinmonth Den. At Whitehill Quarry, near Bogincabers, the lavas overlie a tuffaceous sandstone.

C. *The Arbuthnott Group.*

In the Arbuthnott group, as in the last, we find a markedly different assemblage of rocks on the two sides of the Strathmore syncline. In the south-eastern part of the area it includes the thickest and most widespread of the lava belts; in the north and west its chief member is a remarkable volcanic conglomerate.

(*a*) *The Hypersthene Andesite and Hypersthene Basalt Series, with their Associated Sediments.*—As will be seen from the accompanying map, the hypersthene andesites and hypersthene basalts, with occasional intercalations of sandstone and conglomerate, may be followed continuously along the southern limb of the syncline from the North Esk to Bruxie Hill, where they swing round and continue along the steeply inclined northern limb as far as the Stonehaven-Laurencekirk road. Then, like the hornblende andesites of the Crawton group, they are lost sight of for nearly two miles, concealed doubtless under the thick mantle of drift which here completely obscures the solid geology. Reappearing again at the Knock Hill, they may be followed as occasional flows intercalated in the volcanic conglomerates along the slopes of the Haerscha Hill to Paldy Fair Den. Then, circling round the Elfhill anticline, they cross the Bervie Water between Dillavaird Ford and Tipperty. Between that stream and the Highland fault they are again concealed under the drift. This group of lavas undoubtedly thickens towards the south and east.

If we exclude a few intercalated flows of doleritic basalt which occur chiefly at or near the base of the series, the lavas of the Arbuthnott group form an assemblage of types altogether different from those found in any other part of the Lower Old Red succession in Kincardineshire. Detailed descriptions of these will be given in another paper, but meanwhile it may be noted that they are mainly hypersthene-bearing andesites and basalts. At one extreme we find normal hypersthene andesites without olivine; at the other, hypersthene basalts containing much olivine and very little hypersthene. Numerous transition types are characterised by varying proportions of the above two constituents.

Like the similar types in the Ochils and Cheviots, these hypersthene-bearing basic lavas are remarkably rich in chalcedony, fine red veinlets of which are usually to be found ramifying through the rock in every direction, while the vesicular portions of the flows yield beautiful examples of agates in great variety and abundance. It is on this horizon, at Usan on the Forfarshire side of the Montrose anticline, that the vesicular lavas occur which yielded many of the finest specimens in the Heddle collection.

That the lavas of this group underwent contemporaneous erosion, although not on the same extensive scale as those of the Crawton and Dunnottar groups, is seen at more than one locality, but particularly well in a stream section about 200 yards below the bridge near Biddrie. There between two of the flows occurs a bed of volcanic conglomerate containing numerous boulders derived from the slaggy portions of the underlying lava. The general assemblage of the pebbles in this conglomerate, together with a typical intercalation of tuffs, recalls, however, the conglomerates of the Clattering Bridge section, which are believed to represent the Arbuthnott group on the north side of the Howe of the Mearns.

"Sandstone-veinings" are of frequent occurrence in the slaggy upper portions of the lavas, the material of the veins consisting usually of hardened, red or green, fine-grained micaceous sediment. The green veins in one of the flows near St Cyrus show curiously contorted bedding, and they exhibit also vesicular structure. The vesicles are filled with agate material similar to that found in the adjacent lava.

In Paldy Fair Den I have mapped a flow which possesses somewhat unusual characters. It is, or at least it had been originally, a very vesicular vitrophyric type, with abundant phenocrysts of plagioclase and scattered phenocrysts of hypersthene and augite. But its most striking feature is the abundance of xenoliths of rounded boulders, mainly of hornblende andesites; in places the xenoliths are so numerous that the rock might be mistaken for a volcanic conglomerate. The enclosed blocks are similar to the boulders in the underlying conglomerate. Probably the xenoliths were collected by the lava as it flowed over an unconsolidated gravel.

At the base of the group everywhere along the southern limb of the syncline we find a very coarse "Highland" conglomerate whose chief constituents are well-rounded quartzites. Locally it contains boulders of the underlying basalts. Comparing it with the "Highland" conglomerates of the Crawton group, we notice at once a marked decrease in the proportion of boulders derived from the Jasper and Green-rock series. This zone of coarse conglomerate is succeeded by a belt made up of finer conglomerates, associated with sandstones and flaggy beds; sometimes the sandstones, sometimes the fine conglomerates predominate. This belt may be traced along the strike by a line of quarries mostly now disused. Three Wells quarry, near Bervie, is still worked, and there I was fortunate enough to find a good specimen of *Cephalaspis Lyelli.* As the base of the lavas is approached we begin to find, particularly in the north-eastern part of the area, intercalations of the volcanic conglomerates and tuffs which occupy almost the whole thickness of this group along the northern limb of the syncline.

(*b*) *The Volcanic Conglomerates and Tuffs.*—The volcanic conglomerates and tuffs, which occur at intervals interbedded with the ordinary conglomerates and sandstones along the southern limb of the syncline, attain a considerable thickness in the vicinity of Law of Lumgair. It should be noted, however, that the width of the outcrop there is in great part accounted for by the low angle of dip. From Mid Fiddes westwards they form almost the whole thickness of the Arbuthnott group, taking the place which is occupied by the hypersthene andesites and basalts and the ordinary sediments in the south-eastern part of the area. Their base rests on the hornblende andesite of Harlingtongue, and their upper limit is found a short distance above the top of the Knock Hill lavas. Westwards from the Knock Hill the top of the series may be traced in an east-and-west direction as far as Glensaugh, while the basal members swing round the Elfhill anticline, and, as we have seen, along with the accompanying andesite cross the Bervie Water near the Horse Pot, Dillavaird. In the drift-covered country to the east of the Bervie the only satisfactory exposures of these beds are found in a stream section a short distance west of the Bridge of Bogincabers. Near the ford of Dillavaird the beds strike north and south and dip towards the west at an angle of 30°. In the neighbourhood of Drumtochty Castle the direction of strike is almost east and west, and, consequently, at Glensaugh the series is almost entirely cut out by the Highland fault. The direction of strike changes again to south-west and north-east, and a very fine section of the volcanic conglomerates and their associated tuffs is seen in the Ferdun burn at the Clattering Bridge. There, although the base of the series is not seen, it attains a thickness of about 2000 feet. From the Clattering Bridge westwards these rocks may be hammered in almost every stream section, until, the direction of strike changing gradually to west-south-west and east-north-east, they are eventually lost against the Highland fault about half a mile from the river North Esk.

