the size of the mandibular suspensorium; the basi-hyal is very large, is composed of two parallel pieces, and is very *Myxinoid*.

Brief and imperfect as this "Abstract" is, I trust it is sufficient to show the extremely interesting and suggestive nature of this type; anyhow, no clear understanding of the morphology of this type of skull can be had unless it be seen in the light derived from that of the Elasmobranchs, the Sturgeon, and the Anurous larva on one hand, and that of *Amia calva* and the Teleostei on the other.

III. "On the Structure and Development of *Lepidosteus*." By F. M. Balfour, LL.D., F.R.S., and W. N. Parker. Received November 24, 1881.

(Abstract.)

The authors commence this paper by thanking Professor Alexander Agassiz for the material, both embryological and adult, on which these researches were made.

The first section is devoted to the general development. In this section an account is given of the structure of the ripe ovum, of the segmentation, of the history of the germinal layers, of the first development of the principal organs, and of the external features of the embryo during embryonic and larval life. The more important points established in this section, are—

(1.) The ovum when laid is invested by a double covering formed of (*a*) a thick inner membrane, the outer zone of which is radially striated, and (*b*) an outer layer made up of highly refractive pyriform bodies which are probably metamorphosed follicular epithelial cells.

(2.) The segmentation is complete, though very unequal; the lower pole being very slightly divided into segments, and its constituent parts subsequently fusing together to form an unsegmented mass of yolk, like the yolk-mass of Teleostei.

(3.) The epiblast is divided into an epidermic and a nervous stratum, as in Teleostei.

(4.) The walls of the brain, of the spinal cord, and of the optic vesicles are formed from a solid medullary keel, like that found in Teleostei.

(5.) The lens, the auditory vesicle, and the olfactory pit, are wholly developed from the nervous layer of the epidermis.

(6.) The segmental or archinephric duct is developed, as in Teleostei, from a hollow ridge of the somatic mesoblast, which becomes constricted off, except in front; thus forming a duct with an anterior pore leading into the body cavity.

The section on the general development is followed by a series of sections on the adult anatomy and development of various organs.

The Brain.

The authors give a fuller description of the adult brain than previous anatomists. The new features in this description are (1) that the parts identified by previous anatomists as the olfactory lobes, are really parts of the cerebral hemispheres; the true olfactory lobes being small prominences at the base of the olfactory nerves; (2) that there is attached to the roof of the thalamencephalon a peculiar vesicle, which has not hitherto been noticed, but which is similar to the vesicle found by Wiedersheim on the roof of the thalamencephalon of Protopterus. They further show that the cerebrum is divided into a posterior portion, with an unpaired ventricle, and an anterior portion in which the ventricle is paired. They consider the presence of a portion of the cerebrum with an unpaired ventricle, to be an indication that this part of the brain retains characters which are only found in the embryonic brain of other groups. They point to the presence of lobi inferiores on the infundibulum, of tori semicirculares in the mid-brain, and of a large cerebellum as indications of an affinity between the brain of Lepidosteus and that of Teleostei. In the embryological section full details are given as to the development of the thalamencephalon, the pineal gland, the cerebrum, and the olfactory lobes.

At the end of the section the characters and affinities of the Ganoid brain are dealt with at some length; and the authors attempt to show that brains of Ganoids are distinguished (1) by the large size of the thalamencephalon, and (2) by the cerebrum being divided into an unpaired portion behind and a paired portion in front.

Organs of Special Sense.

Olfactory Sacs.—An account is given of the development of the olfactory sacs, in which these sacs are shown to originate as invaginations of the nervous layer of the epiblast; the communication between the sacs and the exterior being effected by the rupture or absorption of the superficial epidermic layer of the epiblast. The double opening of these sacs in the adult is described as arising from the division of the primitive single opening. The olfactory nerve arises as an outgrowth of the brain prior to the first differentiation of the olfactory bulb as a special lobe of the brain.

Eye.—In the adult eye a vascular membrane is described bounding the retinal aspect of the vitreous humour. This membrane is supplied by an artery piercing the retina close to the optic nerve, and the veins from it fall into a circular vessel placed at the insertion of the iris. The membrane itself is composed of a hyaline ground substance with numerous nuclei.

