XIX. *Description of* Ceratodus, *a genus of Ganoid Fishes, recently discovered in Rivers of Queensland, Australia.* *By* Albert Günther, *M.A., Ph.D., M.D., F.R.S.*

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Contents.

Introductory Remarks.

At the beginning of last year my valued correspondent, Mr. Gerard Krefft, Curator of the Australian Museum, Sydney, informed me of the discovery in Queensland of a large *Lepidosiren*-like animal, of which he enclosed a photograph*, and which he assigned to *Ceratodus*, a genus of fishes known from fossil teeth only, naming the species after its discoverer, the Hon. William Forster, *Ceratodus forsteri*.

Before my reply had time to reach Mr. Krefft, a short communication of his on the subject was read before the Zoological Society of London (April 28, 1870); it is entitled "Description of a gigantic Amphibian allied to the genus *Lepidosiren*, from the Wide-Bay district, Queensland" (Proc. Zool. Soc. 1870, p. 221). The author describes in this note the principal points of the external appearance and dentition, and mentions also that "the skeleton is partly ossified, partly cartilaginous, the vertebræ being pure cartilage, and the ribs hollow tubes filled with a cartilaginous substance. The palate and upper part of the skull are bone, and the head is covered with two enormous scales."

* From this photograph the woodcut in the Proc. Zool. Soc. 1870, p. 222, is taken.

Mr. KREFFT's specimen was evidently only roughly preserved, and the internal organs had been removed.

Another specimen, acquired by the Sydney Museum some months after, was forwarded to me, through the great liberality of the Trustees of that Institution, for the purpose of a more detailed examination. It reached me towards the end of August last, and proved to be a fine example, 38 inches in length, unfortunately without any of the soft internal organs, but with the external and skeletal parts nearly perfect. From this specimen, which I have deposited in the British Museum, the subsequent descriptions of the skeleton, scales, and fins are taken.

Professor OWEN received a third (male) specimen from Professor A. M. THOMSON, of Sydney, in the month of November; he very kindly handed it over to me; and it proved to be of the greatest value, as it was not only but little inferior in size to the one previously received (32 inches), but also had the soft organs in a good state of preservation. Finally, by the same mail, and apparently from the same source, the Secretary of the Zoological Society received a fourth example, smaller than the preceding (26 inches), but of great interest, because by it I was enabled to ascertain the structure of the female organs in an immature condition. As it is destined for the collection of the Royal College of Surgeons, I availed myself of the permission to dissect it only so far as to elucidate some points which could not be satisfactorily made out from the preceding specimens*.

Mr. KREFFT was certainly most fortunate in assigning, from the beginning, to this fish its proper place in the system, by describing it as "allied to *Lepidosiren*," and referring it to *Ceratodus*. Indeed the principal reason which appears to have induced him to state in so definite a manner an affinity to *Lepidosiren*, was his having been informed that this fish was in the habit of living temporarily on land; but the affinity extends much further, and consists in a nearly perfect identity of the skeleton, in the coexistence of a lung with gills, in a great resemblance of the intestinal tract, and also of the dentition—a resemblance recognized by Professor OWEN† at a time when *Ceratodus* was still considered to be a Shark, but denied by Mr. KREFFT‡.

The genus *Ceratodus* was established by Professor AGASSIZ§ for teeth which are found in strata of Jurassic and Triassic formations in various parts of Europe. Professor OLDHAM, F.R.S., has described teeth which were found in India, at Maledi, south of Nagpur||, and differ scarcely from Muschelkalk examples; the stratum from which the

* Whilst this paper was passing through the press, the Trustees of the British Museum received from those of the Sydney Museum three other examples in a perfect state of preservation. One proved to be a female with fully developed sexual organs, a description of which will be added hereafter.

† Trans. Linn. Soc. 1839, vol. xviii. p. 331. "These teeth, in their paucity, relative size, and mode of fixation to the maxillæ, resemble those of the *Chimæra*, and some of the extinct cartilaginous fishes, as *Cochliodus* and *Ceratodus*."

‡ "This newly found amphibian has a dentition different from that of *Lepidosiren*."—Proc. Zool. Soc. 1870, p. 221.

§ Recherch. Poiss. Foss. vol. iii. p. 129.

|| Geological Survey of India, p. 295.

Indian specimens have been extracted is not yet determined with certainty. These teeth have always been found isolated, sometimes with a portion of the bony base attached to them; no other part of the fishes to which they belong has hitherto been found associated with them; and with our present knowledge of the organization of the living representative of these extinct species, we can hold out but little hope that other parts may have been preserved which can be recognized as the remains of *Ceratodus*.

These fossil teeth (Plate XXXI. fig. 10), of which there is a great variety with regard to general shape and size, are much longer than broad, sometimes 2 inches long, depressed, with a flat or slightly undulated, always *punctated* crown, with one margin convex, and with from three to seven prongs projecting on the opposite margin. Professor Agassiz pointed out, from their shape, that there must have been only two of them in the upper jaw and the same number in the lower, that the convex margin was directed inwards and the prongs outwards—a view also held by Pander*, who made considerable additions towards an accurate knowledge of the structure of these fossils.

We shall see hereafter that all the characters mentioned are found in the teeth of our living fish, that the teeth of some of the fossil species (for instance *Ceratodus runcinatus*) are surprisingly similar to those of the living (see Plate XXXI. figs. 9 & 10), and that their position and their number is exactly as shown by Agassiz and Pander (to whom, however, the vomerine teeth were unknown). Therefore Mr. Krefft was quite right in referring the recent fish to this genus†.

Geographical Distribution and Habits.

Before I proceed to the description of the fish, I may notice the little that is known of its geographical distribution and habits. Hitherto it has been found in Queensland

* Ctenodipt. Devon. Syst. p. 33.

† At a time when nothing was known in this country of *Ceratodus forsteri*, except the description and photographs which were afterwards published by Mr. Krefft in Proc. Zool. Soc., doubts were expressed as regards the propriety of associating a recent fish with a genus living in the Jurassic and Triassic epochs. It may be said in reply that fishes very closely allied to, although generically distinct from, *Ceratodus* and *Lepidosiren*, are known from a much earlier epoch, viz. the Devonian (*Dipterus, Cheirodus, Conchodus, Phaneropleuron*), and that the scanty representation and wide distribution of this ichthyic type in the present epoch (one in Africa, one in South America, and one in Australia) is a sure proof of its extreme antiquity. Further, there is not the slightest evidence that the recent and fossil Ceratodonts differed from each other. It is true we have only the teeth for our guidance; but these are so well marked by peculiar characters, and the recent teeth so similar to those of certain extinct species, that we should be better justified in making generic distinctions among the fossil forms, than in separating the living from the extinct. Naturalists can be guided only by the evidence before them, and not by such vague hypothetical notions as that distance in space or in time has *necessarily* effected generic or other differences. I expressed these views at the meeting of the Zoological Society when Mr. Krefft's paper was read. However, an anonymous reporter in a semipopular journal could not withstand the temptation of proposing a new generic name by translating the term "Wonder of the Rivers" into Greek, a term more expressive of the amount of knowledge of the author than of the peculiarity of the fish. If *Ceratodus forsteri* had proved to be the type of a distinct genus, the honour of naming it would, of course, have been claimed by that writer!

only. Mr. E. S. Hill writes*, "The fish *Ceratodus forsteri* is found in most of the rivers north of, and abundantly at Wide Bay; the northern limit, so far as is yet known, is the Burdekin, and the southern the Mary river; these fishes do not go higher than the brackish water, and at night leave the streams and go out among the reeds and rushes on the flats subject to tidal influence: this has been particularly observed on the banks of the Mary, where of a still night they may be distinctly heard. The aborigines catch many. Locally the Europeans call them 'Flat-head.' In the Fitzroy river, above Yamba and the Falls, there is a fish known to the aborigines as 'Barramundi' of excellent quality, and attaining the size of twenty pounds; it does not come down to the brackish or salt water" (June 30, 1870). The specimen sent to Professor Owen was accompanied by the following notes†:—"The fish was captured at Gootchy, on a tributary of the Mary river, in freshwater about thirty miles inland. The common name 'Barramundy' given to the fish is applied to different fishes in different places." Specimens 6 feet in length have been mentioned. The intestinal tract of two specimens was found by me crammed full of more or less masticated leaves of various plants, which my colleague, W. Carruthers, Esq., F.R.S., determined as fragments of various *Myrtaceæ* and *Gramineæ*. In both specimens they had lost the green colour entirely, being of a uniformly deep black, as if they had lain in water for some time, and were eaten when in a decomposing condition. The quantity of these vegetables contained in the intestine is enormous; and there is no doubt that they constitute the principal food of the fish. Some fragments of small shells, which, Mr. Krefft informs me, have been found in the stomach, appear to have been swallowed accidentally with leaves. Whether a fish with such a diet "will at certain seasons rise to a fly" is a point requiring further observation. Some remarks regarding the alleged amphibious habits of this fish are, perhaps, better reserved for the chapter on the organs of breathing (p. 541). Nothing is known about its propagation or development.

External Parts.—Ceratodus forsteri and *Ceratodus miolepis.*

With regard to the *general habitus* of the body (Plate XXX.), *Ceratodus* much resembles *Lepidosiren*; but it is less elongate, and the large scales of the body, joined with fin-like paddles and distinctly rayed vertical fins, give to it an appearance which approches more nearly to the ordinary fish-type than that of *Lepidosiren*.

The *head* is broad and depressed, with the upper surface slightly convex and gently sloping towards the sides; the snout rather short, spatulate, becoming narrower towards its extremity, which is truncate. The total length of the head (to the gill-opening) exceeds considerably its greatest width; and its depth is less than one half of its length. The upper surface, the jaws, and cheeks are covered with thick skin perforated by small pores, which, however, are not regularly arranged. The gill-cover and the throat behind the mandibles are covered with large scales, scarcely different in size from those of the

* Note kindly communicated by Sir D. Cooper, Bart.

† Letter of Professor Alex. M. Thomson to Professor Owen, dated Sydney, Sept. 6, 1870.

trunk. The eye is small, lateral, much nearer to the extremity of the snout than to the gill-opening; orbit with a free edge. The mouth narrow, its corner being at some distance in front of the eyes; lips rather thick and soft, simple, except on the side of the mandible, where the skin forms a simple, pendent fold.

At the angle of the mouth, and hidden below a duplicature of the skin, there is an opening wide enough to admit an ordinary quill (Plate XXX. fig. 2, *a*); it leads into a spacious cavity (*b*), irregular in shape, clothed with a mucous membrane, and containing coagulated mucus in which an immense number of mucous corpuscles are deposited. This cavity is separated from the cavity of the mouth by the membrana mucosa only, and there is no direct communication between them; a branch cavity runs forward into the interior of the upper lip.

The gill-opening begins on the side of the occipital region, and descends to below the pectoral paddle; its entrance is covered, not by the bony gill-cover, but by a broad cutaneous fringe of the operculum, the scales of this part of the cutis being very small.

The foremost portion of the trunk is depressed, like the head, but it soon passes into the compressed remaining portion—the boundary between trunk and tail being externally indicated by the vent only, which is *in the median line of the abdomen*. The tail evidently varies in length; it is sometimes shortened, as I have also observed in *Heterotis* and other diphycercal fishes; and it appears that injuries of this part, particularly when inflicted in early youth, are readily repaired. The depth of the trunk decreases slightly behind; and the tail diminishes rapidly in vertical dimension, till it ends in a thin point which is externally scarcely distinguishable, being enveloped by the vertical fin.

The dorsal part of this *fin* commences as a low membrane on the back behind the middle of the trunk, and the anal part at a short distance behind the vent. It is supported or formed by innumerable simple rays, becomes gradually deeper in the same proportion as the depth of the fleshy portion of the tail decreases, and finally tapers rapidly into a point.

The *limbs* consist of two pairs of paddles, similar in appearance to the termination of the tail; viz. a longitudinal axis, formed by the endoskeleton and muscles and covered with scales, is surrounded by a broad rayed fringe. These paddles are structurally identical with the fins of *Lepidosiren*; only the axis and also the fringe are much dilated. The pectoral and ventral paddles taper to a fine point, the former being longer than the head, the latter rather shorter. The ventral paddles are inserted at a short distance in front of the vent.

The entire body is covered with very large *scales*, presenting on the exposed portion a smooth surface with several faint concentric lines of growth; the margin is smooth and membranaceous. Towards the extremity of the tail the scales rapidly diminish in size, passing into the small scales with which a great part of the vertical fin is covered. The axial portion of the paddles is also covered with small scales; whilst the gill-cover is protected by small scales nearest to the branchial cleft, some large scales overlapping the small ones. The lateral line is clearly marked, its scales being perforated at the base of the exposed portion. From the head to opposite the vent there are 22–23 scales in the lateral line; thence the size of the scales diminishes, and about seventeen more scales may be counted in the continuation of the lateral line. So far our description applies to all the specimens known at present; but with regard to the number of longitudinal series of scales, a remarkable difference exists between the examples first known and the two others obtained at a later period from the Mary river.

In the former the middle of the trunk is surrounded by eighteen series of scales, five of which are above, and eleven below the lateral lines. This form has been obtained from the Burnett river; and the type of *Ceratodus forsteri* belongs to it.

In the second the scales are conspicuously smaller, and their external sculpture is less intricate than in the former. The middle of the trunk is surrounded by twenty-one series of scales, six of which are above, and thirteen below the lateral lines. This form may be named *Ceratodus miolepis*.

Structure of the Scales (Plate XXXI.).

In an example of *C. forsteri* 38 inches long, a scale taken from the middle of the side is $2\frac{3}{8}$ inches long and $1\frac{5}{8}$ inch broad (figs. 1 & 2). Anteriorly its outline is rounded, the lateral margins being almost parallel, and meeting the hind margin at nearly a right angle. The exposed part of the scale is not more than about a fourth of the entire surface of the scale, and is covered with a brownish-black membrane. The outer surface, especially of the imbedded portion, is rough, the inner perfectly smooth. Four areas can be distinguished on the outer surface:—1, the exposed portion, covered with a thin brownish-black membrane; 2 and 3, the lateral areas of the imbedded portion, divided into oblique rows of trapezes arranged like scales of a Ganoid fish; and, 4, a median area, triangular in shape, extending from the centre of the scale to its posterior angles, and irregularly longitudinally striped. The inner surface (fig. 2) is quite smooth, but furrowed by lines indicating the course of blood-vessels, with which the membrane of the pouch of the scale is provided; they form an irregular network on the exposed and median areas, densely distributed on the former and sparingly on the latter, and follow the sutures between the trapezes of the lateral areas. The inner surface of the exposed portion shows also numerous pores by which vessels enter the interior of the scale.

The microscopic examination of the scale reveals the following structure*. In a vertical section (figs. 3 & 4) it is shown that each scale is composed of an inner thicker, and an outer thinner and harder stratum. The former consists of numerous layers of fibrous cartilage ("membranous laminæ" of WILLIAMSON), more numerous in the centre of the scale (I count about forty-two), the number of layers decreasing towards the margins. The fibres of one layer run parallel to one another, but generally cross those of the next layer at an angle of either 90 or 45 degrees (figs. 4 & 5). I have not found any of the isolated lenticular calcareous bodies which WILLIAMSON saw imbedded in the

* For comparison with the structure of other cycloid scales I refer to WILLIAMSON's original researches, in Phil. Trans. 1851, p. 647.

membranous laminæ. The outer stratum (fig. 4, *d*) is calcified, the inorganic matter consisting chiefly of phosphate of lime, and in much less quantity of carbonate of lime. The thinnest vertical and horizontal sections give but an indistinct image of the arrangement of its constituent tissues; the greater portion is composed of a great number of transparent calcareous globules, the form of which is less regular towards the surface, which is studded with conical prominences; and these prominences are constantly reproduced from the underlying globules, of which I have seen several assuming a conical form (fig. 4, *d*). When we destroy the organic matter by burning, the scale breaks up into the smaller divisions indicated by the superficial sutures. In the central parts the surface of the calcified matter (fig. 6) is then found to be raised into numerous conical spines, the base of each spine being surrounded by small foramina*. In the marginal and basal portions of the scale (fig. 8) the spines are placed on ridges running parallel with the longitudinal axis of the scale, and separated from one another by valleys. The bottom of these valleys is perforated like a sieve. The spines are more densely placed on the basal part of the scale than on the sides, and are entirely absent on its exposed portion (fig. 7), where the ridges run at a right angle to the free border of the scale, and are frequently connected with each other by transverse ridges.

In the scales of *Protopterus annectens* the outer stratum contains but a small quantity of salts of lime, which form a very thin sieve-like lamina.

In no part of the scales of *Ceratodus* have I discovered bone-corpuscles, which is very singular, inasmuch as Kölliker has not only found them in *Lepidosiren*, but also in those fishes the bones of which are provided with those corpuscles.

Nasal Cavity.

As in *Lepidosiren*, there are two nasal openings on each side (Plate XXXIV. fig. 3, *n*), both being situated within the cavity of the mouth, the anterior somewhat in front of the vomerine teeth, and the posterior outside of the front part of the molar. The nasal cavity is coated with the transversely folded pituitary membrane, the transverse folds being divided by one longitudinal fold; there are about twenty-three transverse folds.

Eye.

The eyeball has a transverse diameter of 13, and a longitudinal one of 10 millims. The optic nerve perforates it somewhat out of its axis. The pupil is circular; the lens spherical, and not steadied by a falciform process. Also the choroid gland is absent, as in *Polypterus* and *Lepidosteus*. The uvea is of a deep black colour, but leaves a great portion round the entrance of the optic nerve uncovered. The sclerotic capsule is strengthened by a single cartilaginous spheroid, which, in a horizontal section made through the greatest periphery of the eyeball, is three fourths of a millimetre thick.

The *Organ* of *Hearing*, being enclosed in the cranial cavity, will be described in connexion with the skull (p. 526).

* Resembling the sculpture of a shield of *Asterolepis*.

Dentition.

The *dentition* is essentially that of *Lepidosiren*, and resembles that of certain extinct genera (*Dipterus*, *Cheirodus*, *Conchodus*, *Psammodus*, &c.), as we shall see hereafter. It consists of a pair of vomerine teeth, and of a pair of maxillary and mandibulary dental plates; but whilst the dentition of *Lepidosiren* is chiefly adapted for piercing and cutting, that of *Ceratodus* is modified for the functions of cutting and crushing. The *vomerine* teeth (Plate XXXIV. fig. 3, *v*, and Plate XXXV. fig. 1, *v'*) are broad and rather low laminæ with a convex and trenchant margin, the outer or posterior part of which is slightly serrated. Each lamina is 13 millims. long, and in the middle 5 millims. deep. They are inserted in an oblique direction to the longitudinal axis of the vomer, and meet in the middle at a right angle; being implanted in cartilage, they are slightly moveable. Each maxillary dental plate (Plate XXXIV. fig. 3, and Plate XXXV. figs. 1 & 2) is an oblong piece with a grinding-surface, a convex inner side, and with the outer side divided into six prominent trenchant ridges or prongs by five notches, of which the foremost is the deepest, the others becoming shallower posteriorly. The foremost ridge passes to the inner border of the tooth, which is likewise somewhat raised. The grinding-surface has a great number of minute depressions (punctuations). The total length of a maxillary tooth is 32 millims. ($=1\frac{1}{4}$ inch), and its greatest width 13 millims. ($=\frac{1}{2}$ inch). In form and size the mandibulary teeth (Plate XXXV. figs. 1–3) are very similar to the maxillary; only the grinding-surface is less uneven. These teeth are anchylosed to the bone, and inserted in an oblique direction: the upper teeth nearly meet each other in the median line; but there is rather a wide interspace between the lower. The double kind of action which these teeth have to perform may be easily understood when the mouth is closed. The flat surfaces of the upper and lower molars are opposed to each other, and serve for crushing or grinding food, whilst the sharp lateral ridges of one tooth fit into the notches of the opposite tooth (Plate XXXV. fig. 1) like the shells of a *Cardium*, this part of the arrangement being adapted for cutting. The foremost ridges of the upper molars are received in the wide space between the lower ones, the vomerine teeth being opposed to the concave dilatation of the symphysial part of the lower jaw.

In a vertical section of one of the grinders (Plate XXXII. fig. 1) it is seen that the real depth of the tooth (that is, of that portion which is formed by dentine) is much less than it appears from a merely outward inspection. It rests, in fact, on an elevated plateau of the dentary bone (fig. 1, *c*), which has exactly the same outlines as the tooth itself, and the substance of which passes so gradually into that of the tooth that it is only by the difference in the shade of colour that the boundary between osseous base and dentinal crown is indicated. This anchylosis, however, is limited to the circumference of the base of the tooth; for its central parts are separated from the bone by the extensive but shallow pulp-cavity (fig. 1, *b*). We must remember that our specimens of living *Ceratodus* are by no means aged individuals, certainly much smaller and younger than those gigantic individuals of extinct species must have been, of which teeth 2 and more inches long are preserved. In such fossil teeth no pulp-cavity is visible, but the dentine passes into the bone across the whole base of the tooth. It is not at all improbable that the pulp-cavity disappears altogether with age.

In our specimens the structure of the bony base of the tooth differs in nothing from that of the remainder of the dentary bone (Plate XXXV. fig. 5): there is the same spongious structure, the same proportion of bone-corpuscles, &c.

Microscopical Structure of the Teeth (Plates XXXII. & XXXIII.).—The teeth of *Ceratodus* present that modification of the tubular structure which is known from *Cestracion*, *Ptychodus*, *Psammodus*, and other fossil genera*; the resemblance in this respect to the structure of a *Psammodus* tooth is particularly striking. In a vertical longitudinal section (Plate XXXII. fig. 2) the substance of the mandibulary tooth is seen to be traversed in the direction from the root towards its upper surface by about fifty-five or fifty-seven medullary canals, following a slightly undulated course, and running nearly parallel to, and at nearly equal distances from, one another. Some of them dichotomize; but no anastomosis can be observed between them. Their terminations clearly correspond to the punctate impressions on the surface of the crown; and those canals which do not actually terminate on the surface of the crown, have the ends surrounded by a great number of dentinal tubes ramifying in every direction. The boundaries between their respective systems are indicated by an intermediate space, into which the dentinal tubes do not penetrate, or in which only their minute terminations can be traced.

In a horizontal section (Plate XXXIII. fig. 2) made near the crown of the tooth the lumina of the medullary canals appear opaque, of an irregularly ovate shape, surrounded by an opaque ring. The opaque centre and opaque ring are separated by a clear interspace traversed by the wavy dentinal tubes. These tubes penetrate through the dark ring, branching off into a great number of finer and extremely minute tubules, so that the outer periphery of the ring appears to be surrounded by a crown of tubules like a fungoid growth. The width of the clear interspace is about equal to that of the dark ring. Sometimes the lumina of two or three and even more medullary canals are surrounded by the same dark ring; they represent the branches of an originally single medullary canal which has been split up by bifurcation into two, three, or more branches. Each of these branches retains its own system of dentinal tubes, not anastomosing with that of the next.

All these remarks refer to the principal vertical medullary canals in the body of the tooth; but towards the surface of the processes (prongs) of the tooth (in the same horizontal section) smaller medullary canals may be observed which have a horizontal position, running obliquely towards the surface, and ramifying in an irregular manner into dentinal tubes which penetrate near to the enamel-like surface of the tooth. These canals are entirely similar to those figured by PETERS in *Protopterus* (MÜLL. Arch. 1845, Taf. 3. fig. 4). There are no bone-corpuscles in any part of this section.

In a second horizontal section, made near the base of the tooth (Plate XXXIII. fig. 3), the lumina of the medullary canals are rather wider than in the first; they are open,

* See OWEN, 'Odontography,' p. 11.

not filled with opaque substance, and the opaque ring is narrower and very close to the periphery of the canal, with a very narrow clear interspace. On the level of this section fewer of the medullary canals are bifurcate. Bone ascends from the base of the tooth to the level of this section, especially at the ends of the tooth; and some bone-corpuscles are observed also in the notches between the processes near the surface.

In vertical (Plate XXXIII. figs. 4 & 5) and horizontal (Plate XXXIII. fig. 6) sections of a large tooth (2 inches long) of the fossil *Ceratodus runcinatus* I find exactly the same structure, making due allowance for the much greater age of the individual, which must have been very large, and for changes due to fossilization. We find the medullary canals arranged in the same manner, of nearly the same width, surrounded by a dark ring from which densely set (fungoid) dentinal tubes proceed. In consequence of greater attrition of the tooth's surface, all the stems of the medullary canals penetrate to the surface, and the corresponding punctations lead directly into the canals.

On the other hand, the microscopical structure of the tooth of *Psammodus* (Plate XXXII. figs. 6 & 7) does not sufficiently agree with that of *Ceratodus* to justify us in assuming, from this part alone, a close affinity between these two fishes. The medullary canals are conspicuously narrower, the dentinal tubes are much less numerous and more simple; there is scarcely a trace of a dark ring; and no tufts of surrounding minute tubules can be seen.

The dentition of *Lepidosiren* differs still more, as far as the minute structure is concerned. That of the upper tooth has been examined and figured by OWEN ('Odontography,' p. 168, pl. 59. fig. 4). The medullary canals form there a network; the main branches run "nearly parallel with the plane of the upper surface of the tooth." In the mandibulary tooth (which I have examined) (Plate XXXII. figs. 3, 4 & 5) the medullary canals are few in number, chiefly running from the base towards the upper parts of the tooth, emitting coarse processes which abruptly break up into very fine spreading ramifications. Near the anterior and posterior surfaces of the tooth the medullary canals are narrower, running in an oblique or vertical direction, parallel to the outer surface of the tooth, emitting dendritically branched processes. In a horizontal section of the tooth the lumina are not surrounded by a dark ring; their arrangement and size, as well as the distribution of dentinal tubes, is exceedingly irregular.