Representative collections of boulders from these conglomerates at various horizons show that the boulders consist almost entirely of acid andesites and rhyolites. A big percentage of the former belongs to types found in the acid andesite zone of the Crawton group. None of the basic andesites or basalts are represented in the collections made from these conglomerates along the Highland Border. Sometimes the volcanic conglomerates are built up entirely of the debris of volcanic rocks, but more frequently they contain a small percentage of boulders derived from the Highland schist series—a point which is of interest in showing that the material was being derived from the area to the north of the Highland fault. Locally, too, there occur thin conglomerates of the "Highland" type, but such form an insignificant part of the succession. The volcanic conglomerates are associated invariably with interbedded "tuffs." While some of the latter may have been derived from an already consolidated series of lavas by the ordinary agents of denudation, numerous occurrences have been noted in which the sharply angular nature of the constituent fragments clearly shows that they are true pyroclastic tuffs. These tuffs are rhyolitic rather than andesitic, and in this way differ from the tuffs associated with the Crawton group. Excellent examples occur in the Bervie Water near the ford of Dillavaird, and in the Shag Burn opposite Honeybank. The tuffs are not separated from the volcanic conglomerates on the accompanying map, but they make up no inconsiderable part of the whole series.

Indeterminable plant fragments, found in a thin intercalation of grey micaceous shales near the ford of Dillavaird, are the only fossils which have been noted in this part of the Arbuthnott group.

D. *The Garvock Group.*

This group consists for the most part of coarse "Highland" conglomerates, with intercalated grits, sandstones, flagstones, shales, and limestone. It includes also the highest of the lava zones.

The main belt of lavas extends from the North Esk near Marykirk to Cairn of Shiels. A minor group at a somewhat lower horizon occurs on either side of the Bervie Water near Whitefield, and a small development of lavas is found also to the north of Canterland Den, almost at the base of the Garvock series. The lavas are all basalts, occasionally with phenocrysts of olivine, but more usually coarsely crystalline, non-porphyritic doleritic types. The slaggy surfaces show the usual "sandstone-veining," but the material of the veins in the highest flow at Balmakelly is a sandy limestone. The basalts give no evidence of having undergone contemporaneous erosion. This lava series does not appear in the northern limb of the Strathmore syncline, and, like the hypersthene-bearing series in the Arbuthnott group, thickens towards the south and east.

In the coarse quartzite conglomerates of the group the boulders which occur in greatest numbers are flaggy gneisses. Quartzites and vein quartz also play an important part. Jasper and "green rocks" are much less numerous than in the lower conglomerates, although locally, on the Garvock side of the syncline, they are fairly abundant. The presence of many boulders of rhyolites and acid andesites shows that the acid volcanic rocks had not yet been entirely removed from the Highland area. It may be noted in this connection that the finer sediments of this group often contain a remarkable amount of felsitic debris. The chief characteristic of the conglomerates, however, is undoubtedly the great abundance of boulders of flaggy gneisses. The flat boulders of the gneisses frequently show beautifully an imbricated arrangement similar to that found in torrential flood gravels. This is seen particularly well in the conglomerates of Sarah's Den on Strathfinella Hill, where it is very evident that the boulders have been transported from the north or north-west.

Of the many intercalations of finer sediments two persistent belts call for special description. The first occurs between the Strathfinella conglomerates and the top of the volcanic conglomerates of the Arbuthnott group, and is separated from the latter by lenticels of "Highland" conglomerate. It consists of reddish micaceous sandstone —often pebbly, and in places containing so much felsitic debris that it assumes a pink tint—interbedded with red, grey, and chocolate-coloured flagstones which are usually crowded with clay galls. Beautiful ripple-marked surfaces are often conspicuous, and fine examples of sun-cracks are not uncommon. The only evidence of organic life is the presence of worm burrows and castings.

The other belt also occurs near the base of the group, but on the south side of the syncline, and comes on almost immediately above the highest lavas of the Arbuthnott group. It consists of purplish sandstones, with which are intercalated grey and chocolate-coloured sandstones with grey and olive-tinted sandy shales. The best section in this series is at the Den of Morphie (Canterland Den), about two miles east of Marykirk. The shales contain plant remains in great abundance, but the only form determined so far is *Parka decipiens*, which seems to have been the first fossil recorded from this locality. The occurrence of *Kampecaris forfarensis* has been noted by several collectors, probably first by DAVID PAGE, who figured it in the first edition of his *Advanced Text-Book*. This interesting fossil was considered by PAGE to be an anomalous form of isopod crustacean; C. W. PEACH first recognised that it was a myriapod; and a detailed description, based on specimens from Kincardineshire and Forfarshire, was subsequently published by Dr B. N. PEACH.* Dr PEACH gives an excellent drawing of one of PAGE's specimens from Canterland Den. Our knowledge of the fossils of Canterland, however, we owe chiefly to the work of that enthusiastic local collector, the late Rev. HUGH MITCHELL of Craig. In addition to *Parka decipiens*† and *Kampecaris forfarensis*,† MITCHELL discovered *Pterygotus*† sp., *Cephalaspis Lyelli*,† *Parexus incurvus*,† *Climatius scutiger*,‡ and *Thelodus Pagei*. The last is the *Cephalopterus Pagei*§ of POWRIE. It was redescribed and renamed first as *Turinia*

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* *Trans. Roy. Phys. Soc. Edin.*, vol. vii. p. 1, 1882.

† *Quart. Jour. Geol. Soc.*, vol. xvii. p. 145, 1861.

‡ *Geol. Survey Mem.: Organic Remains*, dec. x. p. 68, 1861.

§ *Trans. Edin. Geol. Soc.*, vol. i. p. 298, 1870.

and afterwards as *Thelodus* by Dr Traquair,[*] who has figured several scales of the Canterland specimen. The Geological Survey collection includes a specimen of *Ischnacanthus gracilis* from this locality. Among material collected in recent years by Dr W. T. Gordon and myself, there are fragments of *Pterygotus anglicus*, and plant remains, among which may be noted the occurrence of casts of large ribbed stems up to two inches in diameter.

A sandy limestone occurring near the top of the Garvock group appears to be the only limestone in the whole of the Lower Old Red Sandstone succession in Kincardineshire. Although at present exposures of the bed are few in number, it seems formerly to have been worked extensively, as, for example, at Balmakewan, at Burn of Balmakelly, and in the south-western portion of the parish of Garvock. Further north it is found at the Bervie Water, near Pitskelly, where it is represented by a calcareous sandstone, with nodules containing fragmentary plant remains. There can be little doubt that this calcareous belt is continuous along the southern limb of the Strathmore syncline. It occupies approximately the same horizon as, and is in all probability a continuation of, the limestone mapped by the Geological Survey in Forfarshire.

The sandstones of this group as a rule contain numerous clay galls, possibly the result of the erosion of beds of the so-called marls. Such an explanation is suggested by a section in the North Esk, south of Balmakewan House, in which may be seen an actual instance of contemporaneous erosion of marls interbedded with the sandstones.