In the developmental section devoted to the eye the main subject dealt with is the nature of the mesoblastic structures entering the cavity of the optic cup, through the choroid slit. It is shown that a large non-vascular mesoblastic process first enters the optic cup, and that together with the folded edge of the choroid slit it forms a rudimentary and provisional *processus falciformis*. At a later period an artery, bound up in the same sheath as the optic nerve, enters the optic cup, and the vascular membrane found in the adult then becomes developed.

The Suctorial Disk.

The structure of a peculiar larval suctorial organ, placed at the end of the snout, is described, and the organ is shown to be formed of papillæ composed of elongated epidermic cells, which are probably glandular (modified mucous cells), and pour out a viscid secretion.

Muscular System.

The lateral muscles of Lepidosteus are shown to differ from those of other fishes, except the Cyclostomata, in *not* being divided into a dorso-lateral and ventro-lateral group, on each side of the body.

Vertebral Column and Ribs.

This section of the paper commences with a description of the vertebral column and ribs of the adult. In this part special attention is called to a series of cartilaginous elements, placed immediately below the ligamentum longitudinale superius, which appear to have escaped the notice of the anatomists who have previously worked at Lepidosteus. These elements are shown to be intervertebrally situated.

With reference to the ribs the authors point out that for the greater part of their length they course along the bases of the intermuscular septa, immediately external to the peritoneal membrane, but that their free extremities bend outwards and penetrate between the muscles along the intermuscular septa till they nearly reach the skin.

In the embryological part of this section a detailed account is given of the development of the vertebral column, of which the following is a summary:—

There is early formed round the notochord a mesoblastic investment which is produced into two dorsal and two ventral ridges, the former uniting above the spinal cord. Around the cuticular sheath of the notochord, an elastic membrane, the membrana elastica externa, is next developed. The neural ridges become enlarged at each intermuscular septum, and these enlargements soon become converted into cartilage, thus forming a series of neural processes, riding on the membrana elastica externa, and extending about two-thirds of the

way up the sides of the spinal cord. Hæmal processes arise simultaneously with and in the same manner as the neural: they are small in the trunk, but at the front end of the anal fin they suddenly enlarge and extend ventralwards. Behind this point each succeeding pair of hæmal processes becomes larger than the one in front, each process finally meeting its fellow below the caudal vein, thus forming a completely closed hæmal arch. These arches are, moreover, produced into long spines supporting the fin-rays of the caudal fin, which thus differs from the other unpaired fins in being supported by parts of the vertebral column, and not by separately formed skeletal elements.

In the next stage which the authors have had the opportunity of studying (a larva of $5\frac{1}{2}$ centims.), a series of well-marked *vertebral* constrictions are to be seen in the notochord. The sheath is now much thicker in the vertebral than in the intervertebral regions: this being due to a special differentiation of a superficial part of the sheath, which appears more granular than the remainder, and forms a cylinder in each vertebral region. Between it and the gelatinous tissue of the notochord there remains a thin unmodified portion of the sheath, which is continuous with the intervertebral parts of the sheath. The neural and hæmal arches which are of course placed in the vertebral regions are now continuous with a cartilaginous tube embracing the intervertebral regions of the notochord, and continuous from one vertebra to the next. A delicate layer of bone, developed in the perichondium, invests the cartilaginous neural arches, and this bone grows upwards so as to unite above with the osseous investment of separately developed bars of cartilage, which are directed obliquely backwards. These bars, or dorsal processes, may be reckoned as parts of the neural arches. Between the dorsal processes of the two sides are placed median rods of cartilage, which are developed separately from the true neural arches, and which constitute the median spinous elements of the adult. Immediately below these rods is placed the ligamentum longitudinale superius. There is now the commencement, not only in the tail, but also in the trunk, of a separation between the dorsal and ventral parts of the hæmal arches where the latter pass ventralwards, on each side of the body cavity, along the lines of insertion of the intermuscular septa. They are obviously the ribs of the adult, and there is no break of continuity of structure between the hæmal arches of the tail and the ribs. In the anterior part of the trunk, the ribs pass outwards along the intermuscular septa till they reach the epidermis. Thus the ribs are originally continuous with the hæmal processes. Behind the region of the ventral caudal fin the two hæmal processes merge into one, which is not perforated by a canal.

Each of the intervertebral rings of cartilage becomes eventually divided into two parts, which are converted into the adjacent faces

of contiguous vertebræ, the curved line where this will be effected being plainly marked out at a very early stage. As these rings are formed originally by the spreading of the cartilage from the primitive neural and hæmal processes, the intervertebral cartilages are clearly derived from the neural and hæmal arches. The intervertebral cartilages are thicker in the middle line than at their two ends.