Before we proceed to the examination of the skeleton, it must be mentioned that the general arrangement of the *muscles*, especially of the trunk, is identical with that of *Lepidosiren*; the limit between the dorsal and ventral series is indicated by the course of a continuous mucous canal corresponding to the lateral line.

The Skeleton.

The greater part of the skeleton is cartilaginous; where ossification appears, it is in the form of a covering replacing the perichondrium and more or less completely enveloping the cartilaginous substratum, but never taking its origin in the interior and by transmutation of the cartilage. A layer of white connective tissue sometimes binds the bone and cartilage together; but generally the bone rests immediately upon the cartilage. (See, for instance, the vertical transverse section through the mandible, Plate XXXV. fig. 5, or through the vertebral segments, Plate XXXVIII. figs. 3–8.) Most of the bones are thin, sometimes flexible; and those which are thicker, like the ethmoid, mandibularies, and pterygo-palatine, have a spongy texture with numerous small medullary cavities (Plate XXXV. fig. 5). Bone-corpuscles are found in nearly all the ossified portions of the skeleton; they have but few and very short processes. Their shape is subject to great variations; for instance, they are short in the sclero-parietal (Plate XXXIV. figs. 5 & 6) and other parts of the skull, and very elongate in the articulary bone of the mandible (Plate XXXV. fig. 6).

General Configuration of the Skull.—The Relations of its Cartilaginous and Osseous Parts (Plates XXXIV. & XXXV.).

The skull consists of a completely closed *inner cartilaginous capsule* (Plate XXXIV. fig. 2, and Plate XXXV. fig. 2) and an *outer incomplete osseous case*, to which, again, some outer cartilaginous elements are appended. In the former the confluence of cartilage is so complete that no distinct divisions are traceable by sutures; its parts can be designated only by reference to the locally corresponding bones of the teleosteous skull. The bones of the outer case have their outlines more or less distinctly marked; but, although they are few in number, their determination is very difficult. The vertebrate skull which approaches most closely the type of *Ceratodus* is that of *Lepidosiren*; and nearly every part of this latter has been differently named by its describers.

In order to facilitate the description of this skull, we may distinguish four regions of the *cartilaginous capsule*, viz.:—(1) the *central* region, much depressed, extending from the occiput to the orbit, enclosing the brain and auditory apparatus, raised in the middle into a slight longitudinal crest; (2 & 3) a *lateral* region on each side of the former, in which the cartilage is expanded into a broad thin roof (Plate XXXIV. *p*) covering the gill-cavity, and which, anteriorly, is formed into the suspensory pedicle (*s*); (4) the *facial* region, a continuation of the central, but much more narrowed, tapering in front, and armed (in its vomerine portion) with two incisor teeth.

The bones which form the *outer osseous case*, and will be described in detail hereafter, are attached to the cartilaginous case in the following manner. The upper side of the *facial* region is covered by a triangular bone (*ethmoid*) (Plate XXXIV. *b*, and Plate XXXV. *b*); it is intimately united with the underlying cartilage (which is perforated by the olfactory nerves), and forms the roof over the nasal cavity. At its hinder angle this bone forms a serrated suture with a second bone (*os frontale*) (Plate XXXIV. *c*, and Plate XXXV. *c*), which emits a process downwards and in front of the orbit, to form a firm connexion with the palatine portion of the *os pterygo-palatinum*. This latter bone (Plate XXXIV. *l*, and Plate XXXV. *l*) occupies the edge of the lower side of the facial region, and bears the large upper pectinated tooth. It is narrow, but very strong, and forms, in front, a short and firm suture with its fellow, both bones diverging behind, the space between them being entirely filled by the anterior part of the basal bone (o).

The *central* region is covered above by a median and two lateral flat thin bones, the latter being the continuations of the frontals: the former might be designated as *sclero-parietal* (Plate XXXIV. a, and Plate XXXV. a). These bones are united with one another by squamous sutures, are more solid in front where they are connected with the ethmoid, and become thin and almost membranaceous near the occiput; they form a continuous roof over the skull, but are separated from the cartilaginous capsule by the enormously developed and dilated *musculus temporalis* (see Plate XXXV. fig. 2, *mt*). This muscle is expanded as in a carnivorous mammal, and covers entirely the upper surface of the cartilaginous brain-capsule, taking its origin from the longitudinal median crest, and from some protuberances above the occiput. The lower side of this region is nearly entirely covered by the *basal* (*sphenoid*) bone (o).

The *lateral* region has only one ossification; it is a covering of the outer edge of the suspensory pedicle; superiorly it is dilated into a lamina (Plate XXXIV. d, and Plate XXXV. d), which assists in forming the supramuscular roof of the skull. To the edge of the cartilage of this region is attached the *gill-cover* apparatus, which consists of an *operculum* (h) and *suboperculum* (Plate XXXV. fig. 1, h'); a small cartilage behind, and hidden by the opercle, may be regarded as a rudimentary *præoperculum* (Plate XXXIV. k).

A further insight into the relations between the cartilaginous and osseous portions of the skull is obtained by a vertical section along its longitudinal axis (Plate XXXV. fig. 2. To this figure we shall have to refer subsequently, and in the explanation of the figures at the end of this memoir).

Detailed Description of the Parts of the Skull.

We proceed now to describe those details of the definable bones, cartilages, and other parts of the skull which are not included in the preceding general account.

Distinct maxillary or intermaxillary elements are not developed; they are replaced by *facial cartilages*, which can only be separated artificially from the external cutaneous integuments, and pass into the front part of the cartilaginous skull, and into the suborbital ring.

These superficial facial cartilages (Plate XXX. fig. 2, and Plate XXXIV. fig. 1) may be divided into three groups:—1. The upper labial (f'), surrounding the front part of the upper jaw, extending over the nasal region, and attached to the side of the ethmoid and, at the upper anterior angle of the orbit, to the frontal; it is nearly continuous with (2) the infraorbital ring (f), in which three ossifications (e) are imbedded, viz. two on its origin behind the orbit, and one just below the eyeball. The infraorbital ring passes by a broad bridge into the lower lip. There is a large cavity (Plate XXX. fig. 2, c) with several divisions in the interior of this bridge; it is quite distinct from the labial cavity (p. 515), and appears to be entirely closed, without external openings; but in one (badly preserved) example a wide foramen at the inside and near the angle of the mouth leads into this pouch; during life it was probably closed by the mucous membrane of the mouth. 3. The lower labial cartilage (see also Plate XXXV. fig. 3, *la*), forming a broad trenchant fringe round the extremity of the mandible.

The part of the cartilage which bears the two trenchant front teeth I consider to be the *vomer* (Plate XXXIV. fig. 3, *v*). It is very similar in form to the vomer of many Teleosteous fishes, and has two free lateral edges, whilst behind it is suturally connected with the pterygo-palatines; it is entirely cartilaginous, and passes into the sphenoid cartilage above the symphysis of the pterygo-palatines. The corresponding part in *Lepidosiren* has been regarded by Professor OWEN* as the intermaxillary, and by Professor BISCHOFF, PETERS, and others as belonging to the ethmoid or nasal bone, Professor BISCHOFF and PETERS considering the cartilaginous space *behind* the palatal arch to be the vomer. From the fact that the vomer occupies nearly always the same position in the skull of fishes, and from the frequency of its being armed with teeth, I conclude that this part of the *Ceratodus*-skull is the vomer. A comparison with the skull of *Menopoma* will also much assist in determining it as such.

Towards the upper surface of the skull the vomerine cartilage passes into the *ethmoid* or *nasal* portion†, which is easily distinguished by its double perforation by the olfactory nerves (Plate XXXV. fig. 1, *b'*, and fig. 2, *ol'*); its upper surface has a thick osseous layer (Plate XXXIV. fig. 1, *b*, and Plate XXXV. *b*), which appears as a distinct triangular bone without median suture, the apex being directed forwards, whilst its base forms a serrated suture with the frontals and sclero-parietal; anteriorly it passes into the rostral cartilage.

The *frontal* bones (Plate XXXIV. fig. 1, *c*, and Plate XXXV. fig. 1, *c*) are entirely separate from each other; their anterior portion, which forms part of the border of the nasal cavity, and also the upper edge of the orbit, is very solid and closely connected with the underlying cartilage; it emits, in front of the orbit, a strong, broad, concave process (*c'*) for union with, and support of, the upper molar. The posterior part is an oblong, thin lamina, extending to the hindmost edge of the skull, to which it is fastened by fibrous tissue; this part covers the temporal muscle, and is attached by squamous sutures to the tympanic lamina and sclero-parietal. It is the same bone which appears as a free process on each side of the head of *Lepidosiren*; Professor OWEN determined it as postfrontal (Trans. Linn. Soc. xviii. p. 334, pl. 23. fig. 5, *m*), adding that it represents the postorbital and supratemporal bones in Ganocephala (Anat. Vertebr. i. p. 85). HYRTL does not much differ by designating this bone as superciliary, which, although a distinct bone in most fishes, is in reality nothing but a detached part of the frontal.

* In referring to Professor OWEN's account of the osteology of *Protopterus*, not only his first memoir in the Linn. Trans. vol. xviii. is to be consulted, but also the figure (No. 41) in Anat. of Vertebr. vol. i., where some inaccuracies of the former account are corrected.

† So designated in *Lepidosiren* by PETERS and MÜLLER; BISCHOFF considers it to be the intermaxillary; and OWEN also does not distinguish it from the "tooth-bearing cartilage."

BISCHOFF's opinion, that it is homologous with the jugal bone, does not appear to have been adopted by other anatomists.

The space between the two frontals, which in *Lepidosiren* is filled by membrane, is ossified in *Ceratodus* (Plate XXXIV. fig. 1, *a*). Morphologically it is entirely distinct from the parietal of other fishes, corresponding to this bone in situation only. Its distinctness from the parietal of *Lepidosiren* is evident, as this is a partial ossification of the skull-cartilage, and covered by the musculus temporalis, whilst it forms a case over this muscle in *Ceratodus* (Plate XXXV. fig. 2). It is evidently a conspicuous example of ossification of a fibrous membrane, and may be designated as *sclero-parietal*. It is a single bone, without median suture, subquadrangular, and of the same thickness as the adjoining part of the frontals; it passes behind into an occipital fascia, serving for the attachment of superficial muscles of the neck.

To the description of the *pterygo-palatine** bone given above, I have nothing to add (Plate XXXIV. *l*, and Plate XXXV, *l*). The two pieces which are found distinct in Fishes and Reptiles, and indicated by the compound name chosen by me for this bone, are here evidently merged into one; a bony arch extending from the tympanic suspensorium to the vomer necessarily includes both those pieces. Anteriorly the bones are united by a distinct suture (Plate XXXV. fig. 2, *l'*), which seems to disappear entirely in *Lepidosiren*.

The *tympanic pedicle* (Plate XXXIV. fig. 3, *s*, and Plate XXXV. fig. 1, *q*), the substance of which is cartilaginous, is strongly compressed in the direction from the front backwards; it is strengthened on its inner surface by the apposition of the end of the osseous pterygo-palatine, on the outer by a curiously shaped bone (Plate XXXIV. fig. 3, *q*, and Plate XXXV. fig. 1, *q*) which, as it is at least part of the *os quadratum*, may bear this name. This bone forms a not very thick covering of the outer edge of the tympanic pedicle. At its upper end it is dilated into a thin triangular lamella (Plate XXXIV. *d*, and Plate XXXV. fig. 1, *d*), the body of which is detached from the skull, entering into the supracranial roof formed by the frontals and sclero-parietal, and being of the same structure as those parts. Each suspensorium terminates in two condyles, the inner of which is rather narrower and much longer than the outer; they are separated by a deep and rather wide groove; these two condyles correspond to two articular surfaces of each ramus of the lower jaw. On the hinder side of the tympanic pedicle, near its base, there is a small round tubercle for the suspension and articulation of the hyoid arch† (Plate XXXIV. fig. 3, *r*).

The body of the *mandible* (Plate XXXV.) is persistent cartilage; but its entire outer and inner surfaces are covered by bone, forming an articular and a dentary piece. In figure 1 the mandible is shown from the outer (articulary) side, in figure 2 from the inner (dentary). The relative position of the two osseous pieces is represented in figure 3. By making a vertical section across the middle of the mandible, as is repre-

* In *Lepidosiren paradoxa* the "os palatinum" of BISCHOFF.

† The agreement of the suspensory pedicle of our fish with that of the other *Dipnoi* is obvious.

sented in figure 4 of the natural size, and magnified in figure 5, it is readily understood why the fossil teeth are always found isolated, without, or with scarcely any trace of, their osseous support. The bones are of a spongy consistency, with a dense network of wide medullary canals and cavities. The articulary especially has in its interior large cavities filled with marrow. The tooth can easily be broken off, its inner basal margin being anchylosed to the dentary by a narrow strip of bone only, and the outer resting on a layer of connective tissue which intervenes between the tooth and the articulary. The cells of the cartilage (fig. 5) are arranged in concentric rows,—the outer strata containing a greater number of cells, of an elongate ovate shape (fig. 7), whilst the cells of the central portion are fewer in number and more rounded. The articulary and dentary bones meet near the top of a low but strong coronoid process, and again at the symphysis, which is formed by fibrous tissue, and may easily be severed by the knife. The two articular concavities are separated by a narrow groove; and this part consists entirely of cartilage. A wide oval foramen penetrates the cartilage in a vertical direction, opposite to and outwards of the second notch of the tooth (fig. 3, *ar'*). In front of the jaw the cartilage is expanded into a slightly concave lamella (lower labial cartilage).

The *gill-cover apparatus* (Plate XXXV. fig. 1) consists of the same bones as in *Lepidosiren*; but being more developed, it assists in determining the two slender bones in that genus. The *operculum** (*h*) is a flat subrhombic bone, fairly protecting the gill-cavity; its upper edge is inserted in a long groove of the tympanic cartilage behind the base of the suspensorium. To its lower edge is attached, by fibrous tissue, the long styliform *suboperculum*† (*h'*) terminating at a considerable distance from the mandibulary joint. A small moveable piece of cartilage is found inside of the articulary groove of the opercle (Plate XXXIV. figs. 2 & 3, *k*); it is a rudiment of a *præoperculum*. The gill-cover is adpressed to the head by a singular broad *muscle*, which takes its origin from the lateral edge of the occipital cartilage, attaches itself to the upper margin of the opercle, and penetrates into the soft portions of the gill-cover, descending as far as the subopercle. It is divided into eight or nine fascicles by fibrous sheaths which run parallel with the muscular fibres.

The *basal*‡ bone (Plate XXXIV. fig. 3, *o*, and Plate XXXV. fig. 2, *o*) covers the greater part of the lower surface of the brain-capsule; it is lance-head-shaped, broadest between the tympanic pedicles, tapering in front, and still more behind, filling out the entire space between the pterygo-palatines, and extending backwards far beyond the commencement of the vertebral canal, to the level of the third neural spine. It is a thin bone, except in the middle of its length, where large medullary cavities are imbedded in its substance.

* In *Protopterus*, "Præoperculum" of OWEN; "Kiemendeckelstück" of PETERS.

† In *Protopterus*, "Branchiostegal" of OWEN (Anat. Vert.); "Kiemendeckelstück, *o'*" of PETERS. There are also two opercular pieces in *Lepidosiren paradoxa*; but their shape and place of attachment to the skull are, according to BISCHOFF, widely different from the same in *Ceratodus*.

‡ Basi-occipito-spheroidal bone of OWEN in *Lepidosiren*.

Before leaving the description of the skull, I have to add some notes on the *cerebral cavity*, with which the acoustic cavity is in direct communication. These parts may be seen in the vertical section of the skull (Plate XXXV. fig. 2). The brain itself was, unfortunately, found to be destroyed; but we suppose that, as in *Lepidosiren*, it is much smaller than, and does not fill, the cavity; and it appears to be very similar in form to that of the other Dipnoi. We distinguish the broad canals for the diverging lobi olfactorii (*ol'*), a considerable excavation for the hemispheres, a small groove (the lowest portion of the cavity) for a well-developed pituitary gland (*pt*) which is still preserved, and the space for the corpus quadrigeminum and cerebellum, gradually passing into the medullary canal.

Opposite to the origin of the nervus trigeminus, on each side of the brain-cavity, there is a large irregular opening leading into the *cavity of the organ of hearing*; it is closed by membrane (*ac*), which is perforated by the acoustic nerve, and on which are distributed its branches. After the removal of the membrane, three irregular subdivisions of the cavity may be distinguished—one considerably larger than the others, and containing otolithic masses of a chalky appearance and easily dissolved in water. By microscopical examination they are found to be composed of the same prismatic crystals as in *Lepidosiren* (see Hyrtl, *l. c.* tab. 1. fig. 6). The three semicircular canals are rather wide; the planes of the two inner ones are vertical and partly visible through the semitransparent upper surface of the cranial cartilage (see Plate XXXIV. fig 2.). The organ is entirely enclosed within the cartilage, without any other opening beside the communication with the cerebral cavity.

The *hyoid* arch (Plate XXXV. fig. 1) is more complex than in *Lepidosiren*, and approaches more the Teleostean type. It consists of a pair of ceratohyals, a basihyal*, and glossohyal*. As mentioned above, the ceratohyal (*ch*) is suspended from a tubercle at the base of the tympanic pedicle; it is a long, subcylindrical bone, externally well ossified, dilated at its proximal extremity into a subtriangular lamella. The basihyal (*bh*) is short, thick, cartilaginous, interposed between the ends of the ceratohyals and the acutely conical glossohyal (*gh*).

The *skeleton of the branchial apparatus* does not differ from that of Teleosteous Fishes, but is entirely cartilaginous. There are five branchial arches, the last rudimentary and attached to the base of the fourth. There is no peculiar modification of any part of this apparatus; and the middle pieces have the usual groove for the reception of the vessels and nerves.

Vertebral Column (Plate XXX. fig. 2).

Ceratodus agrees perfectly with *Lepidosiren* in the structure of the vertebral column. Its axis consists of a simple cartilaginous chorda dorsalis enclosed in a thick fibrous sheath, and with a gelatinous cylindrical thread along its centre. No transverse divisions in this notochord are visible; and it passes uninterruptedly into the cartilaginous capsule

* Absent in *Lepidosiren*.

of the skull (Plate XXXV. fig. 2); yet in a vertical section of the skull the course and termination of its tapering extremity can be distinctly traced, as the cartilage composing it is of a somewhat lighter colour than that of the skull. The boundary line between the cartilage of the skull and the notochord is still more distinct under the microscope (Plate XXXVI. fig. 1). The cranial cartilage (*c*) is distinguished by a considerable number of cells, many of which are spindle-shaped, having each end produced into a narrow process. These cells are entirely absent in the central parts of the notochord (*n*), the substance of which appears in the form of bundles of undulated fibres running in the direction from the central cylinder towards the periphery.

The central gelatinous body (Plate XXXV. fig. 2, *cd'*) is continued nearly to the extremity of the notochord, which lies opposite to the entrance into the acoustic cavity. The caudal portion of the notochord is tapering behind; and its extremity terminates in a thread which is gradually lost between the upper and lower series of neural and hæmal elements, which, in one specimen, coalesce into two tapering bands, and are persistent further backwards than the notochord.

Wherever an organ is reduced to a rudimentary condition, individual variation occurs. Thus scarcely two specimens of *Ceratodus* will be found in which the caudal termination of the vertebral column is exactly alike. One of the most remarkable variations is figured on Plate XXX. fig. 3. The notochord, with its whitish fibrous sheath, terminates here abruptly at a considerable distance from the end of the tail, its termination (*n*) being rather obtuse. The neural and hæmal arches are continued beyond the end of the notochord, but, being no more separated by it, are now confluent, form one tapering band which extends to within half an inch of the tail, and *which shows a distinct vertical segmentation.* This is all the more worthy of notice, as a similar segmentation of the posterior extremity of the vertebral column has been observed in some other fishes with notochordal skeleton. In *Ceratodus* such a segmentation is evidently within the limits of individual variation; it is confined to a continuation of the neural and hæmal elements, and does not extend to the notochord.

The notochord forms the base for about sixty-eight sets or rings of neural and hæmal elements, the hindmost being quite rudimentary and so indistinct that it is impossible to give the exact number. Twenty-seven of these rings bear *ribs*; and the first (caudal) ring in which the hæmal apophyses coalesce into a spine is the twenty-eighth. The bases of the apophyses are so deeply imbedded in the fibrous sheath of the notochord as to be in immediate contact with the cartilage of the notochord. The boundary line between them may again be discerned by the colour, the cartilage of the notochord being yellowish and slightly iridescent, whilst the cartilage of the apophyses is bluish. Under the microscope the latter appears as cartilage without fibrous basal substance, but with a great number of regularly ovate cells; whilst the cartilage of the notochord shows a distinctly fibrous structure with similar cells sparingly distributed near its periphery, the cells disappearing entirely towards the central parts. We have seen, above, that no cells whatever could be found in the attenuated foremost portion of the noto chord; its attenuation, therefore, appears to be due to the gradual loss of the outer cell-bearing strata.

The neurapophysis of each segment is perfectly distinct from the preceding and following; but all are most intimately bound together by intermediate fibrous ligaments, in which frequently true hyaline cartilage is deposited. Each neurapophysis (see also the sections, Plate XXXVIII. figs. 3–9) consists of a basal cartilaginous portion forming an arch over the myelon, and of a superadded second portion, which is separated from the former by a distinct line of demarcation, and the two branches of which are more styliform, cartilaginous at the ends and in the centre, but with an osseous sheath, and coalesced at the top, forming a gable over the *Ligamentum longitudinale superius*, which is enveloped in a layer of fat (Plate XXX. fig. 2, *l*). To the top of this gable is joined a single long cylindrical neural spine, again with the central cartilaginous centre enclosed in an osseous sheath, and with an upper swollen cartilaginous extremity. This is the arrangement of the first ten segments; but from the eleventh the cartilaginous swelling at the top begins to lengthen into a distinct interneural spine of the same structure as the neural. Further on, from the fifteenth segment, another interneural is developed in the same manner; so that in this part of the vertebral column we have the following series of neural pieces:—

a. Cartilaginous arch of neurapophysis (*c*) for the formation of the medullary canal (*d*).
b. Semiossified gable portion of neurapophysis (*e*) over the Ligamentum longitudinale (*e'*).
c. Neural spine (*f*).
d. Lower interneural (*g*).
e. Upper interneural (*h*), to which the dermo-neurals (*i*) are attached.

Whilst the increase of the number of neural pieces is the consequence of a lengthening of the distal part of the segment, it commences to decrease from the base. We observe that all at once, from the thirty-third segment, the neural spine coalesces with the gable portion of the neurapophysis; further behind, this portion is gradually shortened and finally disappears entirely, so that only the two interneurals remain. Towards the end of the tail the neural elements are reduced to a low and narrow cartilaginous lamella (neurapophysis) and a single short interneural spine; and this latter piece disappears in the last two inches of the vertebral column.

In the first three segments the neur- and hæmapophyses of each set are confluent, but without forming complete rings round the notochord, as the hæmapophyses of a segment do not coalesce below (see Plate XXXVIII. fig. 3).

The *hæmapophyses* (Plate XXX. fig. 2, and Plate XXXVIII. figs. 3–9) are, in form, size, and structure, very similar to the neurapophyses: those belonging to the same segment coalesce below the notochord into a narrow transverse band, at least in the anterior portion of the trunk (from the fourth to the twentieth segment). Those of the first twenty-seven segments bear well-developed *ribs*, about 2 inches long, bent outwards and downwards in the fore part and middle of the trunk, and backwards and downwards in its hind part. Like the neural and hæmal spines, and other parts of the skeleton, the basal and distal portions of the rib remain cartilaginous whilst the central part is enclosed in bone. The terminal cartilages penetrate for some distance into this bone, but without being continuous, the centre of the bone being filled with cellular tissue and marrow. There is no real joint between the rib and hæmapophysis; its cartilaginous head fits into a shallow concavity of the latter, both surfaces being united by short connective tissue, allowing no free motion to the rib. The *first rib* (Plate XXX. fig. 2, Plate XXXIV. fig. 3, x, and Plate XXXVIII. fig. 3) deserves to be particularly noticed, not only because it somewhat differs in shape from the others, but because the corresponding bone in *Lepidosiren* has received various interpretations. It is a long bone, considerably thicker and more cylindrical than the other ribs, horizontally directed outwards and slightly backwards, forming the posterior lower limit of the gill-cavity. Its insertion is opposite to the first neurapophysis, being joined to the first hæmapophysis, and not to the basal bone, which at this place is slightly contracted. It crosses the suprascapula, from which a short ligament passes to a small cartilaginous protuberance (x') on the front edge of the rib. This tubercle, which is placed exactly at the spot where those two bones cross each other, has evidently only a functional, and not a homological significance. Peters (Müll. Arch. 1845, p. 12, pl. 2. no. *p*) is the first who distinctly notices this bone in *Protopterus*, as "a peculiar bone which is to be compared to a similar bone in *Batrachus*." Bischoff (Ann. Sc. Nat. 1840, vol. xiii. pp. 123, 126) represents the neurapophyses of the first vertebral segment in *Lepidosiren paradoxa* as occipitalia lateralia, and the neural spine of the same segment as a cartilage "qui remplace, en quelque sorte, l'écaille de l'os occipital;" consequently he describes the first rib as inserted in the occipital lateral and in the body of the sphenoid, declaring it to be the "os suspenseur de la ceinture pectorale des poissons." According to this view, suprascapulary elements would be absent in *Lepidosiren paradoxa*; future investigations must show whether this is really the case. Hyrtl and Owen (Anat. Vert. i. p. 83, fig. 41. no. 51) have adopted Bischoff's view; and the bone is figured and described by the latter as scapula, in direct connexion with the pectoral arch. Finally, W. K. Parker ('Monograph of the Shoulder-girdle,' 1868, p. 21) not only determines the homology of this bone, but also of the small cartilage attached to the middle of its length; the former is stated to represent the "large first pharyngo-branchial," the latter the "small unossified second pharyngo-branchial."