E. *The Strathmore Group.*

Here are included the highest beds of the Strathmore syncline. They consist in great part of the bright red "marls" which give such a characteristic colour to the boulder clay and the overlying soils of the Howe of the Mearns. The best sections in the group are found in the North Esk between the mouth of the Luther Water and the Gannochy Tower, a short distance north of Edzell. Over most of the great central plain between the Bervie Water and the North Esk the rocks of this group consist almost exclusively of bright red poikilitic "marls." Towards the west and north, however, their place is taken by coarser sediments—flagstones and massive false-bedded sandstones, with occasional lenticels of conglomerate. No fossils have been recorded from these rocks, and this group is the only one in which there is no trace of contemporaneous volcanic activity.

IX. PALÆONTOLOGY OF THE LOWER OLD RED SANDSTONE.

The occurrences of fossils cited above and their localities may be summarised as follows:—

A. *Dunnottar Group.*

Strathlethan Bay.—*Parka* sp.

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[*] *Trans. Roy. Soc. Edin.*, vol. xxxix. p. 595, 1899.

B. *Crawton Group.*

No fossils recorded.

C. *Arbuthnott Group.*

1. Three Wells, near Bervie.—*Cephalaspis Lyelli.*
2. Ford of Dillavaird.—Plant fragments.

D. *Garvock Group.*

1. Canterland Den (Den of Morphie).—*Parka decipiens* and abundance of other plant remains, *Kampecaris forfarensis*, *Pterygotus anglicus*, *Cephalaspis Lyelli*, *Parexus incurvus*, *Climatius scutiger*, *Ischnacanthus gracilis*, and *Thelodus Pagei.*
2. Drumtochty Glen.—Worm burrows and castings.
3. Bervie Water, near Pitskelly.—Plant fragments.

E. *Strathmore Group.*

No fossils recorded.

The above list, it will be seen, does not offer evidence which can be of any great value for purposes of zoning or correlation. *Parka* occurs near the top of the volcanic series and again almost at the base of the Lower Old Red Sandstone, and thus possesses the same extended range as in Forfarshire and Perthshire. The Three Wells and Canterland Den horizon may be correlated with that part of the Forfarshire Old Red which includes the well-known fossil localities of Turin Hill, Farnell, Newtyle, Carmyllie, Leysmill, and Ferryden. According to the distribution of the lava zones on the published maps it seems probable that the Three Wells quarries are on the Ferryden horizon, while the Canterland Den beds are the equivalents of those at Farnell. The rocks of Turin Hill appear to occupy a somewhat higher horizon, but all the fossils found at Canterland Den have also been recorded from the former locality.

X. Volcanic Activity in Kincardineshire during the Lower Old Red Sandstone Period.

Volcanic activity, which had already begun, as we have seen, in Downtonian times, continued to be a characteristic feature in the physical history of the area until far on in the Lower Old Red Sandstone period. Evidence of prolonged, if intermittent, volcanic activity is found in the great development of lavas, tuffs, and volcanic conglomerates, which together form no inconsiderable part of the succession. The lavas include dacites, hornblende-biotite andesites, augite andesites, hypersthene andesites, hypersthene basalts, and olivine basalts, the basic types predominating. The volcanic conglomerates with their associated tuffs consist almost entirely of the debris of already consolidated hornblende and biotite andesites and rhyolites. No trace of volcanic vents has been found. The distribution of the volcanic rocks, however, suggests that the centres of eruption were situated along two lines, one of which lay north of the Highland fault, while the other is concealed under the North Sea. The former we shall call the "Highland group of volcanoes": the latter includes at least two eruptive foci—one in the vicinity of Montrose, the other off the coast at Crawton—and these we shall designate the "Montrose centre" and the "Crawton centre" respectively.

(*a*) *The Highland Group of Volcanoes.*—The lavas which emanated from these volcanoes include the dacites and andesites which extend from Temple of Fiddes to the Highland fault near Bogincabers. Two or three basic flows associated with them perhaps belong rather to the Crawton basalt group; but since in the district where the two groups approach one another the nature of the solid geology is obscured by the great development of drift, it is difficult to obtain satisfactory field evidence. The fact that boulders of the basic lavas are absent from the associated conglomerates rather favours the supposition that the basalts came from the east or south-east. The acid andesites never appear in the coast section, and they attain their maximum development in close proximity to the Highland fault. It is not from the lavas, however, that we get the most convincing evidence as to the nature of the eruptions from this Highland centre or centres. One of the most remarkable features in the succession, from the base of the Downtonian to the top of the Arbuthnott group, is the great part played by acid tuffs and volcanic conglomerates. Wherever continuous belts of these can be traced inland they are found to thicken in the direction of the Highland fault. The constant association of their predominating rhyolite and acid andesite boulders with boulders of "Highland" rocks indicates that the material has come from the north or north-west. The extraordinary thickness of the successive volcanic conglomerates implies the removal of a vast accumulation of acid lavas from the Highland area. Throughout the whole of the Downtonian and a considerable part of Lower Old Red Sandstone times there must have flourished, along the tract now occupied by granites and schists, a series of volcanoes whose chief products were rhyolite and acid andesite lavas and rhyolitic and andesitic tuffs. No vents, so far as I know, have been detected in that region; but some of the intrusive masses of quartz porphyry may possibly represent the position of centres of eruption. It is tolerably certain that there is a genetic connection between the quartz porphyries and some of the newer granites of the Eastern Grampians and the igneous rocks of Downtonian and Lower Old Red Sandstone age of south-eastern Kincardineshire.

(*b*) *The Crawton Centre.*—The lavas erupted from this centre include the doleritic basalts of Tremuda Bay and the porphyritic basalts of the Crawton type. These lava groups thin off to north, south, and west from Tremuda Bay and Crawton, so that the volcanoes from which they came must have been somewhere to the east of the present coast line. I can find no evidence of tuffs belonging to this series. The acid tuffs and volcanic conglomerates, which underlie the Crawton basalts at Kinneff, have come from a centre somewhere to the north-west, and probably belong to the Highland group of volcanoes. The lavas from the Crawton centre have undergone a considerable amount of contemporaneous erosion, but the boulders thus derived form quite an insignificant proportion in the composition of the interbedded "Highland" conglomerates—they never give rise to volcanic conglomerates such as have been produced from the prolonged denudation of the acid lavas of the Highland group.

(*c*) *The Montrose Centre.**—From this centre came the thick accumulation of hypersthene andesites, hypersthene basalts and olivine basalts which constitute the lava contents of the Arbuthnott and Garvock groups. Tuffs again are absent. The reddened character of the upper surfaces of the flows suggested that considerable intervals of time may have elapsed between the outpouring of successive lavas. There is not, however, so much evidence of contemporaneous erosion as in the rocks belonging to the other two centres. "Sandstone-veining" is everywhere a conspicuous feature, and finely bedded shales and mudstones are sometimes intercalated in the lava series of the Arbuthnott group. From such shales in the trap rocks of this series at Ferryden the Rev. HUGH MITCHELL made a collection of impressions which recall the "Upland Fauna of the Old Red Sandstone Formation of Carrick" described by JOHN SMITH. The specimens, now in the Montrose Museum, show trails and footprints of several kinds, burrows, and rain prints. The hypersthene-bearing lavas are remarkable for their fine development of agates; the vesicles of the basalts of the Garvock group contain good specimens of calcite, desmine, and analcite.