In the latest stage examined (11 centims. long) the vertebral constrictions of the notochord are rendered much less conspicuous by the intervertebral cartilages giving rise to marked intervertebral constrictions. In the intervertebral regions the membrana elastica externa has become aborted at the posterior border of each vertebra, and the remaining part is considerably puckered transversely. The inner sheath of the notochord is puckered longitudinally in the intervertebral regions. The granular external layer of the sheath in the vertebral regions is less thick than in the last stage, and exhibits a faint radial striation.

Two closely approximated cartilaginous elements now form a keystone to each neural arch above; these are directly differentiated from the ligamentum longitudinale superius, into which they merge above. An osseous plate is formed on the outer side of each of these cartilages. These plates are continuous with the lateral osseous bars of the neural arches, and give rise to the osseous part of the roof of the spinal canal of the adult. Thus the greater part of the neural arches is formed by membrane bone.

The hæmal arches are invested by a thick layer of bone, and there is also a continuous osseous investment round the vertebral portions of the notochord. The intervertebral cartilages become penetrated by branched processes of bone.

The embryological part of this section is followed by a comparative part treated under three headings. In the first of these the vertebral column of Lepidosteus is compared with that of other forms; and it is pointed out that there are grave difficulties in the way of comparing the vertebræ of Lepidosteus with those of the Urodela, in the fact that in Lepidosteus the intervertebral cartilages originate from the bases of the arches, while in the Urodela they are stated by Götte to be thickenings of a special cartilaginous investment of the notochord, which would seem to be homologous with that cartilaginous sheath which is placed in Elasmobranchii and Dipnoi *within* the membrana elastica externa. On the other hand, the development of the vertebræ of Lepidosteus is shown to resemble in most features that of Teleostei, from which it mainly differs in the presence of intervertebral cartilaginous rings.

In the second section, devoted to the homologies of the ribs of Pisces, the conclusions arrived at are summed up as follows:—

The results of the authors' researches appear to leave two alterna-

tives as to the ribs of fishes. One of these, which may be called Götte's view, may be thus stated:—The hæmal arches are homologous throughout the Pisces; in Teleostei, Ganoidei, and Dipnoi the ribs, placed on the inner face of the body wall, are serially homologous with the ventral parts of the hæmal arches of the tail; in Elasmobranchii, on the other hand, the ribs are neither serially homologous with the hæmal arches of the tail, nor homologous with the ribs of Teleostei and Ganoidei, but are outgrowths of the hæmal processes into the space between the dorso-lateral and ventro-lateral muscles, and outgrowths which may perhaps have their homologies in Teleostei and Ganoids in certain accessory processes of the vertebræ.

The other view, which the authors are inclined to adopt, is as follows:—The Teleostei, Ganoidei, Dipnoi, and Elasmobranchii are provided with homologous hæmal arches, which are formed by the coalescence below the caudal vein of simple prolongations of the primitive hæmal processes of the embryo. The canal enclosed by the hæmal arches can be demonstrated embryologically to be the aborted body cavity.

In the region of the trunk the hæmal processes and their prolongations behave somewhat differently in the different types. In Ganoids and Dipnoi, in which the most primitive arrangement is probably retained, the ribs are attached to the hæmal processes, and are placed immediately without the peritoneal membrane, at the insertion of the intermuscular septa. These ribs are in many instances (Lepidosteus, Acipenser), and very probably in all, developed continuously with the hæmal processes, and become subsequently segmented from them. They are serially homologous with the ventral parts of the hæmal arches of the tail, which, like them, are in many instances (Ceratodus, Lepidosteus, Polypterus, and to some extent in Amia) segmented off from the basal parts of the hæmal arches.

In Teleostei the ribs have the same position and relations as those in Ganoids and Dipnoi, but their serial homology with the ventral parts of the hæmal processes of the tail is often (*e.g.*, the Salmon) obscured by the anterior hæmal arches (*i.e.*, those in the posterior part of the trunk) being completed, not by the ribs, but by independent outgrowths of the basal parts of the hæmal processes.