A comparison of *Lepidosiren* with *Ceratodus* shows that a positively defined boundary between the vertebral column and skull does not exist, that parts which in one genus appear to belong to the skull, are distinctly portions of the vertebral column in the other, and that, with regard to the particular bone which has been so differently interpreted by the authors named, the opinion first expressed was nearest to the truth. The peculiar bone in *Batrachus*, to which Peters directed attention, is in fact nothing but the first rib (see Günther, 'Fishes,' vol. iii. pp. 167, 172), extending and fixed to the upper end of the humerus. Although its insertion into the top of the neurapophysis is a most singular fact, the gradual change of insertion of the following ribs, first to the bottom of the neurapophysis, then to the centre of the axis, and finally to the parapophysis, shows clearly that this bone is a rib. Nor is the application of parapophysial elements of the first vertebra, for support of the scapular arch, of very rare occurrence in fishes; it is observed in *Bagrus* and other Siluroids.

The *hæmal* pieces of the tail (Plate XXX. fig. 2, and Plate XXXVIII. figs. 7–9) are built up similarly as the corresponding dorsal parts. We have again

a. A cartilaginous portion of the hæmapophysis (c^2), supplemented by

b. A hæmal spine (l), with its proximal end osseous and forked to form a canal for blood-vessels (k), but without a trace of a ligamentum longitudinale inferius.

c. Interhæmal first (m).

d. Interhæmal second (n).

These pieces remain distinct very nearly to the end of the tail; but all become gradually weaker and shorter, and also ossification ceases in some of the posterior ones. Finally the number is reduced by the coalescence of the hæmal spine with the hæmapophysis, and the pieces near to the extremity of the tail are quite rudimentary and scarcely distinguishable.

Small and short *dermo-neurals* (Plate XXX. fig. 2, and Plate XXXVIII. figs. 4 & 5 . . .) may be distinguished from the interneural of the seventeenth segment; they gradually increase in length towards the middle of the tail, where they are very long; they are all obliquely directed backwards, assuming a more horizontal direction the nearer they are to the end of the tail. They are exceedingly numerous, four or five or more corresponding to a single vertebral segment—and form a double series, one series on each side of the fin. This peculiarity, which *Ceratodus* has in common with *Lepidosiren*, reminds us of those fin-rays of Teleosteous fishes which can be more or less completely split into a right and a left half. The dermo-neurals of *Ceratodus* are not articulated to the extremities of the interneurals, but overlap them for a considerable distance of their length. The shape and arrangement of the dermo-hæmals is exactly the same as that of the dermo-neurals. No ossification takes place in either of them; they consist entirely of cartilage, in which numerous spindle-shaped cells are imbedded, many of these cells being produced at both ends into a very long process (Plate XXXVI. fig. 7).

The Scapular Arch (Plate XXX. fig. 2, Plate XXXV. fig. 1, Plate XXXVI. figs. 2 & 3).

The scapular arch of *Ceratodus* is, with regard to the persistence of the primary cartilaginous condition and to the development of superficial bones, extremely similar to that of *Lepidosiren**. The primordial cartilaginous arch consists of three pieces, viz. a single

* Professor OWEN was the first who, from the examination of a small example (far from being "half-grown"), pointed out the primordial condition of the scapular arch in *Protopterus*, whilst Professor PETERS was enabled to supplement the account of his predecessor from the examination of fresh specimens. Recently the shoulder-girdle of this fish has been made the subject of special research by Professor GEGENBAUR and Mr. PARKER; and it is singular that these two anatomists prefer to criticise the almost unavoidably imperfect first account, instead of availing themselves of the researches of the second of their predecessors.

median transverse strip (Plate XXXVI. figs. 2 & 3, *a*) and a large irregularly shaped piece (Plate XXXVI. figs. 2 & 3, *b*) with the articular condyle for the pectoral limb (Plate XXXVI. figs. 2 & 3, *c*, and Plate XXXV. fig. 1, *hc*). The latter cartilage forms the base of a large concave bone (coracoid of OWEN, clavicle of most other authors) (Plate XXXVI. figs. 2 & 3, *d*, and Plate XXXV. fig. 1, *co*); and the whole arch is suspended from the skull by means of a broad suprascapula (Plate XXXVI. fig. 2, *e*, and Plate XXXV. fig. 1, *ss*). We proceed now to a detailed description of these parts from the skull outwards.

The *suprascapula** is a thin, broad lamella of an obliquely ovate shape, entirely ossified; it forms the posterior wall of the capacious gill-cavity, fitting into the hinder angle of the lateral cartilaginous region of the skull, to the edge of which two of its sides are fixed by a short continuous ligament. Its distal portion is connected with the coracoid by a broad ligament, which allows the ends of the two bones to slide over each other.

The *coracoid* is a long, curved, rather thin bone, strengthened by several longitudinal ridges, and extending downwards nearly to the median line of the arch. A suture running right across its middle (Plate XXXV. fig. 1, and Plate XXXVI. fig. 2), nearly on a level with the pectoral condyle, divides it into two subequal portions†.

The *humeral cartilage* (Plate XXXVI. figs. 2 & 3, *b*) has an oblong form, spreading out into a shorter upper lamella covering the hinder side of the lower half of the upper coracoid bone, and into a longer lower lamella covering a great part, and projecting beyond the margin, of the lower coracoid; it does not quite extend to the median cartilage. The humeral cartilage is swollen behind into a thick condyle for the pectoral joint.

The *median cartilage* (Plate XXXVI. figs. 2 & 3, *a*) is a single band connecting the two coracoids, into the interior of which it extends for some distance. More of it is covered by bone on the posterior side of the scapular arch than on the anterior.

The Pectoral Limb.

The parts of the pectoral limb are entirely cartilaginous, without a trace of ossification. The cartilage is distinguished by cells of rather short ovate shape, a great number of which have a double nucleus, or are even perfectly divided into two (Plate XXXVI. fig. 8).

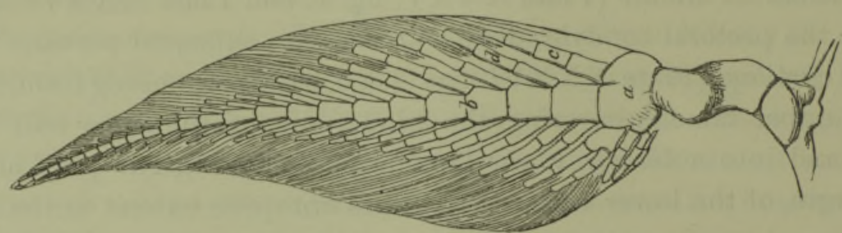
The paddle (Plate XXX. fig. 2) is joined to the scapular arch by an elongate, flattish,

* In *Lepisodiren* "suprascapulare" of PETERS.

† I cannot attach much value to this division; the upper piece is certainly not homologous with the scapula of Teleosteous fishes, which is far removed from the region of the pectoral condyle. The division is also present in *Lepidosiren*; only the upper piece is much the smaller, and Mr. PARKER, by naming it superclavicle, has regarded it as the homologue of the scapula. A division of this bone has also been observed in *Polyodon folium*, where the lower piece is the smaller (see GEGENBAUR, Schultergürtel, Taf. 6. fig. 3).

slightly curved cartilage (*m*); its proximal end has a glenoid cavity, fitting into the humeral condyle; the joint is simple, free, allowing of a considerable amount of motion, its parts being held together by a ligament fastened round its circumference. This is the only true joint in the limb, all the other parts being fixed to one another by connective tissue. I consider this cartilage to be the forearm; a horizontal section along its longitudinal axis does not show any primary division. The next following cartilage (marked *a* in the accompanying woodcut) forms the base of the paddle; although externally it appears as a single flat, broad, short piece, unevennesses of its surface indicate that several primary pieces are coalesced in it. I am confirmed in this view by a horizontal section, in which the lines of the former divisions are preserved in the shape of tracts of a white connective tissue. Three such divisions may be distinguished, corresponding to the three carpals of most Plagiostomes*. If this determination is correct, then the antibrachial cartilage just described is not represented in that order.

The remaining framework of the paddle shows an arrangement unique among the Vertebrata. From the middle of the basal cartilage a series of about twenty-six subquadrangular pieces takes its origin, forming a longitudinal axis (*b*) along the middle



of the paddle to its extremity; the pieces become gradually smaller, and are scarcely distinguishable towards the end of the paddle. On the two posterior corners of each piece a branch (*d*) is inserted, running obliquely backwards towards the margin of the fin; the branches of the first eight or twelve pieces are three-jointed, the remainder two-jointed, the last having no branch at all. Slight irregularities, such as the origin of two branches from one side of a central piece, occur, as also several four-jointed branches (*c*) being inserted immediately on the basal cartilage. As in the vertical fins, so also in the pectoral, the fin-rays are very fine, imbedded in the skin, and arranged in two layers, between which the ends of the cartilaginous branches are received. The analogy of this framework to that of the caudal portion of the vertebral column is striking. *Ceratodus* is not only truly diphycercal as far as the termination of the body is concerned, but this term may be also applied with regard to the extremity of its paired fins. The many-jointed pectoral axis may be compared to the series of neural and hæmal apophyses, both forming the base to a system of superadded processes (here two- and three-jointed branches, there neural and interneural, hæmal and interhæmal spines), which are

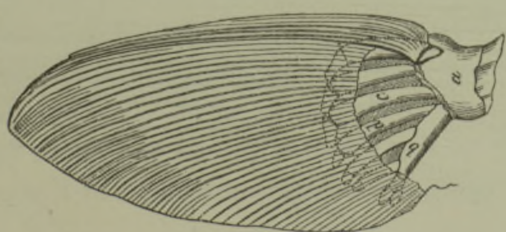
* Pro-, meso-, and metapterygium of GEGENBAUR.

destined to serve as a framework to the surrounding soft parts, and as a support to the rays of the fold surrounding the fin.

I may add here that the muscle moving this fin imitates the form of the cartilaginous framework; a flat, broad band covers and runs along the central axis, sending off towards the right and left small fascicles, one to each cartilaginous branch.

When I designated the arrangement of the parts of this pectoral skeleton unique, I did not mean to convey the idea that no homological relation could be pointed out between the parts of the pectoral skeleton of *Ceratodus* and that of other fishes. It is quite evident that we have here a further development of the simple pectoral axis of *Lepidosiren* in the direction towards the Plagiostomes. The pectoral skeleton of *Lepidosiren paradoxa* consists merely of the central series of cartilages of *Ceratodus*; there is no fin-like expansion of the skin of the pectoral limb, which is a simple tapering filament. In *Lepidosiren annectens* this pectoral filament is bordered by an expansion of the skin along the lower edge; and even minute fin-rays are imbedded in each lamina of the fold; in order to support this low one-sided rayed fringe, very small, single-jointed cartilages are added to the axis*. The fin is still more developed in *Ceratodus*: it has become a broad, scythe-shaped paddle, dilated by a fold of the skin, with two layers of fin-rays surrounding it in its entire circumference; therefore supporting cartilaginous branches are added on both sides of the axis; and most of the branches are composed of several joints, in order to reach the more distant parts which require the support.

The arrangement of the limb-skeleton of *Ceratodus* is foreshadowed in the pectoral fin of *Acipenser*. In the left fin of an *Acipenser sturio*, var. *oxyrhynchus*, four cartilaginous rods are attached to the basal cartilage (a); the innermost (b) consists of three joints, and represents the jointed axis of the *Ceratodus*-limb; it is provided with three two-jointed branches (d), but on one side only, namely the outer, the branches being intercalated between their axial base and the next cartilaginous rod. Having compared the arrangement in *Ceratodus* to a diphycercal tail, we may designate the plan observed in *Acipenser*



Acipenser.

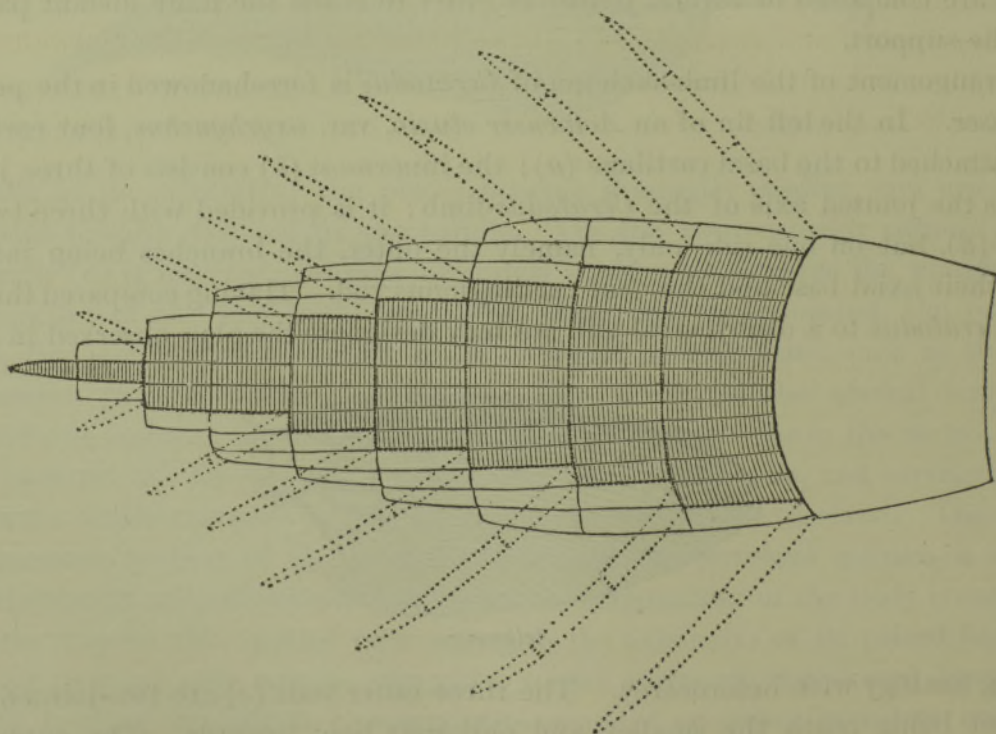
as offering analogy with heterocercy. The three outer rods (c) are two-jointed, the posterior joint being much the smaller, and obliquely bent inwards. The outermost rod

* Four or five of these ray-bearers are obliquely attached to each joint of the axis. PETERS, Müll. Arch. 1845, Taf. 2. fig. 2.

forms the base to the attachment of the pectoral spine, which is deeply furrowed, and undoubtedly formed by coalescent and stiffened soft fin-rays. As in *Lepidosiren* and *Ceratodus*, the fin-rays are not joined to the supporting cartilages, but, being disposed in two layers, their ends overlap the cartilages. The attachment of the pectoral spine to its basal cartilage is not effected by a joint, but by apposition.

The arrangement in *Ceratodus* evidently resembles more that in *Acipenser* than that in *Polypterus*.

On further inquiry into the more distant relations of the *Ceratodus*-limb, we may, perhaps, be justified in recognizing in it a modification of the typical form of the Selachian pectoral fin. Leaving aside the usual treble division of the carpal cartilage (which, indeed, is sometimes simple), we find that this shovel-like carpal forms the base for a great number of phalanges, which are arranged in more or less regular transverse rows (zones) and in longitudinal rows (series). The number of phalanges of the zones and series varies according to the species and the form of the fin; in *Cestracion philippi* the greater number of phalanges is found in the proximal zones and middle series, all the phalanges decreasing in size from the base of the fin towards the margins. In a Selachian with a long, pointed, scythe-shaped pectoral fin, like that of *Ceratodus*, we may, from analogy, presume that the arrangement of the cartilages might be somewhat like that shown in the accompanying diagram, which I have divided into nine zones and



fifteen series. When we now detach the outermost phalanx from each side of the first horizontal zone, and with it the other phalanges of the same series—when we allow the remaining phalanges of this zone to coalesce into one piece (as, in nature, we find coalesced the carpals of *Ceratodus*, and many phalanges in Selachian fins), and when we repeat this same process with the following zones and outer series, we arrive at an arrangement identical with what we actually find in *Ceratodus*.

The Pelvis and Pelvic Limb (Plate XXX. fig. 2, and Plate XXXVI. figs. 4–6).

In the example figured the right ventral paddle is conspicuously narrower and generally smaller than the left; this is merely an individual peculiarity. The pelvis is essentially the same as in *Lepidosiren* and *Protopterus* (fig. 6); it is a single flattened subquadrangular cartilage with two paired processes and a single process. The posterior pair of processes are separated from each other by a deep semicircular notch, each terminating in a condyle to which the basal cartilage of the ventral paddle is joined. The anterior pair of processes are directed outwards and upwards, offering a point of attachment to the neighbouring lateral muscles of the trunk as well as to others stretching to the basal cartilage of the paddle. In our example the process on the side of the larger paddle is considerably broader and stronger than that of the opposite side. Thirdly, the single process arises from the middle of the front margin of the pelvic cartilage; it is very long, cylindrical, tapering, and enclosed in a thick, shining, fibrous sheath (fig. 4, *a*), which is the continuation of the perichondrium of the pelvic cartilage. As is evident from this description, this process points forwards, towards the head, *not backwards*. So it is also in *Lepidosiren* and *Protopterus*. It lies imbedded between the abdominal muscles, in the median line of the abdomen in *Protopterus*, but bent somewhat towards the left side in our example of *Ceratodus forsteri*. If a vertical section is made through the pelvic cartilage (fig. 5), a capacious cavity (*b*) is found to exist in its interior; but the state of preservation of our example did not allow of forming an opinion of the nature of its contents.

The paddle is attached to the pelvis by means of a separate, rather short, subcylindrical cartilage which has a rounded process on its lower outer side; it articulates with the pelvic condyle by a true joint, having a glenoid cavity in front. The endoskeleton of the paddle itself is almost identical with that of the fore paddle; but the segments of the axial series of the right paddle (Plate XXXVI. fig. 4) are more liable to confluence; the insertions of the branches are consequently more confused, and the phalanges are shorter, more feeble, and somewhat less in number. The skeleton of the left paddle (Plate XXX. fig. 2) is much more symmetrical and regular.

The Organs of Circulation (Plate XXXVII.).

The *heart* lies far forwards, its basal half being protected by the middle of the scapulary arch. It is enclosed in a pericardial sac with thick, tendinous walls; the base of this sac is confluent with the diaphragm, which, like the proper tunic of the abdomen, is a strong glistening fibrous membrane. This is the only direct connexion between pericardium and diaphragm; and a separate additional lamina extending from the diaphragm to the middle of the pericardium, as it has been described by HYRTL in *Lepidosiren paradoxa*, and as I have found it also in *Protopterus*, is not developed in *Ceratodus*.

After the pericardium is opened (fig. 1) the ventricle (v) is observed on the right side, and the large single atrium (a) on the left. From the former arises a conus arteriosus* (b), forming a short spiral; that part of it which is visible without further preparation, runs transversely from the right towards the left. Its muscular layer is much more developed along the lower side of the spiral than along the upper. The grooves between the divisions of the heart are covered with a thick layer of a dark semifluid fat. At the upper end of the conus the insertion of the pericardial sheath causes a slight swelling round this portion. The heart hangs freely in the pericardium, except at the two opposite poles, viz. where the sinus communicates with the auricle, and where the conus arteriosus passes into the aorta. A single very short and thin filament fixes the point of the heart to the pericardium.

We begin with opening the ventricle on the side facing the observer (figs. 2 & 3). Its parietes are thick, with well-developed trabeculæ carneæ on its inner surface. Its cavity is spacious, and incompletely divided into two by a papillary muscle (m) rising from the apical portion of the ventricle, and passing into a cartilage (m') which is considerably broader and thicker than the muscle; a number of chordæ tendineæ fix the end of this body to the walls of the atrium, into the cavity of which the cartilage extends. The cartilage, with its muscle, lies in the plane of the atrio-ventricular opening, which is partially closed by it during the systole. Opposite to the base of this papillary muscle (which is also present in *Lepidosiren* and *Protopterus*, and has justly been described by HYRTL as an incomplete septum ventriculi) is a broad valve (c) with semilunar margin; it likewise assists in preventing the blood of the ventricle from regurgitating into the atrium during the systole.

The cavity of the atrium (fig. 3) is about twice as spacious as that of the ventricle; it does not extend beyond the left half of the heart; and there is no long, produced auricular process; its walls are membranous, with a great number of thin muscular fasciculi decussating and forming an open network. Those of these little muscles which are connected with the cartilage are strongest, and terminate in short chordæ tendineæ; but although a careful preparation under water gave a clear view of their arrangement, I could not convince myself that they indicated a division of the atrium, such as HYRTL found in *Lepidosiren paradoxa*.

The vessels carrying the blood to the atrium open into a *sinus venosus* which lies within the pericardium. The sinus communicates with the atrium by a simple *ostium*

* Before I became acquainted with a paper by GEGENBAUR in Jena. Zeitschr. f. Med. und Naturwiss. ii. pp. 365–375, I distinguished the dilatation of the ventricle in Ganoids and Selachians under the name of *Bulbus arteriosus*, from the swelling of the aorta of Teleosteans, for which I retained the term *Bulbus aortæ*. But finding that Professor GEGENBAUR had already proposed the term "conus arteriosus" for the former division of the heart, I shall, of course, adopt the prior nomenclature.

venosum without valve; this ostium is on the dorsal surface of the atrium, a little towards the right of its middle. A right and left *vena cava superior*, beside the principal *vena cava*, terminate in the sinus venosus, the former perforating the pericardium at nearly equal distances on the left and right from the mouth of the latter, which empties its contents a little towards the right of the median line of the end of the pericardium. The single *vena pulmonalis* does not communicate with the sinus, but, passing along its dorsal wall, enters the atrium by a separate opening more towards the left than the sinus; its mouth is provided with a valve. The diameter of the vena pulmonalis is about equal to the sum of those of the two venæ cavæ superiores, and about one half of the vena cava.

The *conus arteriosus* differs from that of *Lepidosiren* less externally than internally. Its anterior wall is thin, though provided with a muscular stratum, which is thickest along the posterior rim of its spiral course. Its beginning is indicated by the absence of trabeculæ carneæ, the inner surface being smooth. The valvular arrangement is entirely different from that which was considered to be the characteristic of the subclass *Dipnoi*. No valve exists on the boundary line between conus and ventricle. Before the conus turns to the left, its interior is rather spacious; but this compartment is separated from the transverse portion of the conus by a cartilaginous valve, which from a certain view appears as a merely papillary prominence (d), but when viewed from various sides proves to be a spiral performing a half turn, to the lower end of which a muscle (d') is attached, which reaches down into the ventricle. This valve closes the lumen of the conus most effectually during the diastole of the heart. In the systole, the muscle attached to it contracts, and draws the valve from its position downwards, thus opening free egress to the blood out of the heart. When the muscle relaxes during the systole, the valve resumes its position through its own elasticity, shutting up the communication between the heart and arterial system.

Beyond this valve the conus turns towards the left, and then for a very short distance forwards. Quite at the end of it, and immediately before it bifurcates, there are two pairs of (ganoid) valves (e), narrow, and rather long, with stiff non-collapsing walls, thicker along the middle than at the sides, and without tendinous chordæ, in a single transverse series. Their tunics are continued in four narrow raised strips behind their bases* (f). So far I have found the arrangement of this part of the heart nearly identical in two examples. On examining the first example, a pair of small papillary prominences (fig. 7, g') were found in a line between the series of stripes and the spiral valve, immediately in front of the latter. These stripes and papillæ appeared to me to represent rudiments of a second and third series of valves, analogous to the plurality of series in other ganoid fishes. Remembering, at the same time, the fact that individual variations in the development and number of valves are not of uncommon occurrence in these fishes, I examined the heart of a second (smaller, female) specimen, and had the

* Such longitudinal pads have been also found in *Acanthias* by GEGENBAUR, Jena. Zeitschr. f. Med. und Naturwiss. ii. p. 366.

satisfaction of finding my supposition confirmed. In this specimen there are, in the series corresponding to the pair of small papillæ, four valves (fig. 6, *g*) corresponding in position to, but much smaller than, the permanent large valves which I have described above.

The conus arteriosus branches off into four *arcus aortæ* (figs. 1 & 5, *h*, *i*, *k*, *l*) on each side, the origins of the two anterior being more on the ventral side, and entirely distinct from each other, those of the two posterior being confluent for a very short distance, and situated more on the dorsal side. The valves are placed close to, and nearly opposite, the origins of the arcus aortæ, so that one valve corresponds to the common origin of the two posterior arches (*k* & *l*), and one to the origin of the first arcus (*h*), whilst the second arcus (*i*) has no separate valve opposed to its root.

These arches diverge, severally entering the ventral end of each of the four gills (fig. 8), and, reappearing at the dorsal end (fig. 9), converge again to form the aorta. They are united in such a manner that the two anterior are confluent into a common stem, and the two posterior into a second. The first arcus, immediately after having left the gill, emits a considerable branch as *Carotis* (*n*), and a second much smaller recurrent branch (*o*), which also enters the brain-capsule on the margin of the basal bone (*ba*).

The common stem of the aorta is formed opposite the beginning of the narrow posterior part of the basal bone. Its walls are at its commencement easily compressible, and collapse when empty; however, very soon they are strengthened by firm, tendinous bands, which at the origin of the arteria cœliaca are so much developed as to form a rigid half-canal covering the ventral side of the aorta.

The strongest lateral branch of the aorta is the *arteria cœliaca* (*p*), which leaves the aorta at a right angle about an inch below its origin: it is present on the right side only; and, as mentioned in the description of the liver, it winds like a collar round the narrow neck of that organ, distributing its contents through the intestinal tract.