The lavas belonging to this centre are present in great force where they appear in the southern limb of the Montrose anticline, but they gradually thin out, and the intercalations of sandstone and conglomerate become thicker as they are traced to the south-west. They thin out in similar fashion in Kincardineshire as they are followed to the north-east; and since no signs of volcanic vents are found in the inland sections, one can only conjecture that the centre or centres of eruption must be concealed to the eastward on the floor of the North Sea.

XI. HYPABYSSAL INTRUSIONS OF LOWER OLD RED SANDSTONE AGE.

The hypabyssal intrusions include dykes of quartz porphyry and biotite porphyry, and thin sills and dykes of lamprophyre and dolerite. Quartz porphyry dykes are found at Cowie, at Clochnahill, at Allardice Castle, and on the shore near Hallgreen Castle; the peculiar Lintrathen type occurs in the North Esk and Clattering Bridge sections. A group of dykes, appearing at intervals along a line extending from the Carron Water near Mill of Forest by the Hill of Seabeg and Fawside, Kinneff, to the coast at the Pintill Stone, may be classed as biotite porphyries. An intrusion of olivine dolerite, which behaves sometimes as a sill, sometimes as a dyke, has been traced from Cadden Castle to Shieldhill, and, shifted by the Whistleberry fault, again appears in the neighbourhood of Crowhillock. It has produced marked contact alteration in the tuffs

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* See also *Ancient Volcanoes of Great Britain*, vol. i. p. 299.

of the Crawton group. A very poor exposure of a dolerite accompanied by similar types of metamorphosed tuffs is seen at Mudlin's Den, near Hallgreen, at approximately the same stratigraphical horizon. Numerous thin sills and narrow dykes intruded into the same volcanic conglomerate and tuff zone between Bervie and Todhead are lamprophyric in character. Their occurrence is restricted to this horizon. They are all much decomposed, and resemble the lamprophyre dykes belonging to the volcanic series of the Pentland Hills.

The above minor intrusions belong to a comparatively late phase in the volcanic history of the area. Most of them are intruded into, and are therefore younger than, the lower portion of the Crawton group; others cut the older part of the Arbuthnott group. There is no evidence to show that any are younger than the hypersthene andesite and basalt series.

Comparing the Kincardineshire Old Red Sandstone with a typical Scottish Carboniferous succession, one is struck at once with the almost entire absence of intrusive sills. A few thin sills occur, but none at all comparable with the massive intrusions of Carboniferous age. In marked contrast again with the volcanic members of the Lower Old Red Sandstone of other areas,—such as the Cheviot group, or the Lorne plateau—is the relatively poor development of the dyke phase. The paucity of sills and dykes may reasonably be correlated with the absence of vents. It is worthy of note, too, that dykes of presumably Old Red Sandstone age show a marked increase in number in the belt of schists which intervenes between the Highland fault and the newer granites; and further, that the development of minor intrusions in the Old Red Sandstone area reaches a maximum at the coast line between Johnshaven and Braidon Bay. Such a distribution of the hypabyssal intrusions strengthens the suggestion that the volcanic centres were situated along two lines—one in the area now occupied by the Dalradian schists, the other to the east of the present coast line.

XII. Physical Conditions during the Lower Old Red Sandstone Period.

The Lower Old Red Sandstone of the Midland Valley of Scotland is characterised everywhere by the development of coarse conglomerates. A study of the succession in south-eastern Kincardineshire brings out very clearly two points: (1) the total thickness of coarse conglomerates is far greater than that of the finer sediments; (2) the coarseness of the average conglomerate is remarkable even for a Scottish Old Red Sandstone district. At many horizons the boulders average about two feet; and frequently the magnificently rounded boulders of quartzites, granites, schistose grits, and other "Highland" rocks measure from three to seven feet along their longest diameter. It is difficult, indeed, to realise that the rounding and transportation of these boulders has been accomplished by the agency of moving water, either by waves or by mountain torrents. Not only are the blocks well rounded, but the hard, fine-grained, homogeneous types show remarkable curved fractures, "chatter markings," which indicate in no uncertain fashion the treatment to which they were subjected before they were finally buried in the wonderful gravels of Old Red Sandstone times. The conglomerates, whether we regard them as old beaches or as stream gravels, and the finer sediments with their prevalent ripple marks and sun-cracks, can only represent shallow water conditions; the association of remains of myriapods and plant debris in the latter undoubtedly indicates deposition in close proximity to a land area. The formation offers no evidence either of marine or of deep-water conditions of sedimentation.

The composition of the conglomerates shows clearly that, throughout the whole of Lower Old Red Sandstone times, the Highland area was undergoing extensive denudation. The extraordinary abundance of jaspers, cherts, and "green rocks" as pebbles in the lower conglomerates necessitates a former wide extension of the Upper Cambrian rocks —they may, indeed, have extended far over the Eastern Highlands. The frequent occurrence of boulders of the "Haggis rock" type of greywacké, again, may mean that Ordovician strata (now probably represented by the narrow belts which Mr Barrow has designated the Margie series) were present in considerable force on the north side of the Midland Valley. In the conglomerates below the Crawton lava zone there is an alternating predominance of pebbles of Upper Cambrian rocks and of acid andesites, and this suggests that at successive periods the supply of Jasper and Green-rock material was temporarily cut off by the discharge of acid lavas from the Highland group of volcanoes. The distribution of granite boulders, too, is of supreme interest; and, while I cannot at present give a detailed account of this, the occurrence of pebbles of granites belonging to the so-called "newer granite" types of the Highlands in the lowest conglomerates is sufficient to show that some at least of these are of pre-Old Red Sandstone age. Such granites may represent the plutonic equivalents of the oldest "Caledonian" volcanics, which, as I have shown, are certainly not younger than the Downtonian, and may perhaps be older. The most striking characteristic of the youngest conglomerates is the marked predominance of pebbles of flaggy gneisses, and along with this may be noted the gradual decrease in the proportions of those of jaspers and cherts and acid volcanic rocks as the former increase in number. Hence, towards the end of the period the "Highland Border" rocks and the Upper Silurian-Old Red volcanic series had either been protected by the overlap of the highest beds to the north and west, or had already been to a large extent removed by denudation.

Conclusions such as the above are suggested by the general observations recorded in the present paper. It is hoped that further detailed investigation of the distribution of the boulders in the conglomerates will throw important light on the history of the Eastern Highlands in early palæozoic times.