In Elasmobranchii a still further divergence from the primitive arrangement is present. The ribs appear to have passed outwards, along the intermuscular septa, into the muscles; and are placed between the dorso-lateral and ventro-lateral muscles (a change of position of the ribs of the same nature is observable in Lepidosteus). This change of position, combined probably with the secondary formation of a certain number of anterior hæmal arches, similar to those in the Salmon, renders their serial homology with the ventral parts of the hæmal processes of the tail far less clear than in other types; and further proof

is required before such homology can be considered as definitely established.

Under the third heading the skeletal elements supporting the fin-rays of the ventral lobe of the caudal fin of various types of fishes are compared and the following conclusions are arrived at.

(1.) The ventral lobe of the tail-fin of Pisces differs from the other unpaired fins in the fact that its fin-rays are directly supported by spinous processes of certain of the hæmal arches, instead of by indently developed interspinous bones.

(2.) The presence or absence in the tail-fin of fin-rays, supported by hæmal arches, may be used in deciding whether apparently diphycercal tail-fins are aborted or primitive.

Urogenital Organs.

With reference to the character of the adult urogenital organs, the authors show that for the female the descriptions of Müller and Hyrtl are substantially accurate, but that Hyrtl's description of the generative ducts of the male is wholly incorrect.

They find that in the male the semen is transported from the testes by means of a series (40—50) of vasa efferentia, supported by the mesorchium. In the neighbourhood of the kidney these vasa unite into a longitudinal canal, from which transverse trunks are given off, which become continuous with the uriniferous tubuli. The semen is thus transported through the kidney into the kidney-duct (segmental duct), and so to the exterior. No trace of a duct homologous with the oviduct of the female was found in the male.

With reference to the development of the excretory system, the authors have established the following points:—

(1.) That the segmental (archinephric) duct is developed as in Teleostei.

(2.) That a pronephros, resembling in the main that of Teleostei, is developed from the anterior end of the segmental duct. But they find that the pronephric chambers, each containing a glomerulus, into which the coiled pronephric tubes open, are not, as in Teleostei, completely shut off from the body cavity, but remain in communication with it by two richly ciliated canals, one on each side of the body.

(3.) The pronephros eventually undergoes atrophy.

(4.) Some of the mesonephric tubes have peritoneal funnels in the larva.

(5.) The ovarian sac continuous with the oviduct, is established by a fold of the peritoneal membrane, near the attachment of the mesovarium, uniting with the free edge of the ovarian ridge to form a canal, the inner wall of which is constituted by the ovarian ridge itself.

(6.) The posterior part of the oviduct is not formed until the ovarian sac has become developed, and had not been developed in the oldest larva (11 centims.) the authors have succeeded in obtaining.

The Alimentary Canal and its Appendages.

In this section the authors give a detailed account of the topographical anatomy of the alimentary tract in the adult. They have detected a small pancreas close to the bile-duct, and call special attention to a ventral mesentery passing from the posterior straight section of the intestine to the ventral wall of the body.

In the embryological part of the section a detailed account is given of the development (1) of the pancreas, which is described as arising as a dorsal diverticulum of the duodenum on a level with the opening of the bile-duct; (2) of the yolk sac and vitelline duct; (3) of the spiral valve, which first appears as a hollow fold in the wall of the intestine, taking a slightly spiral course, and eventually becoming converted into a simple spiral ridge.

The so-called hyoid gill, which the authors expected to find well developed in the larva, is shown not to be found even in the oldest larva the head of which was examined (26 millims.)

The last section of the paper is devoted to the consideration of the systematic position of Lepidosteus. The Teleostean affinities of Lepidosteus are brought into prominence, but it is shown that Lepidosteus is nevertheless a true Ganoid.

The arguments used in this portion of the paper do not admit of being summarised.

IV. "On a New Mineral found in the Island of Cyprus." By Paulus F. Reinsch (Erlangen). Communicated by Professor Stokes, Sec. R.S. Received November 3, 1881.

In the western part of the Island of Cyprus I detected, during my journey in June this year, a peculiar mineral, very remarkable not only from its chemical composition but also from the large percentage of extremely well-preserved siliceous shells of microscopic Radiolaria. The locality in this not much known part of Cyprus,* is situated between the village Chynussa and the mountains running in a north-

* In the fine map of Kiepert (Berlin, 1878) this part of the island, in which the locality lies, is marked as "wooded hill country, unexplored." In all the reports of travellers through Cyprus before and after the British occupation I find no notice of this tract, which must have attracted the attention of passing travellers.