At the same place where the arteria cœliaca branches off, a right and left *arteria subclavia* (*q*, *q'*) take their origin. The right is much narrower than the left, and carries blood merely to the fore limb of its side. The left is about twice as strong, sends off a small muscular branch, and then divides into two arteries. One of the latter runs straight towards the left paddle, emitting two small branches, which enter the foremost extremity of the testicle. The second artery forms a very peculiar anastomosis (*r*) with the left *vena cava superior* (*s'*). This anastomosis is also indicated on the right side; but its arrangement is somewhat different; namely, the right *vena cava superior* (*s*) emits a branch (*t*) inwards, towards the aorta, running parallel with the arteria cœliaca. The branch is widely open at its origin, and colouring fluid can easily be injected into its cavity from the *vena cava*; but the canal is gradually obliterated, and closed entirely before it reaches the aorta. Probably there exists an open communication between the vein named and the aorta at an earlier period of life.

The number of intercostal arteries, which are of inconsiderable calibre, has not been ascertained.

The venous trunks, by which the blood is carried to the atrium of the heart, have been mentioned above. The two anterior *venæ cavæ* collect the blood from the head and fore limbs, and offer no further peculiarity. The course of the vena pulmonalis is noticed with the organ to which it belongs. The single vena cava posterior (Plate XL. *x*, and Plate XLI. *e*) is the largest vessel in the whole system, having a diameter of 3 lines, and collecting the blood from the trunk, tail, and the abdominal organs, except the lung and intestine. Immediately below the diaphragm it enters the liver, collecting the blood from this organ, and descends through the substance of the right lobe of the liver (Plate XXXIX. *x*) to and along the inner margin of the testicle (or ovary) of the same side, being rather superficial whilst it accompanies this organ. It receives in succession from the front towards behind the following branches:—

a. A number of very small branches from the right testicle (or ovary) which join the main trunk at right angles.

b. A stronger branch from the hindmost lobe of the right testicle and upper part of right kidney (Plate XLI. *g*).

c. A very strong vein from the left testicle (Plate XLI. *f*), which corresponds in situation and function to the main trunk, and might be called a left vena cava posterior; but the currents of blood in the two run in opposite directions, that of the right (main) trunk running towards the head, that of the left towards the tail.

d. The *vena caudalis* (Plate XLI. *h*) is the strongest tributary; it enters the main trunk on its dorsal surface, immediately after having penetrated through the muscles and fascia which cover at this place the vertebral column.

e and *f.* A pair of venæ renales revehentes (Plate XLI. fig. 1, *i i*).

The Gills (Plate XXXVII.).

The gill-apparatus differs considerably from that of *Lepidosiren*, and approaches in structure that of the common Teleosteous type. Of the five branchial arches, four bear complete gills (figs. 8 & 9). Each gill is a broad membranous fold, to which a series of numerous simple branchial laminæ is attached in front and behind; most of the laminæ extend somewhat beyond the connecting membrane, having their extremities projecting free beyond its edge. The outer point of attachment of the gills is not on the branchial arches, but beyond them, on the wall of the gill-cavity (*u*, *u*)—the three anterior being fixed to the lower surface of the lateral expansion of the skull, and the fourth to the inner surface of the suprascapula. The fifth pair of arches (*w*) (commonly called "lower pharyngeals") retain in our fish their primitive function, and, although not bearing a perfect gill, are, at least, provided with gill-rakers. Two series of short, closely set gill-rakers, closely interlocking with those of the neighbouring arch, run along the concave side of each of the four principal arches.

Further, to this gill-apparatus is added a very distinct *pseudobranchia* (*x*). This pseudobranchia is the gill originally belonging to that branchial arch which is modified into the hyoid. It is also accompanied by two series of gill-rakers, one of which (*x'*) runs in an oblique direction from the front end of the pseudobranchia inwards; the other (x'') remained attached to the cerato-hyal ($c\,h$). The pseudobranchia of *Ceratodus* corresponds evidently to the opercular gill of *Lepidosiren* and *Protopterus*; but it cannot have the same function, inasmuch as in these two genera a separate portion of the first arcus aortæ branches off to carry (venous) blood to this gill, thus proving its function to be respiratory (Kiemendeckel-Kieme of MÜLLER), whilst in *Ceratodus* the first arcus aortæ has no branch for the pseudobranchia before it enters the foremost real gill.

Spiracles are absent.

Thus we can add another combination with regard to the coexistence of opercular gill, pseudobranchia, and spiracle in Ganoids, to those pointed out by MÜLLER (Ganoid. p. 135):—

1. Opercular gill, pseudobranchia, and spiracle: *Acipenser*.
2. Opercular gill, pseudobranchia, no spiracle: *Lepidosteus*.
3. Opercular gill, no pseudobranchia, no spiracle: *Scaphirhynchus*, *Lepidosiren*, *Protopterus*.
4. No opercular gill, but pseudobranchia and spiracle: *Planirostra*.
5. No opercular gill, no pseudobranchia, but spiracle: *Polypterus*.
6. No opercular gill, but pseudobranchia, and no spiracle: *Ceratodus*.

The Lung (Plate XXXVIII.).

The *pneumatic apparatus* of *Ceratodus* may be described either as a single lung with symmetrical arrangement of its interior, or as two lungs confluent into a single sac without any trace of a septum. The sac is wide, and extends from one end of the abdominal cavity to the other; it occupies the middle of the dorsal region, being firmly attached to and along each side of the aorta. Its external surface shows numerous small rounded prominences, corresponding to the minor cells of its cavity, and surrounded by the network of the pulmonal vein. These prominences are absent in a stripe (a) running along the middle of its ventral surface, and bordered on each side by the branches of an arterial vessel (f, f'). The minute ramifications of the blood-vessels extend only sparingly into this smooth stripe, having probably only a nutritive, and not a respiratory function. The attachment between intestine and lung is also most intimate along this stripe, which is opposed to the aorta, and indicative of a division of the lung into two lateral halves. Such a division is also indicated by a slight prominence in front (b), and behind (c). The right half is contracted at its anterior extremity, slightly bent towards the right side, and opens, by a very short duct terminating in a *glottis* (gl), *into the ventral side of the œsophagus, somewhat to the right of the median line.* The *glottis* is a slit about one eighth of an inch long, and provided on one side with a duplicature of the membrane, which acts as a valve.

The interior of the lung is best seen by cutting it open along the smooth stripe in its median line (fig. 2). Both halves are then seen to have an identical and nearly symmetrical structure, being divided into a number of compartments formed by strong transverse septa; there are twenty-eight on the left side, and thirty-three on the right, the latter half extending more forwards than the former. The foremost and hindmost compartments are much shallower than the others, which have a cubic shape, being about half an inch wide, and one third of an inch long and deep. The septa separating the compartments are imperforate membranes, so that each compartment can be separately filled with fluid, only the side towards the median line of the lung being open. The bottom of these compartments is again divided into a number of larger and smaller cells by reticulated septa, which are very irregularly disposed. A very dense network of the branches of the pulmonal arteries and vein extends all over the surface of the lung, and its principal and secondary septa; the terminal branches of both arteries and vein are rather wide, and can be injected with great facility.

The principal arterial vessels of the lung are on the dorsal side of the organ, running along, and very close to, each side of the aorta; that on the right side is much stronger than the left, and can be injected from the arteria cœliaca. There is no direct arterial communication between the lung and the arcus aortæ, as in *Lepidosiren*. The two arteries mentioned distribute blood through the entire length of the lung, to its posterior end; their ramifications are confined to the inner surface of the organ, and not visible externally.

On the median line of the ventral side of the lung, opposite to the dorsal arteries, are two vessels (f and f'), of the arterial nature of which I could not satisfactorily convince myself. Their ramifications are also spread over the inner surface and collected into the two stems running along each side of the smooth band in the median line of the lung, the left stem being wider than the right. After their union near the anterior end of the lung, the single vessel turns off towards the right side of the œsophagus, which it then crosses from the right towards the left, at a short distance above the glottis. Arrived on the left side, it descends again, as far as the basal portion of the first rib, and splits up (at g) into three very small branches, which I could not follow further. Great care was taken in ascertaining the very singular termination of this vessel, which I expected to take its origin from the left arteria subclavia; but no such connexion could be discovered.

The ramifications of the venæ pulmonales (e and e') are more visible on the external surface of the lung than on the internal; they are collected into a common branch, running near to the outer margin of the ventral surface of each half of the lung; the left branch is stronger than the right; both unite near the anterior end, and on the right side of the lung; its passage through the diaphragm and separate entrance into the atrium have been noticed above in the description of the heart.

At the beginning of this paper (p. 514) statements have been referred to, from which it would appear that *Ceratodus* is in the habit of going on land, or at least on mud-flats; and this assertion seems to be borne out by the fact that it is provided with a true lung. On the other hand, we must recollect that a similar belief was entertained with regard to *Lepidosiren*, of which now numerous examples have been kept in captivity, but none have shown a tendency to leave the water. I think it much more probable that this animal rises now and then to the surface of the water in order to fill its lung with air, and then descends again until the air is so much deoxygenized as to render a renewal of it necessary. The fish is said to make a grunting noise, which may be heard at night for some distance. This noise may be produced by the passage of the air through the œsophagus, when it is expelled for the purpose of renewal. From the perfect development of the gills we can hardly doubt that, when the fish is in water of normal composition, and sufficiently pure to yield the necessary supply of oxygen, these organs are sufficient for the purpose of breathing, that the respiratory function rests with them alone, and that the lung receives arterial blood, returning venous blood, like all the other organs of the body. But when the fish is compelled to sojourn in thick muddy water charged with gases which are the product of decomposing organic matter (and this must be the case very frequently during the droughts which annually exhaust the creeks of tropical Australia), it commences to breathe air with its lung in the way indicated above. Under this condition the pulmonary vein carries purely arterial blood to the heart, where it is mixed with venous blood and distributed to the various organs of the body. If the medium in which the fish happens to be is perfectly unfit for breathing, the gills cease to have any function; if only in a less degree, the gills may still continue to assist in respiration. *Ceratodus*, in fact, can breathe by either gills or lungs alone, or by both simultaneously.

It is not probable that this fish lives freely out of the water, the limbs being much too flexible for supporting the heavy and unwieldy body, and too feeble generally to be of much use in locomotion on land. However, it is quite possible that it is occasionally compelled to leave the water, although I do not believe that it can exist without it in a lively condition for any length of time.

Relative Situation of the Abdominal Viscera (Plates XXXIX. and XL.).

The part which first attracts attention on opening the abdminal cavity is the extremely large and wide intestinal sac (*a*), which fills the cavity nearly entirely. It is perfectly straight from its entrance below the diaphragm to the vent, without any circumvolutions, and of a nearly black colour, whilst the inside of the walls of the abdomen is of a silvery white. In the specimens examined it was throughout distended with food, apparently provided with thin walls, except below the stomachic region, where the walls were thicker, offering greater resistance to pressure. In the middle of its course it is crossed by six lines placed at regular intervals and indicating the insertion of the internal spiral valve. Below the last line the intestine is gradually contracted to its end.

This large intestinal sac is fixed by a ligament (*b*) to the ventral surface of the cavity; this very peculiar ligament commences from the first turn of the spiral valve, and is continued to the end of the intestine, fixing it, not exactly along the median line of the abdomen, but somewhat to the right hand of it. It is a very strong ligament, and, behind, firm like a tendon; there is a slit in it (b'), on the level of the pelvis, allowing of communication between the two sides of the abdominal cavity. The ventral portion of the upper part of the intestine is without mesenteric ligament.

On its dorsal side the intestine is fixed by its attachments to various organs—thus, along the median line, to the smooth band of the lung; more towards the side a portion of the testicles or ovaries adheres so firmly to the intestine that it is difficult to separate them. Along each side of the intestine lie the generative organs (g), the lung (l) occupying the place below the vertebral column, without the peritoneal sac. A greater portion of the lung is visible on the left side than on the right; and in order to expose it to view more fully, we have (at least in the male) to penetrate an extremely singular cellular tissue (h) filling up the interspaces between the peritoneal sac and the walls of the abdomen*. HYRTL appears to have observed a similar tissue in *Lepidosiren paradoxa*. Its cells are very wide, and the meshes so strong that, at the first glance, it may be taken for a distinct lung-like organ.

The kidneys (k) are entirely hidden from view, lying without the peritoneal sac, and enveloped in an adipose tissue. They occupy the side of the posterior part of the abdominal cavity, forming, with regard to position, merely a continuation of the generative organs, to which they are intimately attached.

The liver (c) lies immediately below the diaphragm (d), to which it is attached only in the neighbourhood of the large vessels penetrating the diaphragm; its upper lobe is thin and short, covering the uppermost part of the intestine, and subdivided in the middle by the very large and pear-shaped gall-bladder (e), which thus occupies the median line of the abdomen. This upper lobe is connected by a narrow bridge with a lateral triangular lobe (c') lying on the right side of the intestine; it is also thin, and its tapering posterior end is firmly attached to the extremity of the testicle or ovary (g) of the same side. The liver has no other attachment to the intestine, except at the place where the ductus choledochus enters the wall of the latter.

Intestinal Tract (Plate XXXIX.).

The buccal cavity is clothed with a soft and rather thin membrane of brown colour, the surface of which is uniformly covered with small papillæ. A small and short prominence, a fold of the mucous membrane between the front prongs of the lower molars, represents a rudimentary *tongue* (Plate XXXV. fig. 3, *t o*). The *œsophagus* (Plate XXXIX. fig. 2, *oe*) is rather narrow at its commencement, but widens rapidly behind the glottis, passing into the stomach (f) without a distinct boundary line. The membranes of the œsophagus do not show either folds or striæ; but there is on each side a longitudinal flat pad (i) of an orange colour; it is a layer of fat deposited below the mucous membrane; the right pad commences at a short distance behind the glottis, the

* I have found this tissue much more developed in the male specimen than in the female, in which it would interfere with the free passage of the ova through the abdomial cavity.

left somewhat more forward. The part which must be regarded as the *stomach* (f) is short, in its posterior portion much wider than the œsophagus, and nearly as wide as the succeeding part of the intestine. It has very thin walls, without folds or crypts. Its end is indicated by a double circular fold (p) of the mucous membrane, each fold being about three lines broad (*pylorus*). On the right side of the stomach, below the extremely thin mucous membrane and the pad of fat mentioned above, there is an extensive rather thin layer of a very soft substance of brownish-black colour (m). Water or any other substance coming into contact with it is coloured brown. This organ descends below the pylorus, and is continued for some distance along the axis of the spiral valve. I am inclined to regard it as a *spleen*; it has no communication with the inside of the intestine*.

The intestine is traversed throughout by a spiral valve, which performs nine gyrations. The extent of the intestine traversed by the first turn is the greatest, measuring about 4 inches; the second is much shorter, and the following are of nearly the same length as the second; the last two or three are again lengthened. The valve retains its spiral course nearly to its end, which is close to the vent.

The part below the pylorus receives the contents of the gall-bladder—the mouth of the ductus choledochus (e') being on the right side of the ventral surface of the intestine, at a short distance below the pyloric valve. The mucous membrane of this portion of the intestine (l) is finely wrinkled, the folds having an obliquely transverse direction parallel to the pyloric valve. The ventral wall is much thicker than the dorsal; and numerous flat glands (q, q') are imbedded between its membranes. These glands are either simple follicles without opening, or much larger, composed of a homogeneous firm substance, and with a small opening which leads into a short simple or bifurcate duct. The mucosa of the remainder of the intestine is smooth; but glands are scattered over all parts, disappearing only within the last two or three gyrations. In their most simple form they are flat, circular or ovate bodies of from 1 to 3 millims. diameter; many have an evenly convex surface; in others the membrane over the centre is sunk in, as if this part of the follicle had been filled with a fluid which has now disappeared; in a third kind the membrane in the centre is actually perforated by a more or less wide opening. Some of these follicles are isolated, in other places two or more are aggregated and more or less confluent. Beside these glands other much larger and thicker ones are placed along or near to the axis of the spiral valve, the largest being within the third and fourth gyrations, where some are more than an inch long, half an inch broad, and about two lines thick. Each of these large glands has several depressed points or openings on its surface, leading into two or three short ducts. These glands are much thicker than the spiral valve in which they are imbedded; consequently some of them project over both the anterior and posterior surfaces of the valve, so that one and the same gland discharges its contents towards two surfaces, or, in other words, into two adjoining compartments of the intestinal spire.

* Hyrtl, who appears to have found a similar organ in *Lepidosiren* and the *Sterlet*, has come to the conclusion that it is a rete mirabile.

I have to add a few words on the termination of the intestinal tract, and on the openings of the neighbouring excretory organs (Plate XL. figs. 1 & 2). The *vent* (*v*) lies in the median line of the abdomen, and leads into a very short and rather narrow cloaca, which is subdivided into two by a projecting fold of the dorsal wall of the rectum (*r*). This fold answers also the purposes of a valve, preventing the contents of either of the cloacal divisions from entering into the other. The abdominal portion of the cloaca passes uninterruptedly into the cavity of the rectum, the dorsal portion (*u*) being a small receptacle for the urine and generative products.

Immediately behind the vent are the two peritoneal openings (*w*), leading directly into the peritoneal cavity.

Liver (Plate XXXIX.).

A general description of the liver and its situation in the abdominal cavity has been given above. Its texture is spongious, not dense, in consequence of the great width of all the venous and biliferous cavities and ducts in its interior; certain portions may be inflated like the lung of a mammal. The gall-bladder (*e*) is very large, pear-shaped, and continued into the ductus choledochus, which is rather wide in its commencement, and enters by a small opening (*e'*) below the pyloric valve on the right side of the ventral wall of the abdomen. In order to reach this spot, the ductus choledochus has to traverse a rather long course below the mucous membrane of the stomach. Of the ductus hepatici, one, coming from the lateral lobe of the liver, and running nearly along the entire length near to the inner surface of the lobe, is particularly conspicuous. These ducts are collected into one trunk, which enters the ductus choledochus in the upper half of its course, before it has reached the wall of the stomach. The common opening of the hepatic ducts is much wider than that of the ductus choledochus.

The *vena cava*, which ascends along the line of attachment of the peritoneum to the right testicle (Plate XL. *x*), enters the hindmost extremity of the lateral lobe of the liver; it becomes much wider within this lobe, and penetrates through its substance, through the bridge connecting the two lobes, and through the upper lobe, where it reappears to enter the sinus venosus communis. Its inner walls are perforated by the openings of numerous small branches; and the venous system of the liver can be filled with matter of injection from either end of the vena cava.

The *arteria cœliaca*, which takes its origin on the right side of the aorta, runs round the bridge, connecting the lateral lobe of the liver with the upper one, and divides into several branches on entering the intestinal canal at the end of the axis of the spire. One of its branches is destined for the liver itself, another for the dorsal portion of the lung. At the same spot several venous trunks leave the intestine, and, entering the liver, where they branch off into smaller stems, represent the portal system.

Uropoëtic Organs (Plate XLI.).

The kidneys (*c*, *c'*) lie in the posterior part of the abdominal cavity, being only about 3 inches long. They are paired, each being firmly attached to the testicle (*b*, *b'*) or ovary of its side, and enveloped in fat. Each kidney is composed of from eight to ten lobes (see fig. 3). The two or three anterior lobes lie on the side of the air-bladder (*a*), by which they are entirely separated from those of the other side; but behind the air-bladder and the vena caudalis (*h*) the lobes of both sides are contiguous and connected by larger blood-vessels, though the renal substance itself is not coalesced. The posterior lobes become smaller and thinner, and, being apposed to the ureters, are again entirely separate from each other.

The ureters (*d*, *d'*) are provided with thick walls, and become superficial in the second anterior fourth of the kidney; they are perforated by only a few primary uriniferous tubes; about half an inch before their termination they externally unite into a single trunk, although they remain separate internally, the right entering the left close to the single opening in the urinal cloaca (see Plate XL. fig. 2, *k''*); this opening is round, dorsad to the genital opening (*g''*), from which it is separated by a slightly raised wall of the mucous membrane. The urinal cloaca (Plate XL. fig. 2, *u*) is small, incompletely separated from the termination of the rectum; in fact it may be described as a dorsal diverticle of the latter. The urine, consequently, passes by the vent.

The kidneys are but sparingly supplied with blood from the arterial system, by a small vessel (*n*) which descends on the dorsal surface of the intestine, and therefore is one of the extreme branches of the *arteria cœliaca*. On the other hand, a great quantity of venous blood is carried to them by *venæ renales advehentes* (*k*, *k'*), which form a portal system of the kidneys, such as has been described by HYRTL in various fishes. I describe here the arrangement of the right side, remarking that that of the left differs in several unimportant points of detail, as also probably many individual variations occur. The posterior *vena renalis advehens* comes from the lower parts of the root of the tail, and communicates with its fellow of the other side by a short anastomosis lying on the back of the cloaca; it emits (or receives?) a slender branch to (or from?) the ureter, and distributes a part of its contents by three stronger branches over the posterior renal lobes. Then it enters into communication with several intercostal veins (*l*, *l'*, *m*), which make their appearance through slits in the fascia of the wall of the abdomen, traverse the peculiar cellular tissue of that region, and merge into the posterior *vena renalis advehens*. The hindmost of these intercostal veins (*l*, *l'*) is much stronger than the anterior (*m*, *m*). From these veins the middle lobes receive their blood. The anterior lobes are provided partly by the remaining portion of the posterior vein, partly by intercostal veins which enter the lobes by themselves. There is one pair of *venæ renales revehentes* (*i*, *i*) running along the base of the posterior and middle lobes and emptying their blood into the *vena cava*. The blood of the anterior lobes is probably collected in one vein, together with that of the posterior lobe of the testicle.

Organs of Reproduction.

The generative organs are paired. Their products pass outwards by a paired oviduct, or vas deferens. These ducts are entirely separate from the ovaries or testicles, each having a distinct abdominal orifice immediately below the diaphragm. They accompany the ureters in their posterior course, but are nowhere confluent with them, and terminate in a common opening into the cloacal dilatation, immediately in front of the uretral orifice. A pair of wide slits *behind* the vent lead immediately into the peritoneal cavity.

Female Organs (Plate XLII.).

The sexual organs of the two sides differ from each other in form. The right ovary is considerably broader than the left ($2\frac{1}{4}$ inches across its middle), but extends forwards only to the extremity of the lateral lobe of the liver, to which it adheres by a fold of the peritoneum enclosing the vena cava. The left ovary extends from one end of the abdominal cavity to the other, and is only $1\frac{1}{4}$ inch broad across the middle; its terminal portions are tapering.

The ovaries (fig. 1) are elongate bands, with an inner and an outer surface, fixed along the dorsal edge to each side of the notochord, otherwise free, with a sharp ventral margin; they are separated from each other by the lung and intestine, and nowhere confluent. They are not closed sacs, being covered by the peritoneum on their inner (intestinal) side only. The outer side is in contact with the walls of the abdomen, and crossed by a great number of transverse lamellæ, the bearers of the stroma in which the ova are developed. These ova are in immense number, and, when ready for exclusion, have a diameter of $2\frac{1}{2}$ millims. The stroma of the ovary with mature eggs is of a very dark colour, irregularly and finely mottled with black and dark brown. The eggs themselves are now brown, and black on that portion of their convexity which is turned towards the surface of the ovary. Remains of a former state of development are visible on both sides, in the form of a linear tract (c, c') commencing at the posterior extremities of the ovaries, and running for some distance along the inner side of the oviduct. The anterior extremity of the left ovary terminates in a similar appendage (b'), but it is broader, band-like, and about 2 inches long; it extends to the abdominal aperture of the oviduct, surrounding a part of its circumference, and contains considerable venous vessels enveloped by an adipose tissue.

It is evident that the ova drop into the cavity of the peritoneum; at first they are received into a shallow gutter (d, d') at the base of the ovary, to commence a very circuitous journey before their final expulsion.

There is, namely, attached to, and along the base of each ovary a thick-walled oviduct (o, o'), 8 or 9 millims. thick, and still thicker in its posterior portion, but nowhere expanded into a sac with thinner walls. It is much convoluted, the convolutions forming a thick knotted rope along the whole length of the abdominal cavity; only posteriorly the convolutions are more simple, and finally open into a serpentine course. These oviducts lie outside the peritoneal cavity, and therefore are entirely separated from the ovaries. Their abdominal aperture (r, r') is a gaping slit, 3 or 4 millims. wide, in the foremost portion of the abdominal cavity, immediately below the diaphragm, at a short distance from the notochord. Consequently on the right side the liver intervenes between the ovary and the orifice of its oviduct. The ducts follow the base of the ovary and the course of the ureters, and coalesce immediately before their termination in the urinal cloaca. In the mature female, during the breeding season, I found their internal structure to be the following. The mucous membrane clothing the duct in the posterior 3 inches of its course (fig. 1, *p*) is raised into numerous transverse folds from 1 to 2 millims. deep, with a sharp margin, closely set, parallel to one another, and more oblique anteriorly than towards the end of the oviduct. So far its structure is extremely similar to that of *Menopoma*. Further above, the duct changes its appearance. Its wall continues to be highly turgescent, and to have a thickness of about 3 millims.; but its substance, instead of being a firm and resistant membrane, like the posterior portion, is a gelatinous mass enclosed in the thin fibrous outer membrane of the duct. This gelatinous mass (which is the mucous membrane) is deeply longitudinally fissured; and when the duct is cut through transversely (fig. 3), the fissures appear to the naked eye as numerous striæ, radiating from the central canal towards the periphery. On a closer examination we find that the transverse folds of the hindmost portion of the duct gradually assume, towards the middle of its length, a more oblique, and finally a longitudinal direction; they become very thin, semitransparent lamellæ, are easily ruptured, very closely packed, and therefore much more numerous. In a section made transversely through the lamellæ, but in the longitudinal axis of the duct (fig. 5), they appear like undulated bands (sometimes with short branches), with a linear tract of fibrous tissue (*b*) along their centre, into which blood-vessels extend, and which is the basis for a thick stratum of epithelial cells (*c*). In a second section, made right across the duct (fig. 4), the lamellæ appear as slightly attenuated cones, again with the epithelial stratum (*c*) and the dark tract (*b*) in the centre, the latter being a continuation of, or proceeding from, the outer fibrous coat (*a*) of the oviduct.