Nowhere in Kincardineshire does the distribution and character of the volcanic conglomerates suggest the destruction of volcanic islands and the consequent formation of coarse beaches. The constant association of "Highland" boulders with those of volcanic origin, and the thickening of the volcanic conglomerates when traced towards the Highland fault, point conclusively to the Highland area as the source of the material. It seems to me that all the conglomerates are old torrential gravels rather than beaches, and for two reasons. (1) The composition of the conglomerates is suggestive. In the magnificent section at Crawton, for example, the rocky foreshore coincides in position with the eroded surface of the Crawton basalt, with many of the hollows still filled with conglomerate. This uneven junction may be traced round an isolated stack which extends seawards for about twenty yards, and may be followed again in the cliff section to the north. If the overlying conglomerate were an old beach, one would expect it to contain a big proportion of boulders of the lava, whereas only a very few can be seen, and that in an exposure, which, as indicated above, extends over a considerable area. Indeed, in all the conglomerates the admixture of rock types brought together from widely separated areas suggests powerful torrents as the chief eroding and transporting agents. (2) The numerous storm beaches on the Kincardineshire coast have received their constituent boulders in large part "ready made" from the disintegration of the local Old Red Sandstone conglomerates, and may, therefore, well be compared with the latter. Both show a characteristic imbricated arrangement of their boulders, and, since the general trend of the coast is parallel to the Highland Border, and therefore probably to the successive shore lines of the Old Red lake, we should expect the boulders of the conglomerates—if those represent beaches—to overlap in the same manner as the stones of the modern beach. Wherever the imbricated arrangement has been observed, however, in the conglomerates, it indicates that the boulders were placed in their present position relative to one another by currents coming from the north or north-west.

There can be no doubt, I think, that the accumulation of the boulders and their exquisite rounding must be ascribed mainly to the action of torrential rivers rather than to wave action along the shores of a lake. None of the beaches of the great fresh-water lakes of the present day are at all comparable with the coarse conglomerates; but the latter recall at once modern torrential flood gravels and the fluvio-glacial gravels of late Glacial times.

In short, the coarse conglomerates of our area represent the coarse torrential gravels swept outwards from a lofty "Highland" mountain range on to the margin of a wide frontal plane, across which extended a great shallow fresh-water lake or chain of lakes where were accumulated the finer gravels, sand, and silt now consolidated to form the finer conglomerates, sandstones, and shales. To the north and west along the flanks of the mountains, and to the east beyond the limit of the present land, stretched two lines of active volcanoes. The former supplied the acid lavas and tuffs, and, indirectly, the volcanic conglomerates; from the latter were extruded the basalts and basic andesites. The eastern volcanoes may have formed a chain of volcanic islands, but no evidence of that has been detected within the area with which we are concerned.

XIII. UPPER OLD RED SANDSTONE.

A narrow interrupted belt along the coast in the neighbourhood of St Cyrus is occupied by rocks which, in their lithological characters, are markedly different from the Lower Old Red Sandstone. No fossils have been recorded from these beds. In the Geological Survey map they are assigned to the Upper Old Red Sandstones, and recent work has fully confirmed this view. As Dr HICKLING * has pointed out, the lithological and stratigraphical evidence together show conclusively that the isolated patches at St Cyrus, Buddon Point, and Arbroath must be regarded as outliers of the extensive tracts of Upper Old Red Sandstone of the Carse of Gowrie and the north of Fife.

The St Cyrus outlier consists of two separated areas—one extending from Rock Hall fishing station to East Mathers, the other from Kirkside to the mouth of the North Esk. In each case, but particularly in the southern tract, the solid geology is to a very large extent obscured, partly by raised beaches and blown sand, partly by boulder clay.

The rocks of the Rock Hall and East Mathers area include cornstones, calcareous sandstones, bright red marls, and red false-bedded sandstones and grits—an association of sediments of frequent occurrence in the Scottish Upper Old Red Sandstone. The dip of the beds is always low, and the total thickness of strata exposed cannot be very great. At Arbroath, as has been shown by Dr HICKLING, the basement beds consist of about 200 feet of conglomerates and sandstones derived chiefly from the disintegration of sandstones and conglomerates of Lower Old Red Sandstone age; at Buddon Point there is a good development of the higher, cornstone, type of sedimentation. In the St Cyrus outlier the base of the series is nowhere visible, since the junction with the older rocks is everywhere a line of faulting and not a natural boundary as indicated in the published maps. On the road leading from the shore to Milton of Mathers there is exposed a group of bright red sandstones and grits, which in all probability underlie the cornstone horizon, and may represent part of the Arbroath series. The sandstones contain occasional rounded pebbles, and among these I noted a chatter-marked boulder of jasper, derived most likely from a conglomerate of the Lower Old Red Sandstone. The cornstone group includes typical cornstones, often with a marked development of chert, flesh-coloured sandstones with a matrix of crystalline calcite, sandstones with calcareous nodules, soft red marls, and red false-bedded sandstones. At Rock Hall the main exposure of cornstone is underlain by a bed of conglomerate made up of fragments of limestone, chert, and sandstone of types found locally in the Upper Old Red series, and obviously indicative of contemporaneous erosion. It is beyond the scope of this paper to give a detailed petrographic account of the curious variations in the sediments of the cornstone group, but such an investigation would undoubtedly throw valuable light on the conditions which prevailed in Upper Old Red Sandstone times.

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* *Geol. Mag.*, dec. 5, vol. v. p. 403.

Between Kirkside and the North Esk the Upper Old Red Sandstone is almost entirely concealed under blown sand and raised beach deposits. The best exposures are found at Kirkside fishing station, where the rock consists of a massive false-bedded white sandstone dipping at low angles to the north-west. Neither the top nor the base of the sandstone is seen, but it is at least 30 feet thick. The direction of strike of the beds suggests that they occupy a position not far below the cornstone of Rock Hall, and they may perhaps be regarded as the equivalents of the thick sandstone which underlies the cornstone series at Buddon Point. Similar sandstones occur also in close proximity to the Lower Old Red Sandstone lava series in the small stream which flows past Pathhead.

From the North Esk to Kirkside the junction between the Upper and Lower Old Red Sandstone is clearly a fault, the line of which skirts the base of the conspicuous cliff feature of 25-feet-beach times. Its position is readily detected from the occurrence of patches of fault breccia, sometimes veined with barytes. A prolongation of the same fault again forms the boundary at Rock Hall, where it is well seen in the cliff section.

The northern margin of the outlier on the coast section near East Mathers is also a fault trending south-east, and bringing the cornstone horizon against the conglomerates and basalts of the older series. As it is traced along the old 25-feet-beach cliff, the fault changes in direction to east-and-west. The next inland exposure showing the character of the boundary is at the south end of the wood of Den Finella, and here again there is clear evidence of faulting, the red sandstone underlying the cornstone horizon being separated from the older lavas by a brecciated sandstone. Westward from Den Finella the solid geology is to a large extent obscured by drift deposits, but the distribution of the lavas and the occasional exposures of sandstone of Upper Old Red type indicate that the fault gradually changes in direction to south-west and north-east.