It was of interest to know whether the similarity in structure observed in the lower part of the oviducts of *Ceratodus* and *Menopoma* extended into the middle and upper portions. This is not the case. In a female Menopome, sexually mature, but killed out of the breeding season, the mucous membrane of those parts of the duct is not lamellated, but perfectly smooth, and in a section (fig. 6) through the wall in the longitudinal axis the lumina of the cavities of numerous tubular glands are seen.

The question naturally arises whether the condition of the oviduct described above, especially the gelatinous consistency of its wall, is not partly due to imperfect preservation of the specimen. I can hardly believe that this is the case, because the neighbouring parts have not suffered from decomposition, and even the epithelium has been preserved in its natural position and continuity. But when we find the mucous membrane turgescent with gelatinous matter, we may reasonably suppose that its secretion is of a similar nature, and destined to form a protecting case for the ova during their passage through the duct, as in Batrachians*.

* Whilst my examination was limited to a female 26 inches long, the undeveloped sexual organs of which will be described on the following page, I expressed the belief that the ova might be expelled through the

This is the condition of the sexual organs in a fish 34 inches long, fully mature, and evidently caught during the spawning season. I am enabled to add a description of the organs in a less developed state (fig. 2) from an example 26 inches long. The extent of the ovaries is the same as in the mature example, but a much smaller portion of their substance is ovigenous; at both ends they terminate in strips of a soft substance (b, b'; c, c') containing a considerable quantity of fat, the posterior strips being narrow and tapering in a fine point. The anterior strip of the left ovary (b') is $2\frac{1}{2}$ inches long (e), and extends, besides, backwards to some distance along the edges of the ovary. The anterior strip of the right side is very short, and replaced by the lateral lobe of the liver (l). The ovigenous part is from two thirds of an inch to an inch broad, and crossed by transverse lamellæ containing an immense number of very small ova, which are not visible to the naked eye. No pigment is as yet deposited in the stroma.

The oviducts (o, o') are in an equally undeveloped state; they are of the thickness of a pigeon's quill, and although tortuous in their course, show only a few complete convolutions. The duct of the right side opens by a minute slit (r) at the same place as in the mature example; but the left duct terminates (r') blind in the substance of the non-ovigenous strip of the ovary of that side. The specimen was in a good state of preservation, and neither air nor fluid could be driven through the end of that duct.

Male Organs (Plates XL. and XLI.).

The following observations have been made on two examples, one of which is the male, 32 inches long, mentioned above (p. 512). The other example*, although larger (36 inches), had the testicles considerably less developed, as if they were shrunk; but I was enabled, by injection of mercury, to trace the vas deferens in its entire course, whilst I had only partially succeeded in this respect by the use of coloured fluid in the former example.

The testicles are entirely separate from each other; they are long flat bodies lying on each side of the lung, between the intestine and the walls of the abdomen. The left extends from the diaphragm to the middle of the kidney in one example, whilst in the other the anterior 2 inches of its length are replaced by an adipose band, as in the adult female described above (p. 547). The right does not extend so far forwards, being arrested by the lateral lobe of the liver, with the extremity of which it is intimately con-

postanal orifices, and that the oviducts had no function, representing merely the remains of the ducts of the Wolffian bodies. However, now it it is clear enough that these ducts resemble a Urodelous oviduct in every way. But have the peritoneal canals no function whatever? They might be useful for discharging semen or ova, which, having lost their way to the abdominal aperture of the oviduct, might injuriously act if retained in the abdominal cavity. The presence of a pair of peritoneal openings in *Acipenser*, one on each side of the vent, is mentioned by several authors. I do not find them in a young example of *Acipenser sturio*, var. *oxyrhynchus*, 24 inches long. In a specimen of *Acipenser maculosus*, 20 inches long, there is one large aperture on the left side, but none on the right. *Lepidosteus* has two *pori abdominales*, lateral to the vent.

* Received whilst this paper was passing through the press.

nected by the *vena cava* and cellular tissue (Plate XXXIX. fig. 1, *g*). The outer margin of the testicles is sharp, slightly undulated or indented. In one example a deep notch almost entirely cuts off a posterior lobe from the right testicle; therefore it is evident that this organ varies considerably with regard to the details of its form, as in other Fishes and Batrachians. The greater (outer) portion of the testicle is free, covered by the peritoneum, which passes thence over to the intestine. The inner third of the ventral surface of the testicle has no peritoneal covering, and is firmly attached to the intestine. Its innermost margin is fixed to the side of the lung.

The structure of the testicle was found not to be identical on both sides. In the *left* testicle three strata can be distinguished on external inspection and by transverse sections made about the middle of its length, viz.:—a light liver-coloured substance, forming by far the greater portion of the organ; then a much thinner and narrower stratum of whitish colour, lying on the liver-coloured substance along the line of attachment to the intestine; finally a still more superficial and still narrower layer of a dark yellow fatty blastema which accompanies the *vena testicularis*. A duct traverses the whitish substance from one end of the testicle to the other (Plate XL. fig. 3 & 4, *a*); it is widest in the middle (scarcely one sixteenth of an inch), and tapers towards its extremities, without penetrating to the surface of the testicle; its walls are perforated by innumerable pore-like openings, leading immediately into the *canaliculi seminiferi* (*d*). Coloured fluid injected into the duct was equally distributed throughout the substance of the testicle, through the whitish portion as well as the liver-coloured; but in the former the canaliculi seminiferi were more distinct, visible to the naked eye, densely packed, parallel to one another, arranged in obliquely decussating rows. The course and arrangement of the canaliculi in the liver-coloured substance of this (left) side could not be clearly made out, as it had too much suffered by decomposition; but on the right side they could easily be filled with fluid, at least those nearest to the surface: they run parallel to one another, across the testicle, at a right angle to its longitudinal axis; they have a slightly wavy course, do not subdivide, and appear to be equally wide throughout their length. The longitudinal duct (*a*) is present, as on the left side but the whitish stratum, if present at all, must be extremely thin, whilst the adipose substance is spread over the inner third of this testicle, surrounding the *vena cava*. In the second example with shrunk testicles I was unable to find again the longitudinal duct.

The *vasa deferentia* are, with regard to their course and orifices, entirely analogous to the oviducts. Their abdominal orifices occupy exactly the same spot as those of the oviducts. They run (Plate XL. fig. 1, *g'*), separated from the testicles by the peritoneum, in a slightly undulated course, towards the posterior end of the testis, are intimately attached to the ventral margin of the ureters (Plate XLI. *o*, *o'*), their canal remaining perfectly distinct from that of the latter, and finally they terminate in a common opening in the dorsal wall of the cloaca (ibid. *p*, or Plate XL. fig. 2, *g''*). This opening is separated from that of the ureters by a low fold of mucous membrane. In their anterior third they are very thin, but their lumen is nearly 2 millims. wide.

They gradually become narrower, until in the middle of their length the diameter of the duct is scarcely more than half a millim. Posteriorly they widen again, and the wall becomes thicker, the mucous membrane being raised into longitudinal folds; but even towards the end they are scarcely half as wide as the ureter.

The manner in which the semen is expelled is not quite understood at present. There is no connexion between the ureters and the testicles. Mercury injected through the ureter penetrated into all parts of the kidneys, and in one case (evidently where the substance had been ruptured) into the vascular system, but never into any part of the substance of the testicle; and as there is no direct communication between the testicle and vas deferens, it is probable that the semen flows into the cavity of the peritoneum, and thence passes through the two abdominal openings of the deferent ducts, taking the same course as the ova in the female. But how does it get from the testicle into the peritoneal cavity? To answer this question, it will be necessary to examine specimens obtained during the process of spawning. Of those examined by me, one was, as I suppose, only approaching such a condition, whilst the other was far removed from it. Perhaps the following observation may assist in solving the question. I found in the left testicle, between the longitudinal seminal duct and the inner margin, a number of cavities, the form or connexion of which could not be determined, as the substance was very soft and evidently somewhat advanced in decomposition. In the corresponding portion of the right testicle I found only two of those cavities, behind the middle of the length of the organ; both were of the size of a pea, close together, and communicating with each other. During the injection of the posterior half of the seminal duct, air had been driven by the injected fluid into those cavities, thus proving a connexion between them and the duct; a narrow branch of the duct led *towards* them; and their interiors were clothed by a distinct membrane. Therefore it is possible that the semen is conducted by the common longitudinal canal to those cavities, where it accumulates. These cavities have very thin walls, and lie immediately behind the peritoneum.

The Affinities of Ceratodus *to other Recent Fishes.*

In the preceding description of the external and internal structure of *Ceratodus*, reference has so frequently been made to *Lepidosiren* (including *Protopterus*) that only a short recapitulation of the more important features of the organization of these fishes will be required to establish their close relationship. We have seen that, with regard to the form of the body and its integuments, the resemblance is striking even to the superficial observer. In both forms the dentition consists of two pairs of molars, with the addition of a pair of vomerine teeth; it is the same type, modified in the one for a carnivorous, in the other for an herbivorous diet. Two pairs of nasal openings within the mouth. The cartilaginous skeleton, with its tegumentary ossifications, not only exhibits the same embryonic condition, but in certain portions (as, for instance, in the central part of the scapular arch, in the first rib, in the pelvis, in the apophyses and dermal appendages) the one is almost a repetition of the other. The limbs are paddles supported by an axial skeleton.

In both the air-bladder has attained to the function of a lung, the blood being brought into contact with air by gills as well as by this lung. The separation of the atrium from the ventricle is effected by the same intricate contrivance, the principal vessels by which the atrium is filled being the same in number and having the same arrangement. The difference of food is not accompanied by a corresponding amount of modification of the intestinal tract; there is the same want of stomachic dilatation, the boundary of this region being indicated merely by a pyloric fold; the same short and straight intestine, with its complete spiral valve and scattered voluminous glands.

The greater part of the characters enumerated are peculiar to *Lepidosiren* and *Ceratodus*; and there is no other recent fish known at present which approaches them in having a similar combination of peculiarities of structure. *Therefore, in a natural system, these fishes must be more closely approximated to each other than to any third living form.* Yet, on the other hand, unexpected and extraordinary differences have been pointed out between them. Instead of finding in the conus arteriosus the longitudinal valves of the "Dipnoous" heart, transverse series of "Ganoid" valves were discovered. In *Lepidosiren* a paired lung is developed, at the expense of the water-breathing apparatus, a considerable portion of the branchial arches being destitute of gill-laminæ. In *Ceratodus* the case is reversed: the gills are in the most perfect state of development, whilst the air-breathing apparatus is confluent into a single cavity, receiving a scantier supply of blood from secondary branches of the aorta descendens. In *Lepidosiren* the gill-cover supports an opercular gill with respiratory function, in *Ceratodus* this rudimentary gill is reduced to a pseudobranchia. Finally, the ovaries of *Ceratodus*, instead of being closed sacs connected with the oviducts as in *Lepidosiren*, are lamellated, discharging their products into the peritoneal cavity, the orifices of the oviducts being separated and even remote from the ovaries. The peritoneal *porus* of *Lepidosiren* is narrow, single, and in front of the vent, in *Ceratodus* this way of communication is paired, wide, and behind the vent.

Thus, Lepidosiren *and* Ceratodus *are well-marked modifications of the same type, the former diverging more towards the Amphibians than the latter.*

With regard to the systematic value of some of the differential characters mentioned, we may be guided by analogous relations in Teleosteous fishes. Thus there will be not much doubt that the modifications of the respiratory organs should be regarded as of generic degree, whilst the difference in the structure of the ovaries may be used as a family character here as well as for Salmonoids or Characinoids. The singular arrangement of the valves in the conus arteriosus is a point of much deeper interest. There cannot be a question that *Ceratodus* should be referred to MÜLLER's subclass of Ganoids, and excluded from that of *Dipnoi*, according to the chief characteristics by which he has defined these divisions.

But I have pointed out above that *Ceratodus* and *Lepidosiren* are most closely allied to each other, and that, even if we regard them as representatives of two distinct *families*, they certainly cannot be referred to two separate *subclasses*. Consequently we shall be obliged either to abandon the subclass *Dipnoi* altogether, or, if we maintain it, to materially alter its definition, so as to comprise *Ceratodus* as well as *Lepidosiren*. It appears to me that of these two courses the former ought to be adopted, and that the *Dipnoi* should be united with the Ganoids, among which they may form a well-marked subdivision, like the *Holocephala* among the Chondropterygians.

In order to justify this view, I will compare the chief characters of the *Dipnoi* with those of Ganoid and Chondropterygian fishes. The presence of a pulsating conus arteriosus is common to all three divisions; a notochordal skeleton is found in the Acipensers* and Chimæras; a cartilaginous skeleton of the paired fins is fully developed in the Chondropterygians, being only foreshadowed by the single row of cartilaginous rods in the fins of *Polypterus*; the cellular air-bladder of many Ganoids, which in *Polypterus* communicates with the ventral side of the œsophagus, is by all anatomists admitted to be a very close advance towards the Dipnoous lung; the gills of *Ceratodus*, which extend and are fixed to the walls of the branchial cavity, represent an arrangement indicating the first step towards the fixed gills of the Sharks and Rays; accessory external gills have hitherto been found in certain examples of *Protopterus* and *Polypterus*†; the presence of a spiral valve in the intestine, again, is common to Ganoids and Chondropterygians; finally, the convoluted oviducts with the addition of peritoneal openings, and the numerous ova of small size, remind us unmistakably of similar conditions among Ganoids, for instance *Acipenser* and *Lepidosteus*‡.

The only remaining absolute characters by which we can distinguish the Dipnoi from the Ganoids and Chondropterygians are the position of the nostrils within the mouth, the dentition consisting of two pairs of molars and one of vomerine teeth, and the lobate fins or paddles, supported by an *axial* cartilaginous skeleton.

These three points cannot be considered to constitute the characters of a subclass equivalent to *Teleostei*, *Ganoidei*, &c.; and therefore the *Dipnoi* are better united with the Ganoids.

But it appears to me that also the Ganoids and Chondropterygians are much more closely allied to each other than either of them to the Teleosteans. It would be beyond the limits of this paper to enter into all the various points of organization which have to be considered with regard to this question. But I may urge, as the most important fact in favour of this view, the treble partition of the heart of all these fishes—the bulbus aortæ of the Teleosteans being, as Müller has shown, simply the thickened origin of the aorta, separated from the pulsating heart by the (almost always) double valve. A heart with a true *conus arteriosus* is always accompanied by a spiral valve of the intestine (which only exceptionally, as in *Lepidosteus*, remains in a rudimentary condition), and by non-

* The similarity between vertical sections of the cartilaginous brain-capsule of *Acipenser* and *Ceratodus* is surprising.

† In the latter genus only recently discovered by Steindachner; they may be found also in young *Ceratodus* and other Ganoids.

‡ The male organs of *Lepidosiren* are not known, and those of Ganoids only imperfectly; Plagiostomes have a deferent duct, but it is in direct communication with the sperm-gland.

decussating optic nerves. The *Holocephala*, which differ in several important points from the other Chondropterygians, approach the Ganoids by these very characters, and are an intermediate form. Furthermore, all those modifications which show an approach of the ichthyic type to that next above it, are found in Ganoids and Chondropterygians, none in Teleosteans; and, finally, the early coexistence and development of Ganoids and Chondropterygians in geological epochs, when no (or only very few) Teleosteans existed, is a circumstance which seems to confirm a conclusion arrived at from an anatomical point of view only.

Therefore I would propose, after the separation of the *Cyclostomata* and *Leptocardii*, to refer the remaining host of living fishes to two subclasses only, viz. the subclass of *Teleostei*, and one for which the name *Palæichthyes* may be used. In order to put the preceding statements into a readily comprehensible form, I have prepared the following synoptical table, in which, at present, reference is made to those fossil genera only which approach most closely the *Dipnoi*:—

First subclass: LEPTOCARDII.

Second subclass: CYCLOSTOMATA.

Third subclass: TELEOSTEI.

Fourth subclass: PALÆICHTHYES. Heart with a contractile conus arteriosus; intestine with a spiral valve; optic nerves non-decussating.

Order I. CHONDROPTERYGII.

Suborder 1. *Plagiostoma.*

Suborder 2. *Holocephala.*

Order II. GANOIDEI.

Suborder 1. *Amioidei.*

Suborder 2. *Lepidosteoidei.*

Suborder 3. *Polypteroidei.*

Suborder 4. *Chondrostei.*

Fam. *a. Acipenseridæ.*

Fam. *b. Polyodontidæ.*

Suborder 5. *Dipnoi.* Nostrils two pairs, within the mouth. Limbs with an axial skeleton. Lungs and gills. Skeleton notochordal. No branchiostegals.

Fam. *a. Sirenidæ.* Caudal fin diphycercal; no gular plates. Scales cycloid. Two pairs of molars and one pair of vomerine teeth.

Subfamily *Ceratodontina.* Conus arteriosus with transverse series of valves. Ovaries transversely lamellated. One continuous vertical fin: *Ceratodus* [*Cheirodus*?].

Subfamily *Protopterina.* Conus arteriosus with two longitudinal valves. Ovaries closed sacs. One continuous vertical fin: *Lepidosiren*, *Protopterus*.

Fam. *b. Ctenododipteridæ.* Caudal fin heterocercal; gular plates. Scales cycloid. Two pairs of molars and one pair of vomerine teeth: *Dipterus*.

?(Fam. *c. Phaneropleuridæ.* Caudal fin diphycercal; gular plates. Scales cycloid. Jaws with a series of minute conical teeth on the margin: *Phaneropleuron.*)

On the Affinities of Ceratodus *to certain Fossil Fishes.*

Those who have followed the researches made of late years into the affinities of Ganoid fishes, must have remarked that in the conclusion of the preceding chapter I have touched upon a subject which had been approached by Professor Huxley from a palæontological point of view*. One result of his examination of the Devonian fishes was the establishing a separate suborder of Ganoids, *Crossopterygidæ*, which comprises the Ganoids provided with fringed or lobate fins and generally with gular plates, branchiostegals being absent. This suborder was divided by him into five families of extinct fishes, chiefly from the Devonian epoch, viz. *Saurodipterini*, *Glyptodipterini*, *Ctenododipterini*, *Phaneropleurini*, and *Cœlacanthini*; *Polypterus* was associated with them as

* "Preliminary Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch," by T. H. Huxley, F.R.S., in Mem. Geolog. Survey, Dec. 10, 1861. At that time, when *Lepidosiren* was still the only representative of Müller's subclass *Dipnoi*, Professor Huxley pointed at its affinity to certain Ganoids:—"Without wishing to lay too much stress upon the fact, I may draw attention to the many and singular relations which obtain between that wonderful and apparently isolated fish, *Lepidosiren*, sole member of its order, and the cycloid Glyptodipterine, Ctenododipterine, Phaneropleurine, and Cœlacanth Crossopterygidæ. *Lepidosiren* is, in fact, the only living fish whose pectoral and ventral members have a structure analogous to that of the acutely lobate, paired fins of *Holoptychius*, of *Dipterus*, or of *Phaneropleuron*, though the fin-rays and surface-scales are still less developed in the modern than in the ancient fish. The endoskeleton of *Lepidosiren*, again, is as nearly as possible in the same condition as that of *Phaneropleuron*, and is more nearly similar to the skeleton of the Cœlacanths than that of any other recent fish [*quære Acipenser*? A. G.]; while, perhaps, it is not stretching the search for analogies too far to discover in the stiff-walled lungs of *Lepidosiren* a structure more nearly representing the ossified air-bladder of the Cœlacanths than any with which we are at present acquainted, among recent or fossil fishes. Furthermore, *Lepidosiren* is the only fish whose teeth are comparable in form and arrangement to those of *Dipterus*. Though *Lepidosiren* may not be included among the *Crossopterygidæ*, nor even in the order of *Ganoidei*, the relations just pointed out are not the less distinct; and perhaps they gain in interest when we reflect that while *Polypterus*, the modern representative of the rhombiferous *Crossopterygidæ*, is that fish which has the most completely lung-like of all air-bladders, *Lepidosiren*, which has just been shown to be, if not the modern representative of the cycliferous *Crossopterygidæ*, yet their 'next of kin,' is the only fish which is provided with true lungs. These are unquestionable facts. I leave their bearing upon the great problems of zoological theory to be developed by every one for himself."

the type of a sixth family. *Ceratodus*, having the fins lobate in an eminent degree, would appear to belong to this suborder; and therefore I shall attempt to examine the affinities of the *Dipnoi* to some Crossopterygian fishes, and finally, perhaps, arrive at a conclusion regarding the limits of this suborder.

I take first the type of the family *Ctenododipterini*, viz. the genus *Dipterus*.

The materials on which the following observations on *Dipterus* are based, are examples in the British Museum, and especially some most instructive specimens belonging to the Museum of the School of Mines in Jermyn Street, and kindly offered for my examination by Professor HUXLEY. PANDER'S excellent Monograph, "Ueber die Ctenodipterinen des devonischen Systems," St. Petersb. 1858, 4to, was my guide in examining these materials.

The characters of *Dipterus* which appear to indicate an affinity to *Ceratodus* may be described thus:—They are fishes with an elongate body covered with cycloid scales; head depressed, snout obtuse; dorsal and anal fins thrown back, belonging to the caudal portion of the vertebral column; paired fins acutely lobate; opercular apparatus well developed, consisting of two, possibly three pieces. No separate maxillary or intermaxillary. The bones of the lower part of the skull and the mandible essentially as in *Ceratodus*, only the pterygo-palatine shows a longitudinal groove as if it had consisted of two bones. Vertebral column not divided into vertebræ*. The palate and mandible armed with a pair of large flat tubercular dental plates, placed as in *Ceratodus*. To these characters, which were previously known, I may add that a specimen in the Jermyn-Street Museum (marked $\frac{\text{R.D.}}{156}$), figured on Plate XXXIV. fig. 4, shows clearly the *presence of a pair of vomerine teeth in* Dipterus. These teeth, indeed, are not preserved themselves; but two small roundish cavities (v), one on each side of the median line of the skull, in front of the palatine teeth, indicate distinctly the place where a pair of vomerine teeth were implanted in the cartilaginous substance of the vomer. In the same specimen the position of the nostrils (n) is indicated by an accumulation of the matrix; it is the same as in *Ceratodus* and *Lepidosiren*.

On the other hand, *Dipterus* differs from *Ceratodus* in being eminently heterocercal; there are two dorsals and one anal fin separate from the caudal; the scales are covered with a layer of enamel, with smooth, porous surface. Head covered with numerous scutes with the same surface as the scales; gular plates behind the mandibulary symphysis. Interneural and interhæmal spines branched at their distal end, to which the dermal rays are joined, the latter being branched and jointed. Finally, as regards the microscopical structure of the dental plates, the medullary canals are more irregular in their course than in *Ceratodus*; they frequently anastomose with one another; the dentinal tubes are coarser, dendritically branched, and less numerous.

Can any thing be more singular than a combination of such characters? If we had had the head only of *Dipterus* with the trunk, we should certainly have seen in it

* No vertebra has ever been found in British specimens; and PANDER, who figures vertebræ (which he found in Russia) in connexion with this genus, is by no means certain of their correct determination.

nothing but a genus most nearly allied to *Ceratodus*, as shown by the arrangement of its three pairs of teeth, form of the snout, position of nostrils, acutely lobate fins, &c.; the presence of the gular plates alone might have offered ground for hesitation. Yet, when we examine the tail, we find that the one genus is truly diphycercal, the other eminently heterocercal, so that they cannot remain even in the same family. I do not attach much importance to the separation of the vertical fins, or to the division of the dorsal into two; such modifications are common in the Gadoid fishes, where they are considered to be scarcely of generic value. Of much greater importance is the junction of the dermal fin-rays with the supporting spines, and the position of the dorsal fin or fins. In the former point *Dipterus* differs from *Ceratodus*; in the latter both genera agree.

Weighing the points of affinity and difference against each other, we must come to the conclusion that *Dipterus* has a better right to be associated with the living *Dipnoi*, than with *Polypterus*.

Wherever *Dipterus* and *Ceratodus* are placed, thither *Cheirodus* (M'Coy, Pander) or *Conchodus* (M'Coy) must follow. But it is probable that this genus is more nearly allied to *Ceratodus*.

At first I thought that *Holodus* (Pander) was another Dipnoous genus; but I changed this opinion after having compared it with *Palædaphus* of Van Beneden and De Koninck (Bull. Ac. Roy. Belg. 2nd ser. xvii. p. 151, pls. 3 & 4). These two genera are evidently closely allied; and the position of their nostrils (as far as we can judge from the fragmentary remains) appears to have been different from that of the Dipnoi; these openings were more lateral, and outside of the mouth. It seems also that there would not have been room for a pair of vomerine teeth, at least not in *Palædaphus*.

There are two other genera of fossil fishes of the Devonian epoch which have been referred to the Crossopterygians, and which appear to approach the Dipnoi more closely than the other fringe-finned fishes, viz. *Phaneropleuron* and *Tristichopterus*. With regard to the former genus I refer to Professor Huxley's description and figures in Anderson's 'Dura Den,' p. 67 *et seqq.*, and Mem. Geol. Surv. Dec. 10, p. 24 *et seqq.* The structure of the skeleton of the trunk and tail and of the fins is extremely similar to that of *Ceratodus*. In those specimens in which I found the foremost part of the snout tolerably well preserved, no interruption in the surface of the osseous substance could be discovered; and therefore it is not improbable that the nasal openings were inside the mouth as in *Dipnoi*. On the other hand, minute conical teeth in rather small number were visible in the margins of the upper as well as lower jaw, thus indicating by their presence a development of maxillary elements which are entirely missing in the *Dipnoi*.

The genus *Tristichopterus* was established and described by Sir Philip Egerton in Mem. Geol. Surv. Dec. 10, p. 51 *et seqq.*, where already the affinities of this highly interesting fish to *Dipterus* were fully considered by its author. The fins were composed of innumerable fine fin-rays closely placed together, and overlapping with their proximal ends the extremities of the interspinous bones as in the *Dipnoi*. But these bones are very much reduced in number, and enlarged, the vertical fins themselves being entirely separate from one another. The peculiar termination of the vertebral column, with an unequal development of the caudal lobes, represents a most curious intermediate condition between the diphycercal tail of the *Sirenidæ* and the heterocercal of *Dipterus*. To this is added "the complete ossification and segmentation of the vertebral column, in which respect this genus stands alone among the contemporaneous fishes." Unfortunately the head and base of the paired fins are destroyed in the only two specimens known; and it is chiefly the last-named character which prevents me from associating this genus with the *Dipnoi*.

However uncertain the affinities of the last-named genera must appear from a zoological point of view, I believe that I have shown that *Ceratodus* clearly proves the correctness of Professor HUXLEY's view regarding the similarity of the *Lepidosiren*-limb with the fringed fin of certain Crossopterygians, and that *Ceratodus*, *Lepidosiren*, and *Dipterus* are most closely allied forms, and must remain together in the same suborder. Consequently if we retained the suborder Crossopterygians with the limits assigned to it by its author, it would comprise four recent Ganoid genera, viz. *Polypterus*, *Ceratodus*, *Protopterus*, and *Lepidosiren*; or, in other words, these four genera would require to be regarded as more nearly allied to each other than to the other recent Ganoids. I am not prepared to adopt this view. MÜLLER was certainly right in regarding the condition of the skeleton as a character of primary importance for the systematic division of Ganoids, and in supporting his opinion by the analogous case of the Chondropterygians, of which the Plagiostomes have the skeleton completely divided into segments, whilst the "Holocephala with their notochordal skeleton form a division distinguished in a marked manner also in other respects" (Ganoid. p. 150). Thus also I have had repeated occasion to draw attention to identity of structure in *Ceratodus* and *Acipenser*; and when we consider that the notochordal or segmented condition of the skeleton is systematically of as great importance at least as the state of development of an air-bladder into a lung, we must admit that the points of affinity of *Ceratodus* to *Acipenser* counterbalance those existing between *Ceratodus* and *Polypterus*, and consequently that the fishes named are representatives of *cosubordinate* divisions of *Ganoidei*.

Thus, from an examination of the living forms, I am inclined to withdraw from the Crossopterygians some of the component parts of this suborder; and I am encouraged in this by the following additional consideration. With the knowledge obtained by means of *Ceratodus*, we are now able to define more distinctly two types of "fringed fin," already indicated by Professor HUXLEY, who terms them "acutely lobate" and "obtusely lobate." Fringed fins of the former type are long, pointed, like those of *Ceratodus*, or even narrower; they are covered with small scales along the middle, and surrounded by a cutaneous fringe containing innumerable fine fin-rays. There can scarcely be any doubt that such fins in fossil fishes were supported, as in *Dipnoi*, by an axial cartilaginous skeleton, extending from the base to the extremity. I have never been able to find any trace of it preserved in the fossil remains, as it is entirely destroyed like the remainder of the cartilaginous portions. In the fringed fins of the second type, termed "obtuse" or "subacutely lobate," the scaly covering is limited to the base; the fin-rays are very distinct, comparatively few in number, and joined to a simple transverse series of cartilaginous rods. Such are the fins of *Polypterus*, of the Cœlacanths as restricted by HUXLEY, and probably also of the *Saurodipterini*. Having drawn attention to this, as I believe, important diversity in the only character on which the suborder *Crossopterygii* is founded, I leave the bearing of this fact upon the further classification of these fossils to be developed by those who are more intimately acquainted with the details of their structure than myself.

I should be found wanting in respect towards the founder of Palæichthyology, were I to pass over in silence the opinion expressed by him with regard to the affinities of *Ceratodus*. In a letter addressed to Sir PHILIP EGERTON ('Nature,' iii. No. 61, p. 166), Professor AGASSIZ states that this fish is clearly a member of the family named by him *Cœlacanthini*. I am not aware how far AGASSIZ has modified the characters and limits of this family since the publication of the 'Recherches' (vol. ii. p. 168) and 'Vieux Grès Rouge' (p. 64); at that time he pointed out as the principal characters the hollow condition of the fin-rays and bones (as in birds), the presence of interspinous bones in the caudal fin, the continuation of the vertebral column between the two lobes of that fin, and the prolongation of the caudal extremity beyond it as a filamentary appendage. *Arapaima* (*Sudis*) *gigas* was stated to be one of the living representatives of this family. Now it is scarcely correct to describe the fin-rays and bones of these fishes as hollow like "those of birds;" before they underwent the alterations during the process of decomposition and fossilization, they were *thoroughly solid*, without hollow space in the interior, like the fin-rays and bones of *Ceratodus* and other notochordal fishes, with or without a bony covering. With regard to the second and third characters, they are common to so many other fishes not reckoned among the Cœlacanths, that no safe conclusion can be drawn from them regarding the affinities of a fish. Finally, the prolongation of the caudal extremity as a filamentary appendage is not observed in *Ceratodus*. No student of recent ichthyology has followed AGASSIZ in placing *Arapaima* among the Cœlacanths, or indeed among the Ganoids; MÜLLER has shown it to be a true Teleostean; and the degree of affinity between this genus and *Ceratodus* is not greater than that between a Salamander and a Lizard*.

THIOLLIÈRE and HUXLEY have independently come to the conclusion that AGASSIZ'S family of Cœlacanths comprises too many heterogeneous forms to allow us to regard the affinities of a fish as determined by its being referred to it. Both have limited the term to the genus *Cœlacanthus* as type, and a few other forms closely allied to it. The family thus restricted appears to me even more remote from the *Dipnoi* than the

* Botanical science is in this respect more advanced than Zoological: no botanist would allow himself to be influenced by merely external similarity; and a system in which the African *Euphorbia* were associated with the American *Cactus* would be repudiated by all.

other "Crossopterygians." Fin-rays in definite numbers, joined to the interspinous bones, obtuse paired fins as in *Polypterus*, a double pelvis, developed upper jaws with small conical teeth, external nostrils, are characters sufficient to prevent us from associating *Ceratodus* and its allies with the Cœlacanths, which form not only a distinct family, but belong, according to my view, to a distinct suborder*.

Concluding Remarks.

The great interest attached to the discovery of *Lepidosiren* lay in the combination of elements of its organization denoting an approach to the Amphibian type, with others which remind us of embryonic stages of development. The supposition of some zoologists, who saw in *Lepidosiren* an instance of the latest step of advancement attained by the struggling ichthyic type towards the higher class, that of Amphibians, is not confirmed; for we find that the *Dipnoi* reach back, with comparatively insignificant modifications, into one of the oldest epochs from which fish-remains are preserved. The modification which would appear to demand our special attention is the condition of the tail, heterocercy being generally taken to be a lower degree of development than diphycercy. Thus one might suppose that the heterocercal *Dipterus* of the Devonian epoch is the less highly organized ancestor of the diphycercal *Lepidosiren* and *Ceratodus*; but then, on the other hand, *Phaneropleuron*, and also *Tristichopterus*, prove that diphycercy is a condition attained even at that early time by fishes more or less closely allied to the Dipnoi.

The defenders of the doctrine of evolution hold that a space of time like that which elapsed from the Devonian epoch to our period, is as a drop in the sea, when compared with the time required for the development of organic life. From this point of view the Ganoid fauna of the Devonian and even the *Pteraspis* of the Upper Ludlow formation, must have been preceded by long and varied ichthyic series. *Tristichopterus* with its osseous vertebral column may have been the surviving representative of a Ganoid suborder then extinct, as *Polypterus* has been regarded as the sole survivor of Crossopterygians; and the Dipnoous type, as it appears to us for the first time in the Devonian epoch, was not the beginning of a series, but the last of many preceding developmental stages. Future discoveries in hitherto unexplored formations may prove these suppositions to be quite correct; but when we limit ourselves for the present to the actual evidence before us, we find it consists of the following facts only:—The Dipnoous type is represented in the Devonian and Carboniferous epochs by several genera (*Dipterus*, *Cheirodus*, *Conchodus*, *Phaneropleuron*); it is then lost down to the Trias and Lias, where the scanty remains of a distinct genus, *Ceratodus*, testify to its presence; no further trace of it has been found until the present period, where it reappears in three genera, one of which is identical with that of the Mesozoic era. Now at present scarcely any

* I do not attach any value to the terms subfamilies, families, suborders, &c., except as expressions of the relative degree of affinity; and in the preceding notes I have used them in accordance with the synoptical table published by Professor HUXLEY.

zoologist will deny that there must have been a continuity of the Dipnoous type; and it is only a proof of the incompleteness of the palæontological record, that we have to derive all our information regarding it from only three so very distant periods of its existence.

The *Dipnoi* offer the most remarkable example of persistence of organization, not in Fishes only, but in Vertebrates. On a former occasion I have shown that numerous recent *species* of fishes have survived from the period of the geological changes which resulted in the separation of the Atlantic and Pacific by the Central-American isthmus. In *Ceratodus* we have now found a *genus* which, as far as evidence goes, persisted unchanged from the Mesozoic era; and in the *Sirenidæ*, a *family* the nearest ally of which lived in the Palæozoic epochs.

Perhaps future palæontologists will be able to demonstrate as complete a series of transitional stages from the Fish to the Amphibian as that obtained by the study of the living and therefore more accessible forms of Hæmatocrya. Zoologists have had to abandon the attempt to separate the two classes by one or several absolute characters; and it is only the concurrence of either decidedly ichthyic or amphibian characters by which they refer a creature to the one or the other class. However, this is a problem upon which *Ceratodus* has only a distant bearing; and I am satisfied if I have succeeded in showing its relations to *Lepidosiren*, and the connexions of both genera with the Palæichthyic type.

Explanation of the Plates.

PLATE XXX.

Fig. 1. *Ceratodus miolepis*, male, $\frac{1}{3}$ the natural size.

Fig. 2. Skeleton of *Ceratodus forsteri*, $\frac{1}{3}$ the natural size.

In the side view of the skull, the facial cartilages are preserved; their extent will be apparent from a comparison of this figure with fig. 1 of Plate XXXV. The three slits on the side of the snout, in front of the eye, are places over which the cartilage does not extend; they are perfectly closed by the skin.

Fig. 3. Termination of the vertebral column of another example.

a. Entrance into labial cavity.
b. The extent of the labial cavity is indicated by dotted lines.
c. Cavity in the interior of the infraorbital cartilage.
l. Ligamentum longitudinale.
m. Antebrachial.
n. Termination of the notochord.
t. Last segments of the confluent neural and hæmal elements.

PLATE XXXI.

Structure of the Scales.

Fig. 1. A scale taken from the lateral line of *Ceratodus forsteri*, outer surface. Natural size.

Fig. 2. Inner surface of the same scale.

Fig. 3. One half of a vertical transverse section across the middle of the scale, magn. 8. The vertical divisions (*a*, *a*) indicate the place where the section passed through the sutures dividing the outer surface into trapezes.

Fig. 4. A portion of the same section, magn. 216.

a. A layer of fibres cut transversely.

b. A layer of fibres cut obliquely.

c. A layer of fibres cut longitudinally.

d. Outer calcified stratum.

Fig. 5. Three layers of fibres crossing each other at angles of 90° or 45°, magn. 216.

Figs. 6–8. Portions of the calcareous stratum, after removal of the organic matter by burning, magn. 216: 6, from the middle of the lateral area of the scale; 7, from the exposed area; 8, from the posterior area.

Fig. 9. Right upper tooth of *Ceratodus forsteri*, nat. size.

Fig. 10. Right upper tooth of *Ceratodus runcinatus*, from the Muschelkalk, nat. size. From a specimen in the British Museum.

PLATE XXXII.

Microscopical Structure of the Teeth, compared with that in Fossil species, Protopterus *and* Psammodus.

Fig. 1. Front part of one half of the lower jaw, with a vertical section through the tooth (nat. size).

a. Dentine.

b. Pulp-cavity.

c. Osseous base of tooth.

d. Dentary bone.

e. Cartilaginous symphysis.

Fig. 2. The same section through the lower tooth, magnified: the clear vertical line indicates that a portion of the length of the tooth is left out.

a. Dentine with medullary canals.

b. Pulp-cavity.

c. Spongious osseous base of the tooth.

Fig. 3. Vertical section through the front prong of the lower tooth of *Protopterus*, magn. 20.

a. Spongious osseous base of tooth.

b. Pulp-cavity.

c. Origin of central medullary canals, which ramify in an irregular manner, chiefly in the direction towards the point of the prong.

d. Narrower superficial medullary canals, running in an oblique or vertical direction, and emitting horizontal branches.

Fig. 4. Horizontal section through the lower tooth of *Protopterus*, of natural size, the darkened part being that of which a magnified view is given in figure 5.

Fig. 5. Part of a horizontal section through the front prong of the mandibulary tooth of *Protopterus*, magn. 216. It comprises several of the smaller medullary canals represented in fig. 3, *d.* Two are nearly horizontal, so that their whole extent is visible; others run in a vertical direction. They ramify in a very irregular manner, and are not surrounded by a dark ring of calcigerous tubes.

Fig. 6. Vertical section through the tooth of *Psammodus*, magn. 216. The horizontal white line indicates that a portion of the depth of the tooth is left out. The upper portion contains three medullary canals, two penetrating to the surface, where they form the "pores;" in the lower portion the canals have a more oblique direction, and consequently the vertical section passes slantingly through them; the concentric lamellated arrangement of the dentinal substance round the canals is also conspicuous, whilst it has disappeared nearer to the surface of the tooth.

Fig. 7. Horizontal section through the tooth of *Psammodus*, magn. 216, made nearer to the root than to the surface.

PLATE XXXIII.

Microscopical structure of the teeth (continued).

Fig. 1. Vertical section through the medullary canals of *Ceratodus forsteri*, magn. 216. The clear horizontal line indicates that a portion of the length of the tooth is left out.

a. Termination of a medullary canal in the pulp-cavity.

b. Termination of a medullary canal in one of the punctate impressions on the surface of the tooth.

Fig. 2. Horizontal section through the same tooth, near the surface of the crown, magn. 216.

Fig. 3. Horizontal section through the same tooth, near its base.

Fig. 4. Portion of a vertical section through a tooth of *Ceratodus runcinatus* (magn. 20), for comparison with the recent species (Plate XXXII. fig. 2).

Fig. 5. Part of the same section (magn. 216), for comparison with the structure of the same part in the recent species (fig. 1). Three medullary canals open on the surface of the crown, producing the appearance of punctate impressions.

Fig. 6. Horizontal section through a tooth of *Ceratodus runcinatus* (magn. 216), for comparison with fig. 2.

PLATE XXXIV.

Structure of the Skull, compared with that of Dipterus.

The cartilaginous parts are coloured blue; figs. 1–3 are $\frac{2}{3}$ the nat. size.

Fig. 1. Upper view of the skull, with the facial cartilages preserved.

Fig. 2. Upper view of the same, after removal of the greater part of the osseous covering and of the temporal muscle, to show the cartilaginous skull.

Fig. 3. Lower view of skull; the soft parts surrounding the upper jaw have been preserved, to show the position of the nostrils.

a. Scleroparietal.
b. Ethmoid.
c. Frontal.
d. Tympanic lamina.
e. Infraorbital ossifications.
f. Infraorbital cartilage; *f'*, facial cartilage.
g, *g*, *g*. Vacuities within the cartilage.
h. Operculum (removed in fig. 3).
i. Part of scapular arch.
k. Præoperculum.
l. Pterygo-palatine.
m, *m'*. Foramina for the 1st and 2nd rami of *nervus trigeminus*.
n. Nostrils.
o. Basale.
p. Cartilaginous roof of gill-cavity.
q. Os quadratum.
r. Tubercle for hyoid.
s. Suspensory pedicle.
t. Foramina for 3rd ramus of *nervus trigeminus*.
u. Foramen for *carotis posterior*.
v. Vomer, with pair of vomerine teeth.
w. Foramina for *nervus vagus*.
x. First rib.
x'. Cartilaginous tubercle attached to the first rib.

Fig. 4. Lower view of the skull of *Dipterus*, of the natural size, from a specimen in the Geological Museum in Jermyn Street, No. $\frac{\text{R.D.}}{156}$.

l. Pterygo-palatine.
o. Basale.
n. Excavated place where the two nostrils were situated.
v. A pair of round holes in which the vomerine teeth were fixed.

Figs. 5 and 6. Horizontal section of the anterior (fig. 5) and posterior (fig. 6) portion of the sclero-parietal bone, magn. 216.

a. Medullary canals.

PLATE XXXV.

Structure of the Skull (continued). Figures 1–3 are $\frac{2}{3}$ the natural size.

Fig. 1, Lateral view (the facial cartilages are removed).

Fig. 2. Vertical section of the skull made along the median line, showing also the inner surface of the mandible and molars.

To facilitate a comparison with figs. 1–3 of Plate XXXIV., the same letters have been used in these figures whenever possible.

a. Scleroparietal.
ac. Acoustic membrane.
b. Ethmoid.
b'. Foramen olfactorium.
bh. Basihyal.
c. Frontal.
c'. Process of frontal for its connexion with the pterygo-palatine bone.
cd. Section through notochord; *cd'*, end of central cylinder.
ch. Ceratohyal.
co. Upper coracoid; *co'*, lower coracoid.
d. Tympanic lamina.
e. Infraorbital ossifications.
f. Facial cartilage, turned upwards in fig. 1, and with its end longitudinally cut through in fig. 2.
gh. Glossohyal.
h. Operculum.
h'. Suboperculum.
hc. Humeral cartilage.
l. Pterygo-palatine; *l'*, symphysis of the pterygo-palatine bones.
la. Lower labial cartilage.
ll. Ligamentum longitudinale.
m. Foramen for 1st and 2nd ramus of *nervus trigeminus.*
m''. Foramen for 3rd ramus of *nervus trigeminus* and part of *nervus acusticus.*
mc. Median cartilage of scapular arch, cut through its median line.
ml. Molar teeth, viewed from the inside of the oral cavity.
mt. Insertion of *musculus temporalis.*
o. Basale.
ol. Passage for olfactory nerve.
op. Foramen opticum.
p. Cartilaginous roof of gill-cavity.
pt. Pituitary gland.
q. Os quadratum.

s. Suspensory pedicle.
ss. Suprascapula.
sy. Symphysis mandibulæ.
v'. Vomerine tooth.
w. Foramen for *nervus vagus.*

Fig. 3. Lower jaw, viewed from the oral cavity; on the left side the soft parts are preserved; on the right the osseous and cartilaginous parts are dissected.
ar. Articulary.
ar'. Large foramen perforating the lower jaw from below.
dt. Dentary.
la. Labial cartilage.
to. Tongue.

Fig. 4. Vertical section through a ramus of the mandible, of the natural size. The centre is entirely cartilaginous, the sides being covered by the articulary (*ar*) and dentary (*dt*). *a* is the section through the tooth which is anchylosed to the dentary, but separated from the articulary by connective tissue (*ct*); pulp-cavity = *pc.*

Fig. 5. The same magnified, without the tooth. This figure shows the porous nature of the bones. *ct* is a strip of connective tissue between the central cartilage and articulary.

Fig. 6. Bone-corpuscles of articulary.

Fig. 7. Cartilage-cells from the margin of mandibulary cartilage.

Fig. 8. Cartilage-cells from its centre.

PLATE XXXVI.

Fig. 1. Termination of the notochord, and its junction with the skull; a vertical longitudinal section, magn. 216.
n. Cartilage of the notochord.
c. Cartilage of the base of the skull.

Fig. 2. Scapular arch (right half), anterior view, of the natural size.

Fig. 3. The same, posterior view.
a. Median cartilage (right half).
b. Humeral cartilage.
c. Condyle for the articulation of the fore arm.
d. Coracoid (scapula).
e. Suprascapula.

Fig. 4. Pelvis (outer view), with right ventral paddle; $\frac{2}{3}$ nat. size.
a. Fibrous sheath of process slit open.

Fig. 5. Longitudinal section through the pelvis, to show the cavity (*b*).

Fig. 6. Pelvis of *Protopterus*, of the natural size, for comparison with fig. 4.

Fig. 7. A longitudinal section of a dermo-neural cartilage, magn. 216.
Fig. 8. Cartilage-cells from a joint of a fore paddle, magn. 216.

PLATE XXXVII.

Heart and Gills. All figures of the natural size.

Fig. 1. Front view of heart of *Ceratodus miolepis*.
Fig. 2. The ventricle opened.
Fig. 3. The ventricle and atrium opened.
Fig. 4. The ventricle and transverse portion of the conus arteriosus opened.
Fig. 5. The right side of the heart opened, to show the spiral valve within the conus.
Fig. 6. Ganoid valves in a normal state of development.
Fig. 7. Ganoid valves partly rudimentary.

a. Atrium.
b. Conus arteriosus.
c. Large valve between atrium and ventricle.
d. Papillary valve within the conus, with its muscle (*d'*).
e. Transverse series of large ganoid valves.
f. Raised stripes (? rudimentary valves).
g. Transverse series of small ganoid valves.
g'. The same reduced to a pair of small papillary prominences.
h, *i.* Anterior arcus aortæ.
k, *l.* Posterior arcus aortæ.
m. Papillary muscle, with its cartilage (*m'*).
v. Ventricle.

Fig. 8. Gills of the right side. The scapular arch has been removed, and only a small portion of the left coracoid (*co*) is preserved; the ceratohyal (*ch*) is pulled forwards, beyond the mandibulary joint of the suspensory pedicle (*sp*). The glossohyal (*gl*) and suboperculum (*so*) are also preserved in this preparation.

h, *i.* Anterior arcus aortæ.
k, *l.* Posterior arcus aortæ.
u. Attachment of the first gill to the roof of the gill-cavity.
u'. Attachment of the fourth gill to the suprascapula.
x. Pseudobranchia.
x'. One series, and *x''* the other series of gill-rakers belonging to the pseudobranchia.

Fig. 9. Anterior parts of the aorta. The branchial arches of the left side are drawn outwards, to show the arrangement of the gill-rakers. The ceratohyal (*ch*) is drawn forwards. Basal bone=*ba*.

h, *i.* Anterior arcus aortæ.
k, *l.* Posterior arcus aortæ.

n. Carotis.
o. Ramus recurrens.
p. Arteria cœliaca.
q, *q'*. Arteria subclavia.
r. Anastomosis between arteria subclavia and vena cava superior.
s. Vena cava superior dextra.
s'. Vena cava superior sinistra.
t. Semiobliterated branch of vena cava superior.
w. Fifth branchial arch.
x' and *x''*. As in fig. 8.

PLATE XXXVIII.

Fig. 1. Ventral aspect of upper half of lung, with the system of the pulmonal vein blood-injected. Natural size.
a. Smooth median band.
b. Anterior end of left half of lung.
e. Vena pulmonalis; *e'*, right branch.
f. Arterial (?) blood-vessel; *f'*, right branch.
g. Place where this vessel breaks up into several terminal branches.
gl. Glottis.
œ. Part of the œsophagus slit open.

Fig. 2. Lower half of the lung, slit open along the ventral median band, to show the internal structure.
c. Posterior end of left half of lung.
d. Dorsal median line of lung running along the aorta.

Figs. 3–9. Vertical sections through the first (3), fourth (4), fifth (5), fifteenth (6), twenty-ninth (7), forty-eighth (8), and sixtieth (9) sets of apophyses, to show the relative extent of bone and cartilage (half the natural size). The ossified portions are represented black, the cartilaginous only slightly shaded.
a. Central cylinder of notochord.
b. Notochord.
c. Confluent neur- and hæmapophysis of first set.
c'. Neurapophysis, cartilage.
c². Hæmapophysis.
d. Medullary canal.
e. Neurapophysis, bony part.
e'. Canal for ligamentum longitudinale.
f. Neural spine.
g. Interneural first.
h. Interneural second.

i. Dermo-neurals.
k. Hæmal canal.
l. Hæmal spine.
m. Interhæmal first.
n. Interhæmal second.
o. Dermo-hæmals.
r. Rib.

PLATE XXXIX.

Upper part of intestinal tract ($\frac{3}{4}$ nat. size).

Fig. 1. Ventral aspect.

Fig. 2. The anterior part of the intestine is opened, the liver (*c*) and gall-bladder (*e*) being drawn forward. A slit is made at *m*, through which part of the next compartment (*o*) may be seen.

a. Intestine.
b. Ligament fixing the intestinal sac to the wall of the abdomen.
c. Liver; *c'*, lateral lobe of liver.
d. Diaphragm.
e. Gall-bladder; *e'*, mouth of ductus choledochus.
f. Stomach.
g. Right testicle drawn away from the side of the intestine.
i. Adipose layer descending from the right side of the œsophagus.
l. First compartment of intestinal spire.
m. Spleen. A slit shows the thickness of this body by *n*, *o* being part of the next following compartment.
œ. Part of œsophagus, opened.
p. Double pyloric fold.
q, *q*. Glandular patches in the wall of the foremost compartment of the spire, as seen from without; and *q'*, *q'*, as seen from within

PLATE XL.