Between Mill of Woodston and West Mathers there are no exposures showing the junction of the older and younger rocks. The brecciated character of the basalts at the former locality, however, suggests the presence of an east-and-west cross fault between the two main faults described above. In short, the boundary between the Upper Old Red Sandstone of the St Cyrus outlier and the Lower Old Red Sandstone is everywhere a line of faulting.

XIV. INTRUSIONS OF [?] CARBONIFEROUS AGE.

In addition to the hypabyssal intrusions of presumably Lower Old Red Sandstone age described above, there occur in south-eastern Kincardineshire a number of quartz dolerite dykes and teschenite sills, whose affinities are rather with the rocks of the Scottish Carboniferous volcanic series.

(*a*) *Quartz Dolerite Dykes.*—As will be seen from the accompanying map (Pl. II.), there are numerous occurrences of quartz dolerite dykes having a general east-north-easterly trend. The dyke described by Professor FORBES* belongs to this group. First seen in close proximity to the Highland fault in the Burn of Balnakettle, it appears again at Coventree quarry, at Phesdo quarry, in several of the gorges on the eastern slopes of the Strathfinella hills, in the Rectory quarry, Drumtochty, and finally in the Broomy Brae quarry, near Auchinblae—a distance in all of about eight miles. Another example, which may be traced for about the same distance, is seen in the North Esk, near Capo, in the Luther Water between South Muirton and Luther Bridge, near Marykirk station, at the Burn of Balmakelly (where it is at present being quarried for road "metal"), and in a small stream north of Craig of Garvock. Other dykes, occurring sporadically and traceable only for short distances, are found at Stonehaven harbour, in the Carmont railway cutting, in the North Esk near the House of the Burn, at Birnie Road siding, and at Johnshaven. The last example presents features of considerable petrographical interest which will be discussed in my paper on the petrography of the igneous rocks of the area.

These dykes are of the same type, and probably belong to the same period of intrusion, as the late Carboniferous east-and-west dykes of Central Scotland.

(*b*) *Teschenite Sills.*—On the rocky foreshore between Bervie Bay and Gourdon there is a considerable development of igneous rocks, including a soft green "serpentine." The "serpentine" was formerly mapped as an intrusive dyke, the other igneous rocks are contemporaneous porphyrite lavas. From the field evidence, however, it is apparent that all are intrusive, and, indeed, that all belong to the same intrusion—a sill with a maximum thickness of about 180 feet—consisting of a soft central portion of highly decomposed doleritic rock or "serpentine," above and below which is a hard, fresh olivine analcite dolerite or teschenite. The teschenites are in places rich in acid "segregations." Towards the top and bottom of the intrusion they become strongly porphyritic with tabular crystals of plagioclase felspar, and such parts of the rock present a deceptive resemblance to the Crawton basalts. Junction specimens show the chilling of the upper and lower margins, and clear evidence of the intrusive character of the mass is seen from the way in which the igneous rock everywhere interdigitates with the overlying and underlying conglomerates and tuffaceous sandstones. Another small teschenite intrusion occurs at Bob's Cove, Kinneff.

These alkali-rich intrusions have in all probability been derived from the same magma as the Carboniferous volcanic rocks of the Midland Valley. Their affinities are certainly with an "Atlantic" series rather than with the "Pacific" or calc-alkali series to which the lavas and intrusions of the Lower Old Red Sandstone period so obviously belong.

XV. SUMMARY OF THE CHIEF STRUCTURAL FEATURES.

Along the greater part of its course across Kincardineshire the Highland fault forms the boundary between the Downtonian-Lower Old Red Sandstone series and the older

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* *The New Statistical Account of Scotland*, vol. xi., *Kincardineshire*, p. 72, 1845.

rocks to the north-west. From St Mary's Chapel to Garron Point (see Sketch-map, fig. 1) a small area of Upper Cambrian occurs on the south side; and at Kirkton in the extreme west [?] lavas of Old Red Sandstone age are found on the north side of the fault. In the coast section at Craigeven Bay, and again in a small stream near Elfhill —the only two localities at which the actual line of dislocation has been observed,—the Highland fault in the Kincardineshire area is an overthrust, not a normal fault as has been supposed.

A strong unconformity separates the Upper Cambrian and the Downtonian.

The dominating structural feature is a continuation of the well-known synclinal fold of Strathmore, the axis of which passes out to sea near Maiden Kaim. In the area to the west of Elfhill there is a tendency to set up a steep-limbed anticline, pitching out to the south-west against the Highland fault, and succeeded towards the north at Bogincabers by an inverted syncline. Convincing evidence of the character of the Elfhill anticline is obtained in the Water of Bervie section, where various beds in the Arbuthnott group can be traced round the fold; in the vicinity of Bogincabers a thick covering of drift obscures the solid geology, but the distribution of the hornblende andesites is strongly suggestive of the presence of an inverted synclinal fold.

An important dip fault crosses the Strathmore syncline from Thornyhive Bay to the Highland fault near Fetteresso, and the southern limb of the syncline is traversed by two sets of powerful faults, trending respectively south-east and north-west, and east-north-east and west-south-west. Frequently also along the same limb—and especially in the southern part of the area—there occur "shatter belts" marked by conspicuous breccias, which form the dyke-like features seen on the foreshore north of Johnshaven. Along these dislocations, however, little, if any, vertical displacement has been effected.

The Upper Old Red Sandstone series is everywhere faulted against the Lower.

XVI. Acknowledgments.

In conclusion, I wish to acknowledge my indebtedness to those who have assisted me in this research—to Professor James Geikie, D.C.L., LL.D., F.R.S., for constant encouragement and advice; to the late Dr R. H. Traquair, F.R.S., who named the fossil fishes; and to Dr John Horne, F.R.S., and Dr B. N. Peach, F.R.S., who have throughout shown a keen interest in my work, and have at all times placed at my service their wide and intimate knowledge of Scottish geology. To the inspiring friendship of Dr. Peach in particular I owe a deep debt of gratitude. Not only has he been ever ready to discuss points of difficulty, but he has on various occasions accompanied me to Kincardineshire and visited all the important sections. Dr Peach also determined all the specimens of the Arthropoda, and has kindly undertaken to describe the new species. I desire to thank most cordially my friend and colleague Dr W. T. Gordon, who has been my companion on many excursions to Stonehaven,

and has given me invaluable assistance in the palæontological part of the work. The splendid collection of fossils from the Highland Border rocks at Garron Point bears witness to the enthusiasm and skill of Mr D. TAIT of the Geological Survey of Scotland. The Rev. J. R. FRASER of Kinneff, the Rev. THOMAS LAURIE of Laurencekirk, and Mr JOHN MASON of Auchinblae gave me valuable help in the field work in these districts.

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XVIII. EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Ruthery Head, near Stonehaven. The white line indicates the position of the unconformable junction between the Upper Cambrian (C) and Downtonian (D).