Fig. 1. Lower half of the abdominal organs ($\frac{3}{4}$ nat. size). The intestine and left testicle are a little pushed towards the right, to render the layer of cellular tissue (*h*, *h*) conspicuous; this tissue has been removed at *l*, to show the position of the lung.

a. Intestine.
b. Ligament fixing the intestine to the wall of the abdomen.
b'. Slit in the ligament.
g. Left testicle; *g'*, vas deferens.

h. Cellular tissue.
k. Kidney.
k'. The two ureters.
l. Lung.
v. Vent.
w. External peritoneal opening.
w'. Probe passed through the peritoneal canal.

Fig. 2. Vertical section through the end of the intestine.

a. Cavity of the rectum.
g'. Vasa deferentia; *g''*, their common orifice.
k'. Ureters; *k''*, their common orifice.
r. Fold of the dorsal wall of the rectum, separating it from
u, the Urinary bladder.
v. Vent.
w. External peritoneal opening.

Figs. 3 & 4. Upper and lower halves of the right testicle, with portions of the circulatory and seminiferous systems injected (natural size).

a. Vas longitudinale; its course is indicated by a dotted line; it is opened at *a'*, to show the pore-like openings of the canaliculi seminiferi.
b. Line of attachment of peritoneum.
c, *c*. Small veins injected from the vena cava.
d, *d*. Canaliculi seminiferi injected from the vas longitudinale.
x. Vena cava.

PLATE XLI.

Uropoëtic organs, with their veins. Figures of the natural size.

Fig. 1. Front view after removal of the intestine.

Fig. 2. The left testicle is turned over to the right, to show the entrance of the *vena caudalis* (*h*) into the *vena cava*.

Fig. 3. Right kidney, with portal system: the tissue in which the organ was imbedded is removed, and the right testicle drawn to the left.

a. Lower part of lung.
b. Lower part of right testicle, with its terminal lobe (*b''*).
b'. Lower part of left testicle.
c. Right kidney; *c'*, left kidney.
d, *d'*. Ureters.
e. Vena cava.
f. Vena testicularis sinistra.
g. Vena testicularis dextra.
h. Vena caudalis.
i, *i*. Venæ renales revehentes.

k, *k'*. Venæ renales advehentes.
l, *l'*. Posterior venæ intercostales.
m, *m*. Anterior venæ intercostales.
n. Arteria renalis.
o. Right, and *o'*. left vas deferens.
p. Orifice of the vasa deferentia.
q. Uretral orifice.

PLATE XLII.

Female Sexual Organs.

Fig. 1. In a fully developed condition. The liver has been removed; only a part of its lateral lobe (*l*) remains. The right ovary (*a*) is shown from the inner surface covered by the peritoneum; the left (*a'*) is turned inwards, so as to show its outer surface and the oviduct. $\frac{2}{3}$ nat. size.

Fig. 2. In an undeveloped condition. The liver (*l*) has been preserved. Of both ovaries the inner side is shown. $\frac{3}{4}$ natural size.

a. Right, and *a'*. left ovary.
b. Adipose anterior termination of ovary of the right side.
b'. The same of the left side; its end is split open in fig. 2 to show the blind end of the oviduct (*r'*).
c, *c'*. Posterior termination of ovary.
d, *d'*. Groove at the base of the ovary.
e, *e'*. Reverted fold of the peritoneum.
k, *k'*. Ureter.
l. Liver.
o. Right, and *o'*. left oviduct.
p. The lower part of the right oviduct is opened, to show the oblique transverse folds.
q. Opening of the left oviduct into the right.
r, *r'*. Abdominal orifices of the oviduct.

Fig. 3. Transverse section through the oviduct, of the natural size.

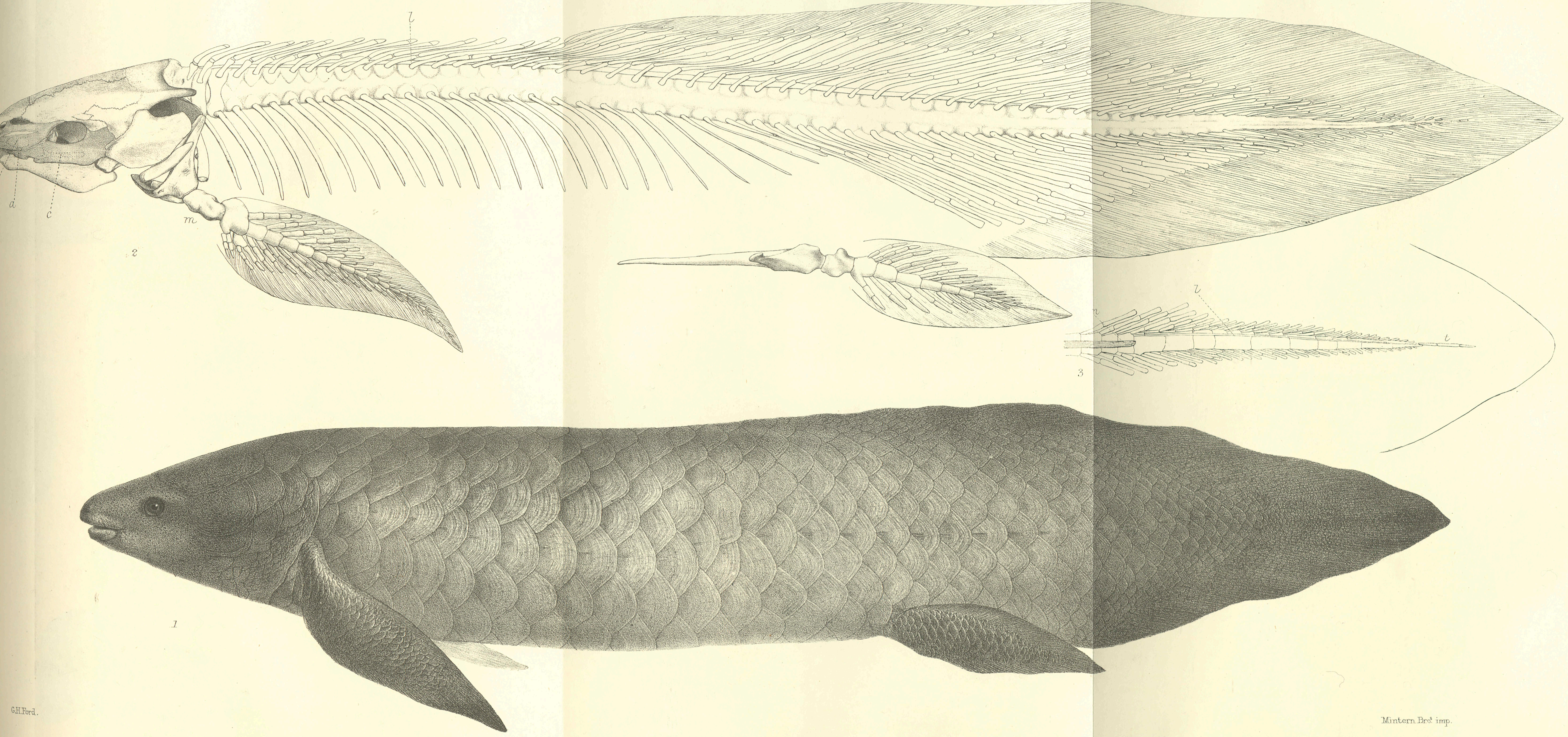
Fig. 4. A portion of the same, containing three mucous lamellæ (magnified).

a. Fibrous outer membrane of the oviduct, sending off
b. Processes into the lamellæ.
c. Epithelial stratum.

Fig. 5. Transverse section through the mucous lamellæ, made in the longitudinal axis of the oviduct (magnified).

b. Central fibrous tract.
c. Epithelial stratum.

Fig. 6. Transverse section through the mucous membrane of the oviduct of *Menopoma*, made in the longitudinal axis of the duct (magnified).



G.H.Ford.

Mintern Bros imp.

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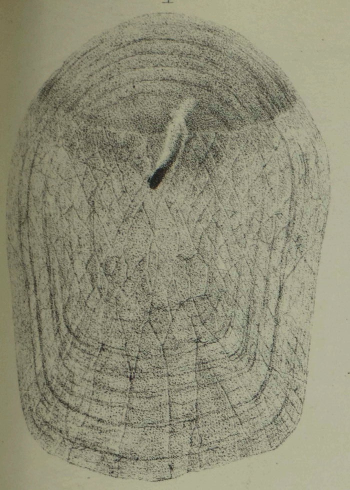

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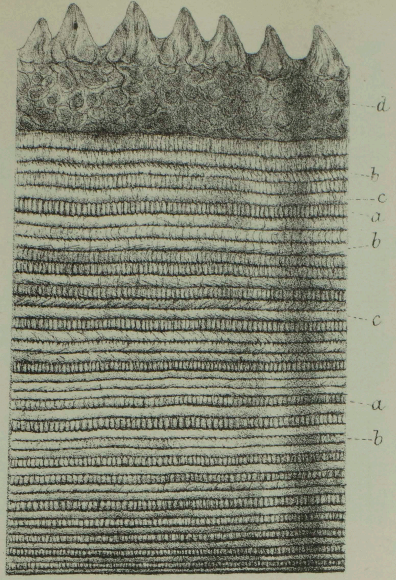

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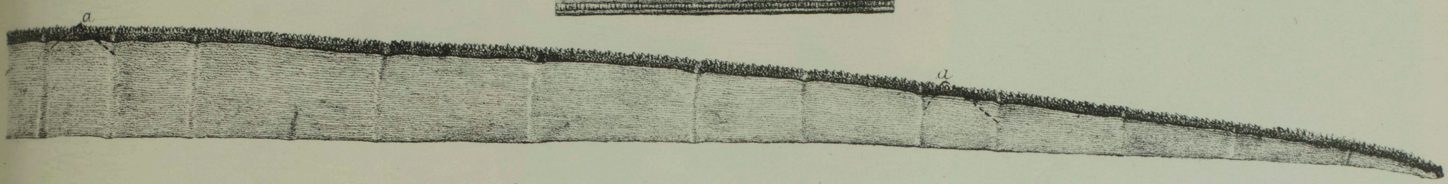

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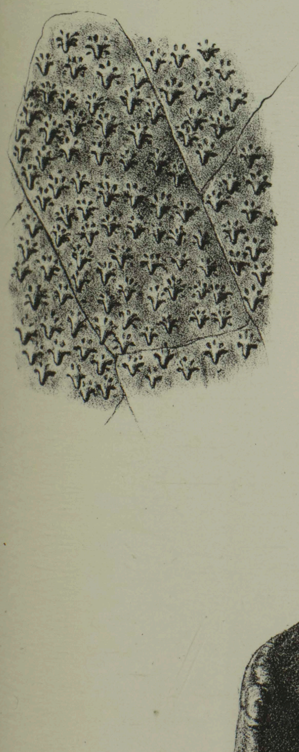

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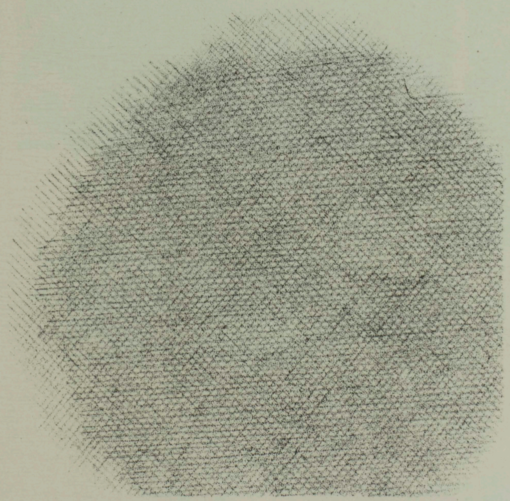

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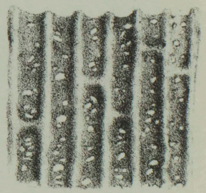

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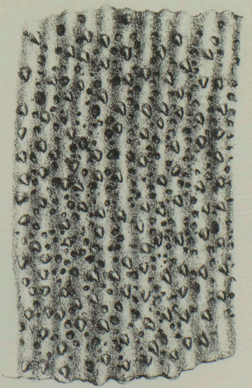

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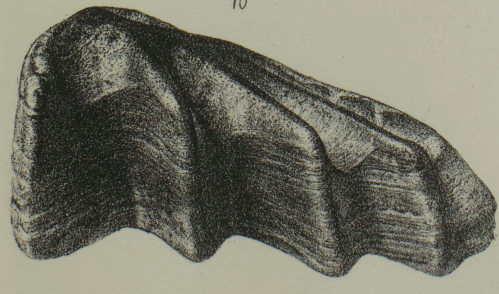

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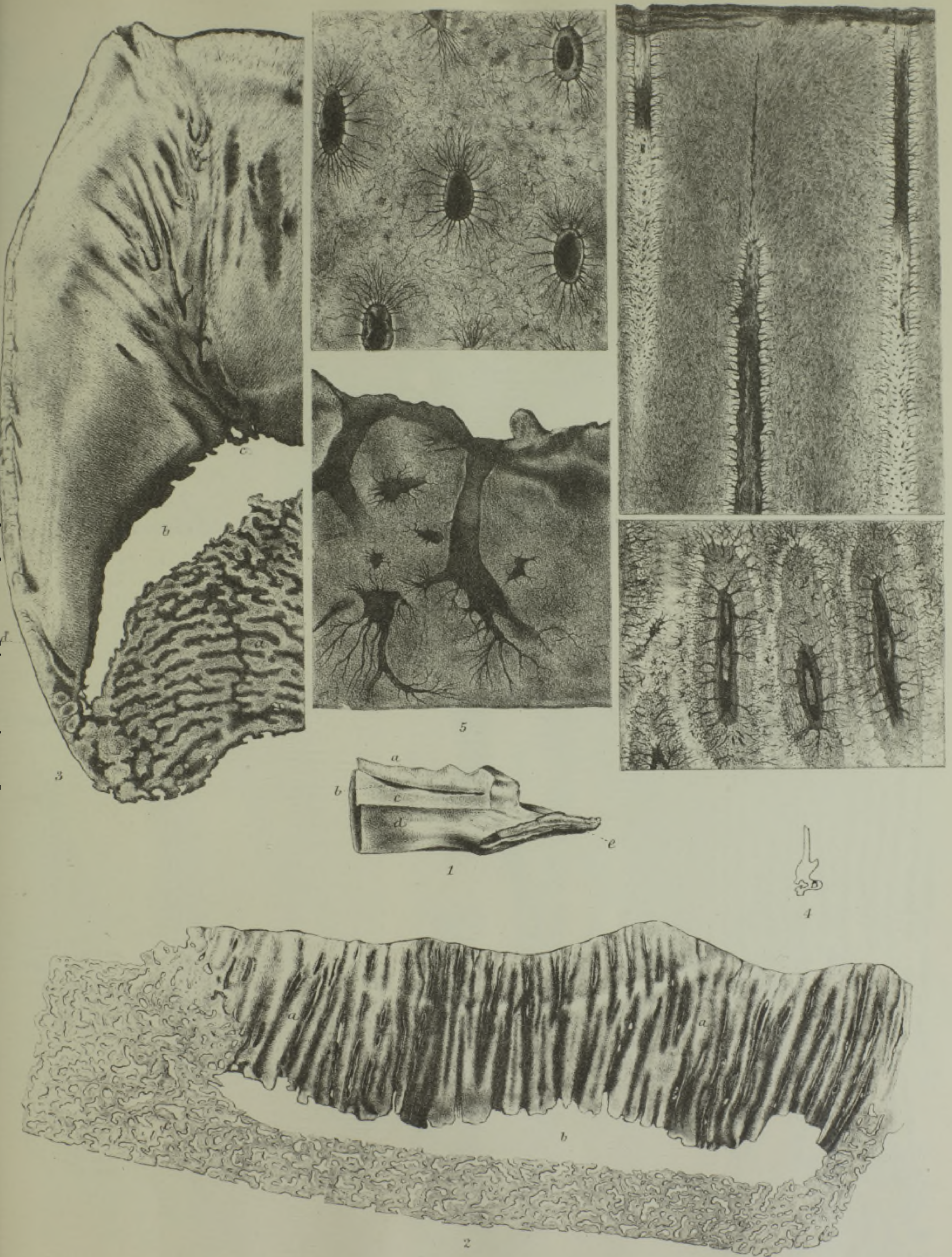

G.H. Ford.

Mintern Bros. imp.

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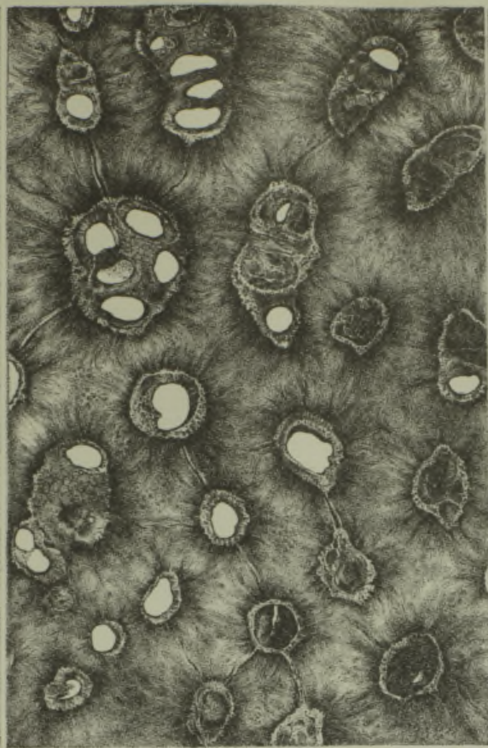

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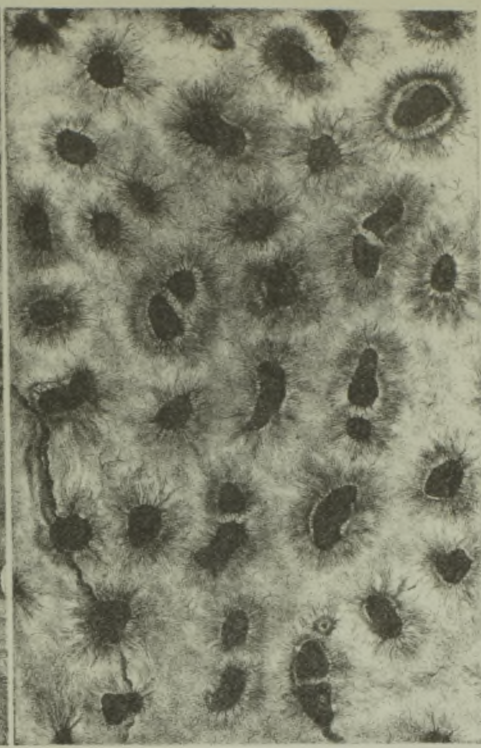

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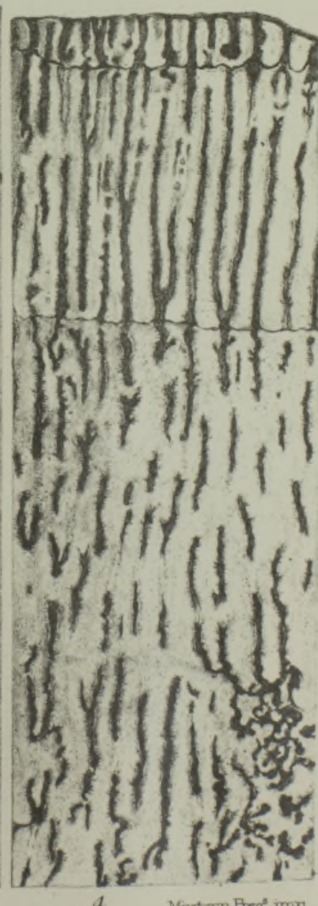

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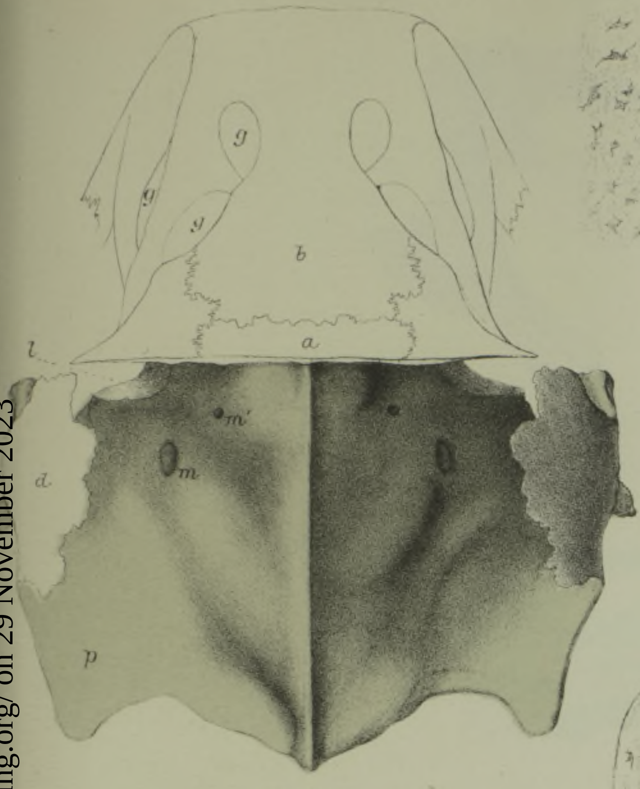
H Ford.

Mintern Bros. imp.



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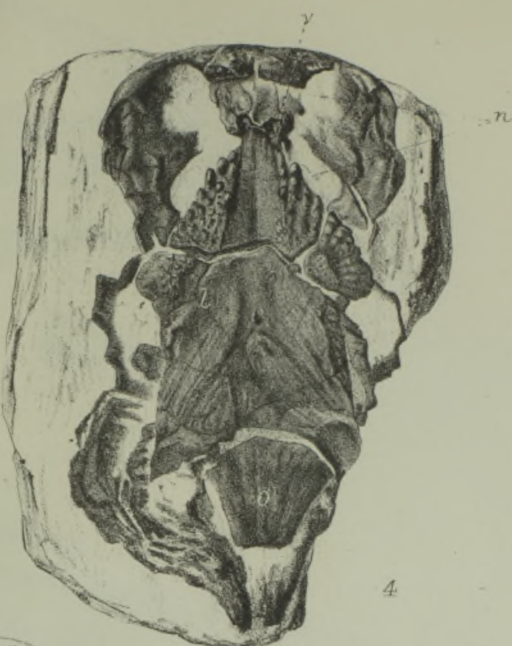