Fig. 2. Ruthery Head. Nearer view of another part of the unconformable junction shown in fig. 1. The broken white line marks the position of a small fault.

Fig. 3. Craigeven Bay, Stonehaven. Downtonian rocks in the foreground; Upper Cambrian strata of Garron Point on the far side of the bay.

Fig. 4. Coarse conglomerate resting on eroded surface of Crawton basalt at Crawton. The photograph shows finer conglomerate filling cracks in the lava.

Fig. 5. "Sandstone veins" in basalt on shore near Whistleberry, Kinneff.

PLATE II.

Geological Map of South-Eastern Kincardineshire. [Geological lines on area north of the Highland Boundary fault are taken from maps of H.M. Geological Survey.]

PLATE III.

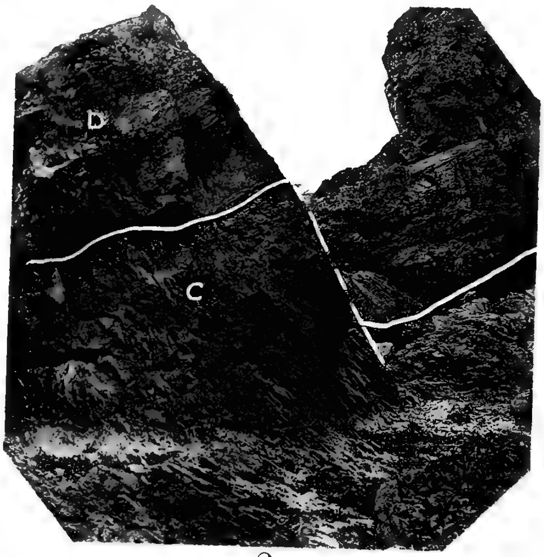
Horizontal sections along lines A, B, C, and D of Plate II.

x.	Dalradian schists.
a^1.	Upper Cambrian.
b.	Downtonian.
Br.	Basement breccia of Downtonian.
Di.	*Dictyocaris* horizon of Downtonian.
c^1.	Lower Old Red Sandstone.
c^3.	Upper Old Red Sandstone.
V.	Volcanic conglomerate and tuffs.
Rc^1.	Dacite.
$h.Ac^1$.	Hornblende and augite andesites.
Cr.B.	Crawton basalt.
$o.Ac^1$.	Hypersthene andesite and basalt.
q.F.	Quartz porphyry.
t.D.	Teschenite.
M.	Quartz dolerite.
F.	Fault.
H.F.	Highland fault.
T.	Thrust plane.
u.	Unconformity.

Trans. Roy. Soc. Edinr. Vol. XLVIII.

R. CAMPBELL: ON THE GEOLOGY OF SOUTH-EASTERN KINCARDINESHIRE.—PLATE I.

1



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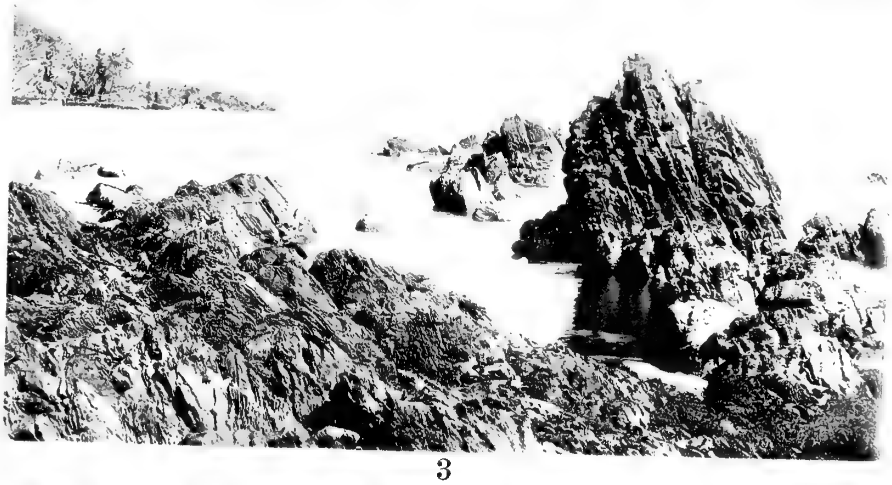

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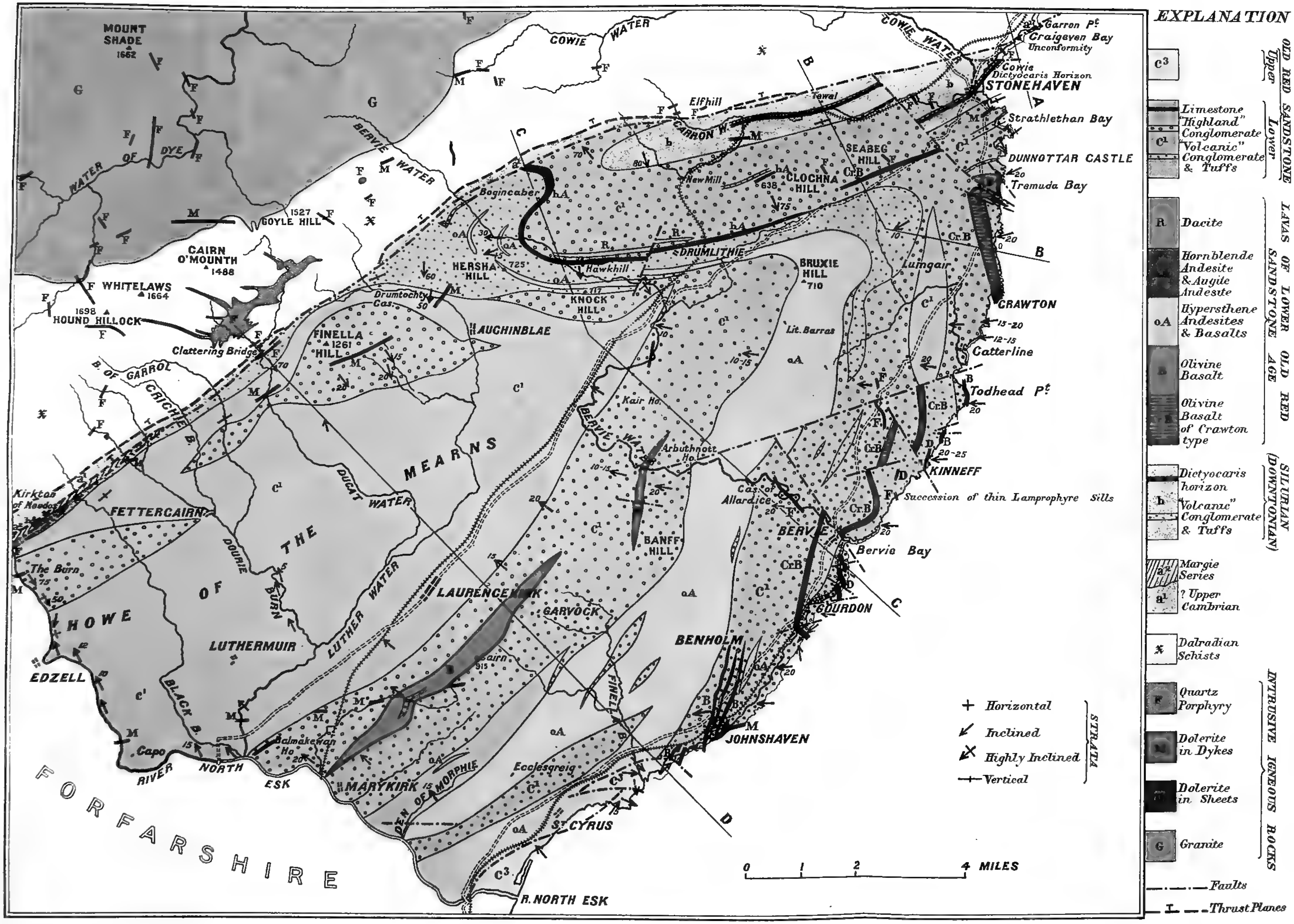
R. CAMPBELL: ON THE GEOLOGY OF SOUTH-EASTERN KINCARDINESHIRE—PLATE II.