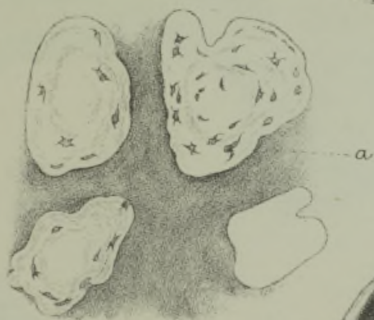

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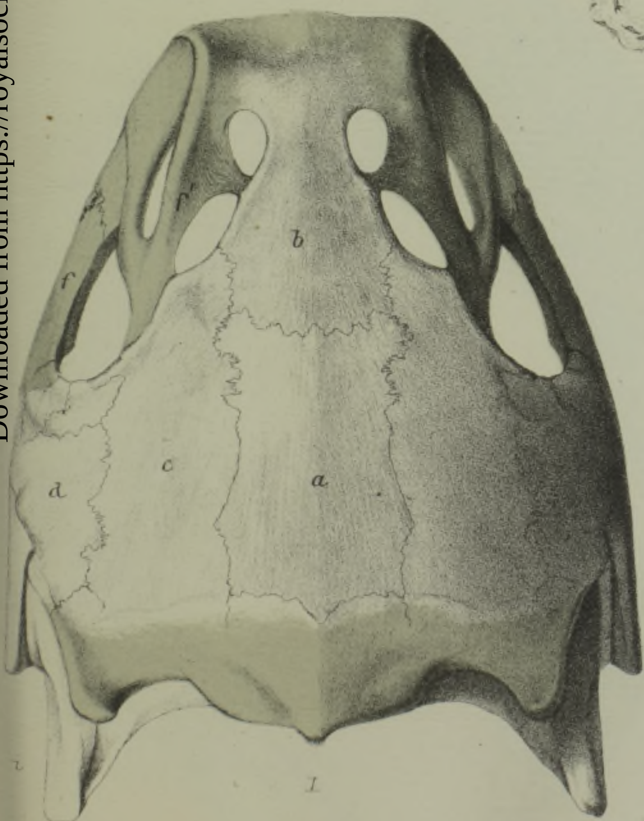
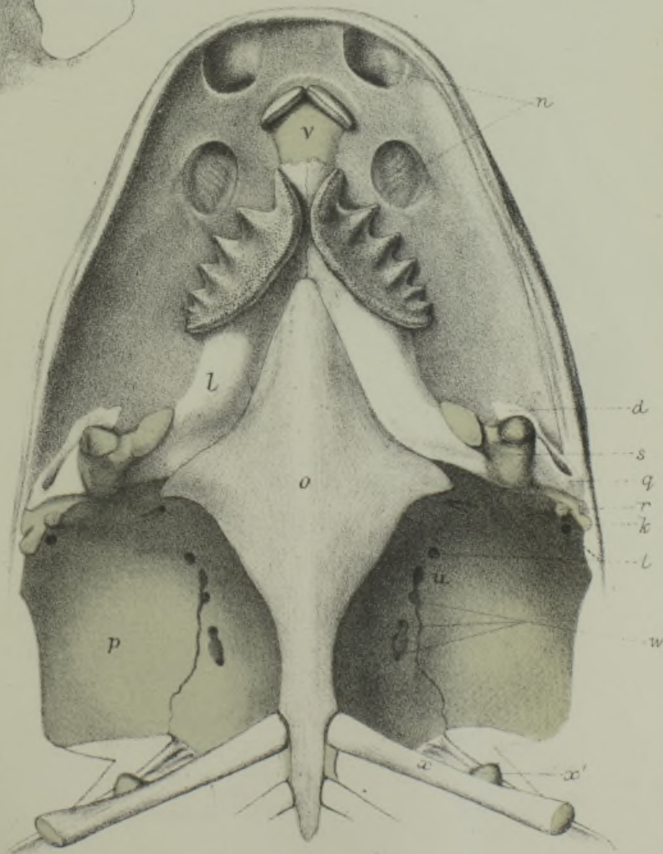
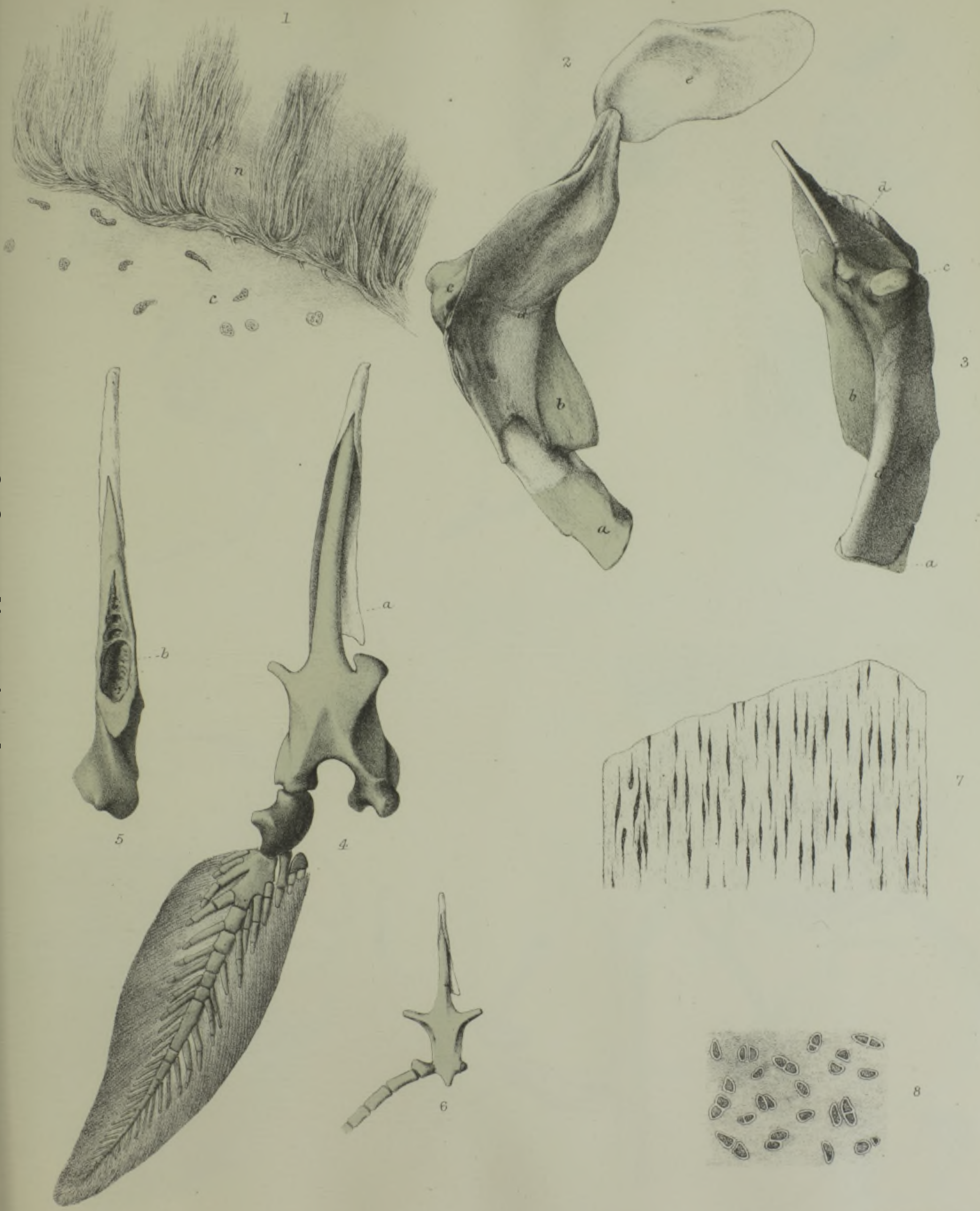




3

G.H. Ford.

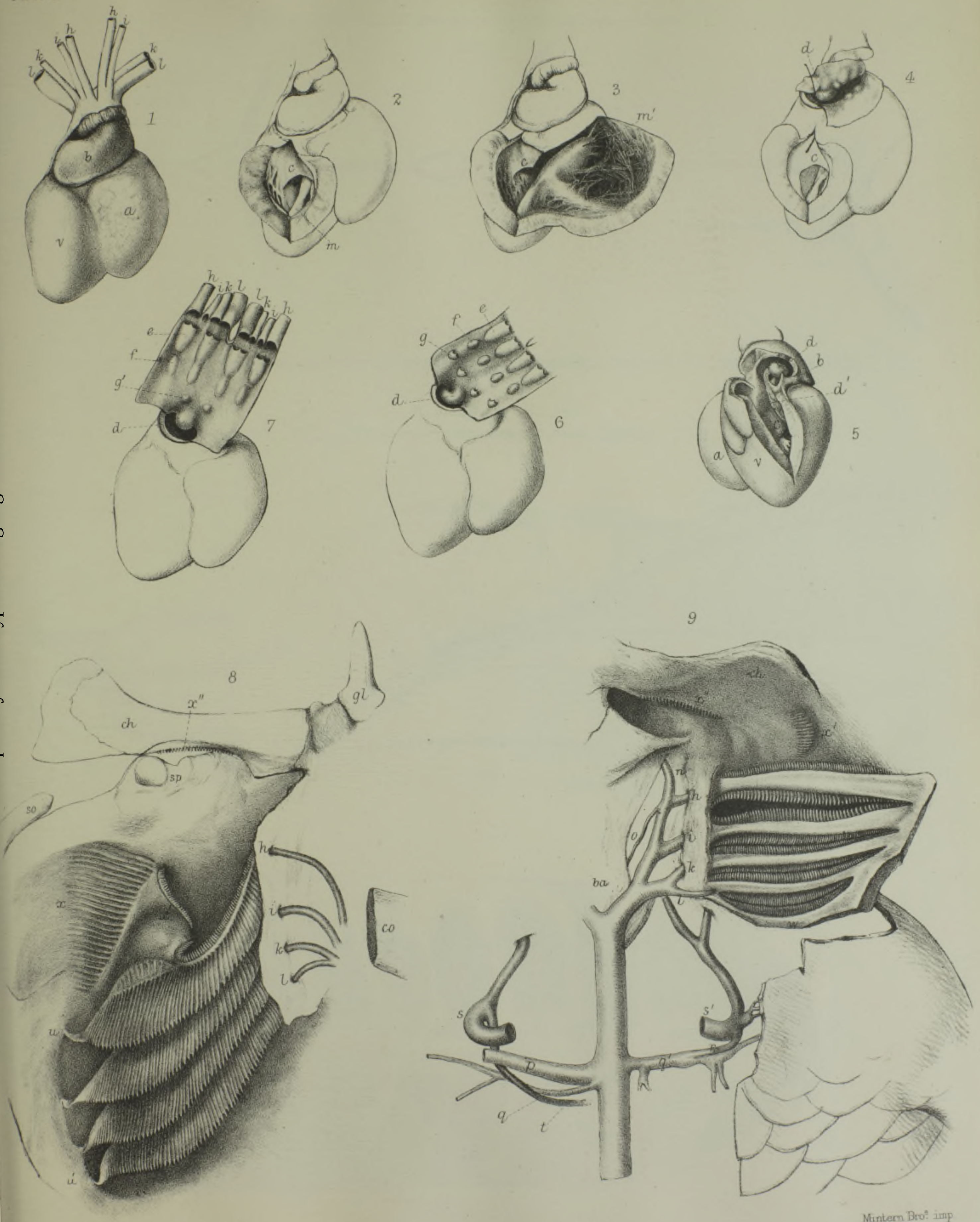
Mintern Bro^s imp.



G.H. Ford.

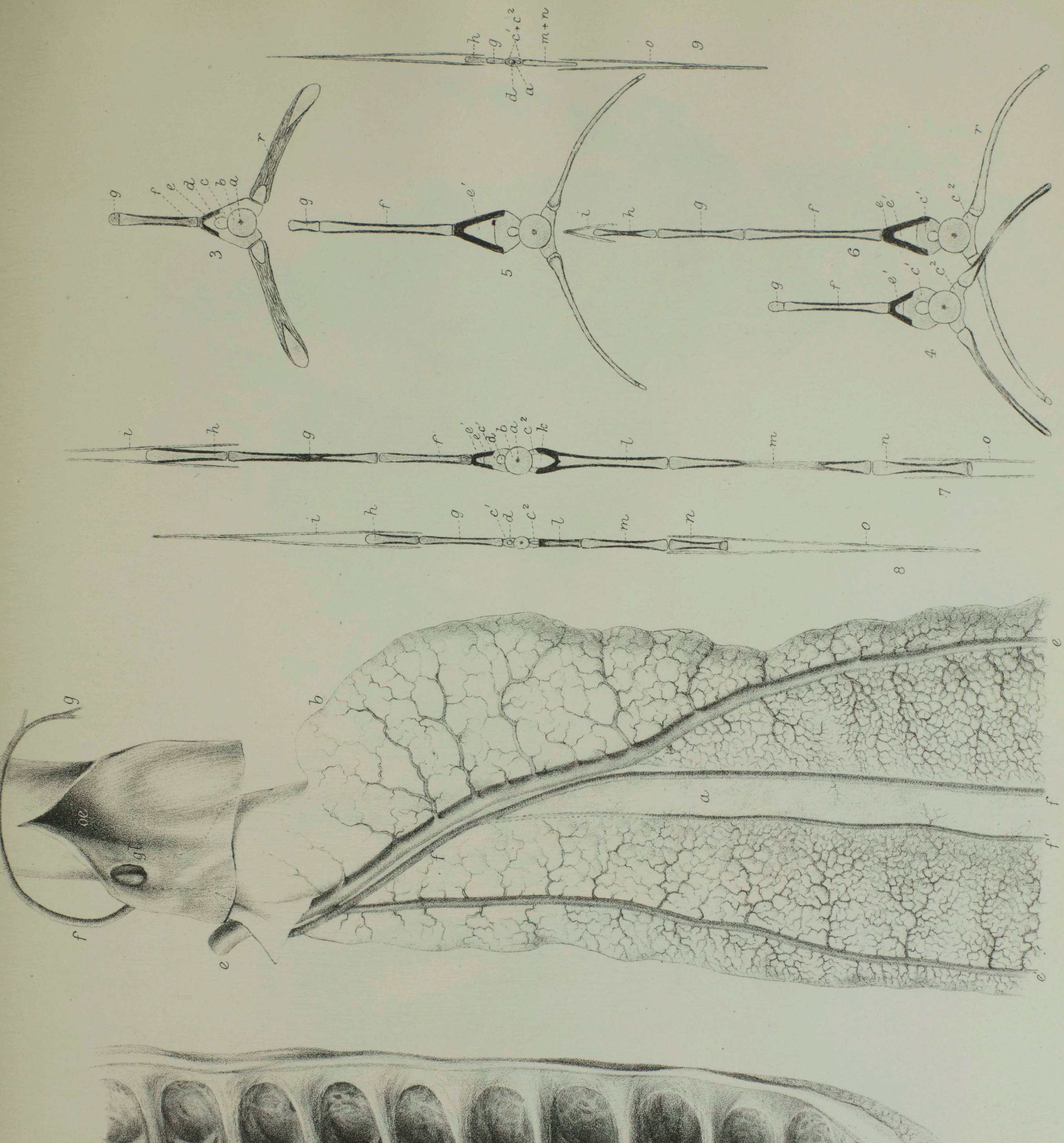
Mintern Bros. imp.

Günther



G.H. Ford

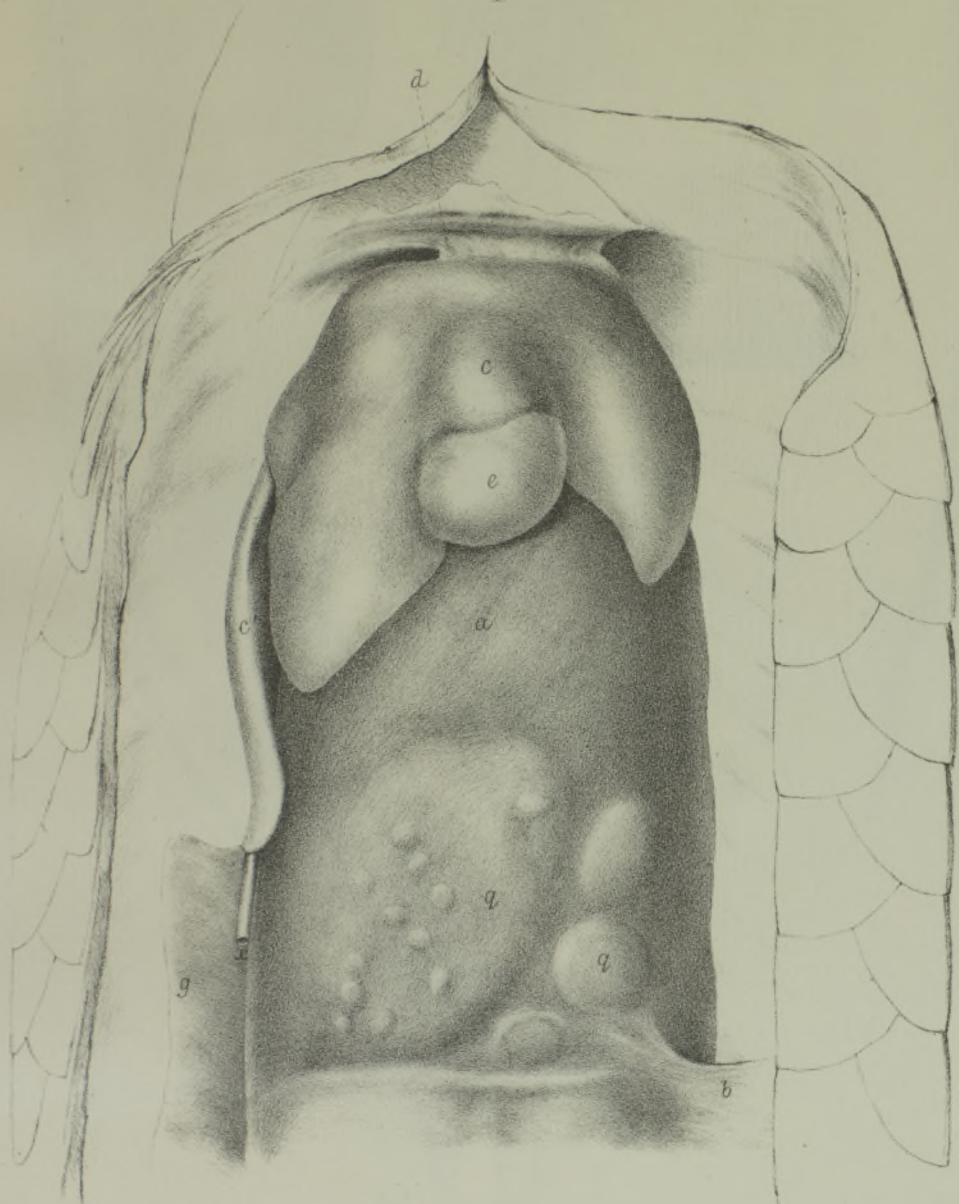
Mintern Bros. imp.



1 nat size

G.H. Ford. Mintern Bros. imp.

1



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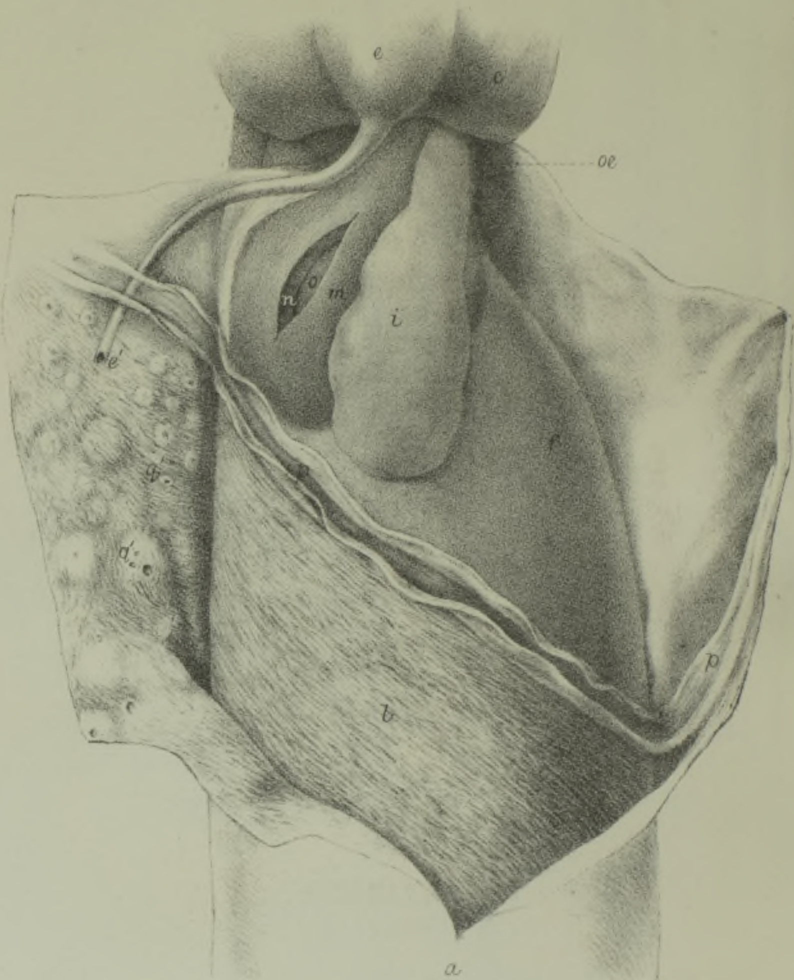
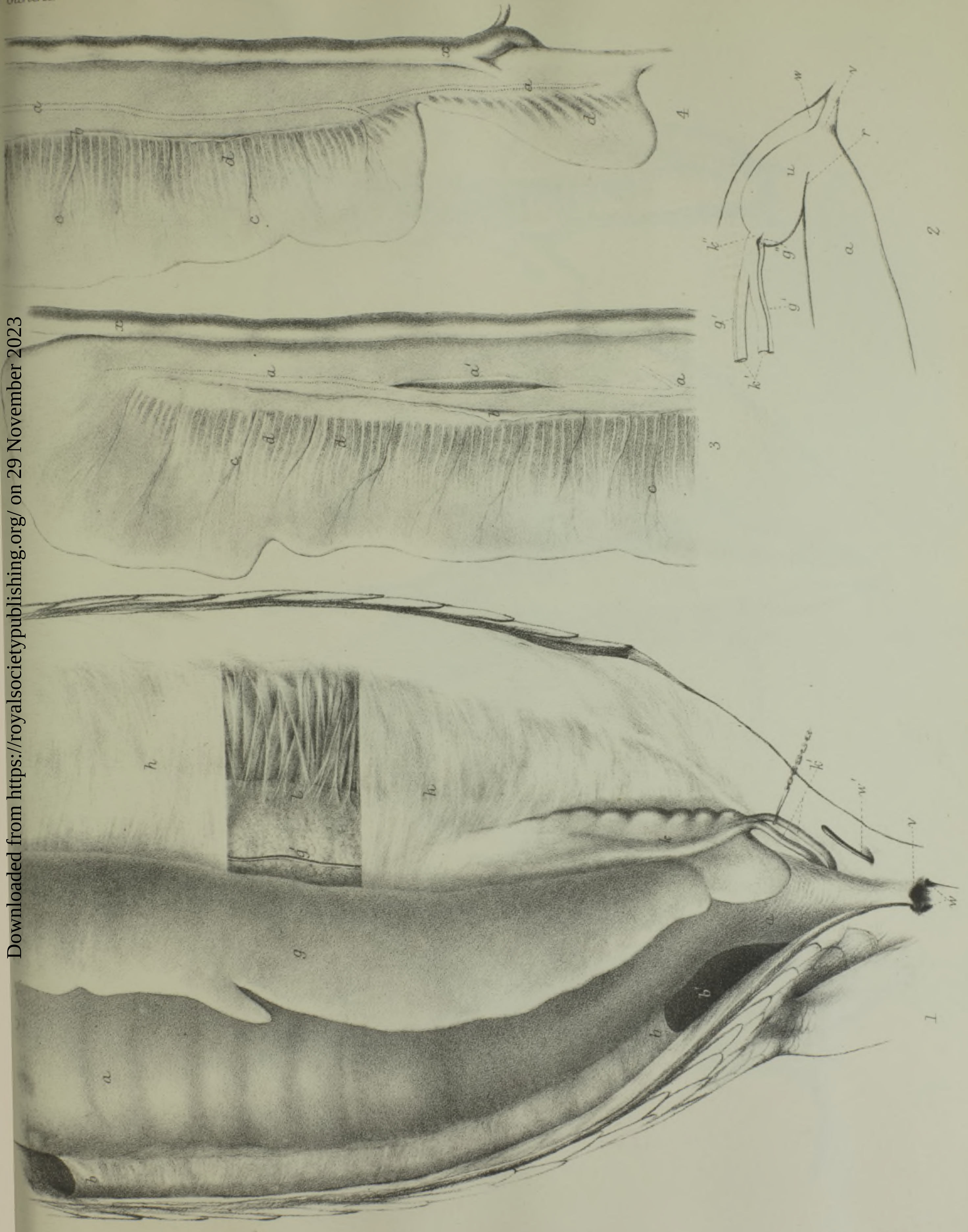


G.H. Ford.

¾ nat size

Mintern Bros. imp.

Günther

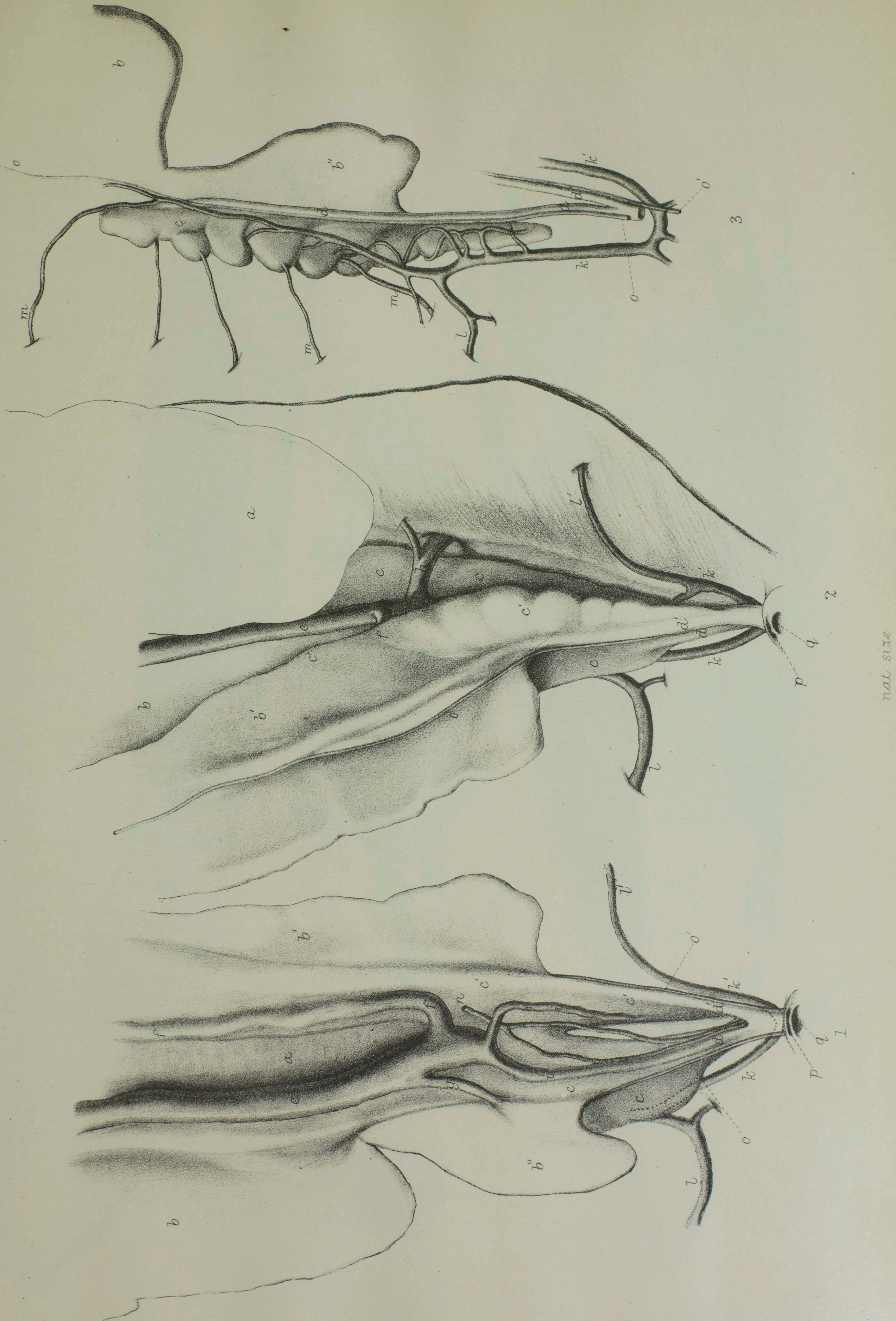


1 2 3 4

3/4 nat size

G.H. Ford

Mintern Bros imp.



G.H.Ford.

Mintern Bros. imp.

H. Ford

Mintern Bros. imp.