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R. CAMPBELL: ON THE GEOLOGY OF SOUTH-EASTERN KINCARDINESHIRE—PLATE III.

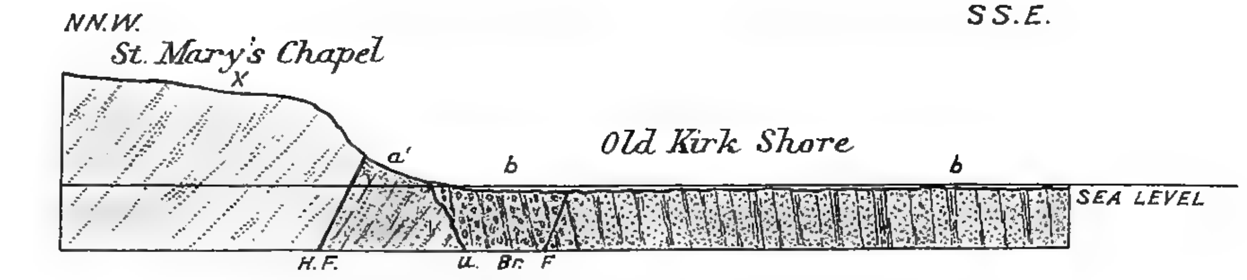

Fig. 1. Section along line A of Map (Plate II.). Horizontal and Vertical Scales: 24″=1 mile.

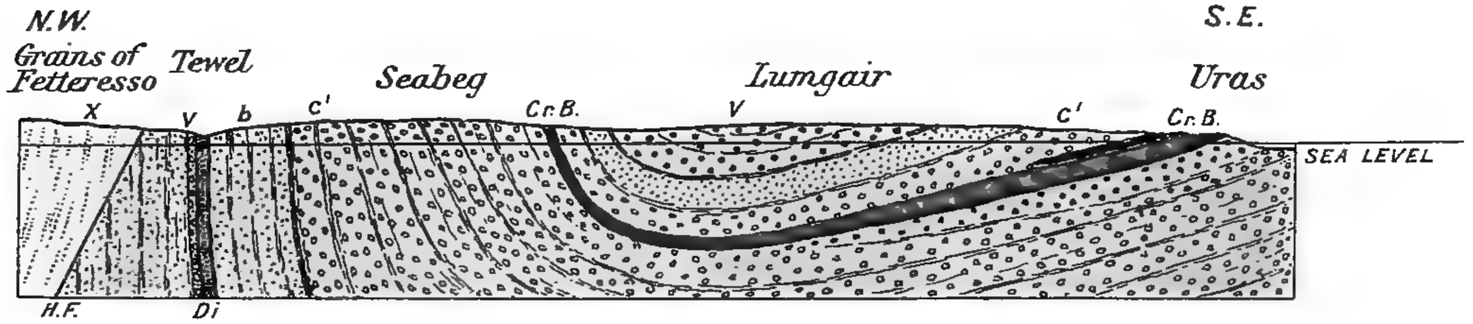

Fig. 2. Section along line B of Map (Plate II.). Horizontal and Vertical Scales: 1″=1 mile.

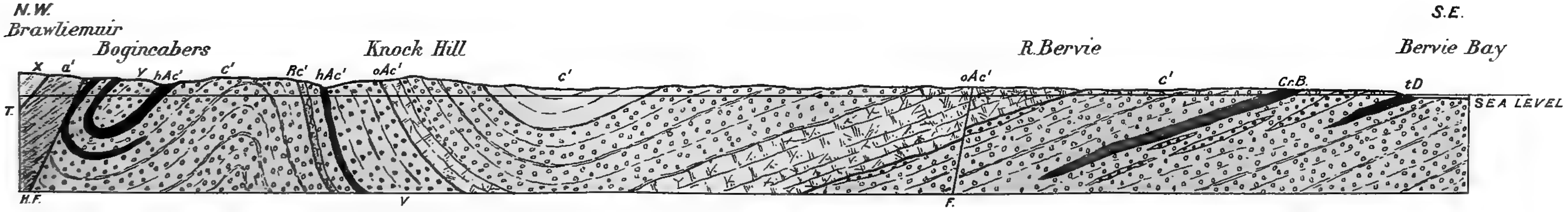

Fig. 3. Section along line C of Map (Plate II.). Horizontal and Vertical Scales: 1″=1 mile.

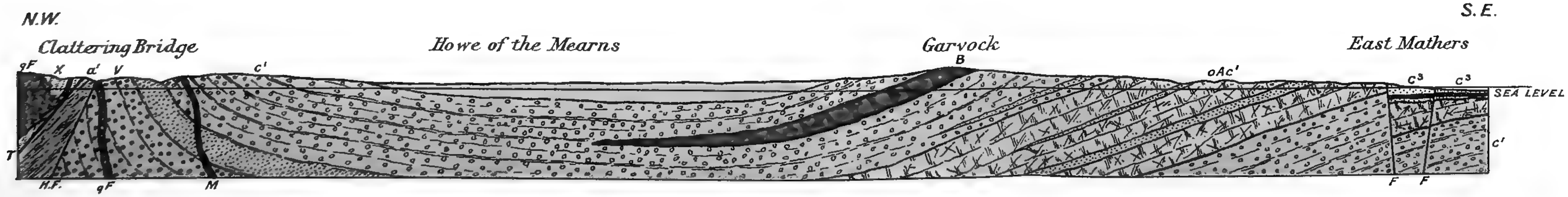

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Fig. 4. Section along line D of Map (Plate II.). Horizontal and Vertical Scales: 1″=1 mile.

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