No. 2. — *On the Lateral Canal System of the Selachia and Holocephala.* By Samuel Garman.

Soon after his return from the Hassler Expedition, in 1872, Professor L. Agassiz placed before me, his pupil at the time, a specimen of one of the Batoidei, with the remark, "See what you can find out about it." A preparation of the lateral line system was one of the results. This was followed, under Professor Agassiz's directions, by other preparations of the same system, which, one after another, were handed over to the artist of the Museum to be figured. The work was continued thus for more than a year, without my knowledge of the fact that Dr. B. G. Wilder had previously been engaged on similar work while assistant of Professor Agassiz. And it was not until about 1883 that the Director of the Museum desired me to prepare for publication my own material, and that accumulated under Professor Agassiz's directions. It was found that, in order to use the manuscript left by Dr. Wilder, many changes would be necessary, and it was thought better on the whole not to attempt to incorporate it with my own. Dr. Wilder's dissections have been used as far as possible in the descriptions. They were figured by Mr. Roetter, and included a representative of each of the following genera: Scoliodon, Prionodon, Mustelus, Triacis, Isurus, Odontaspis, Alopias, Ginglymostoma, Scylliorhinus, Heterodontus, Acanthias, Rhina, Pristiophorus, Pristis, Raia (*R. lævis*), Dasybatus (*D. tuberculatus*), Pteroplatea (*P. valenciennii*), Myliobatis (*M. freminvillei* and *M. aquila*), Aëtobatus, and Rhinoptera (*R. brasiliensis* and *R. jussieui*). In addition to these there were preparations of several types of which no use has been made, as they had been duplicated in my own work. Chimæra and Callorhynchus required no dissection; a drawing of the latter had been made by Mr. Roetter. The figures by this artist were made to be lithographed, and were not at all suited to the engraver's process, by which this publication was to be illustrated. Consequently outlines have been used instead of his drawings.

This leaves me responsible for all the text, and for the dissections and sketches of Dicerobatus, Pteroplatea (*P. hirundo* and *P. marmorata*), Dasybatus (*D. nudus* and *D. dipterurus*), Tæniura, Urolophus, Discens,

Potamotrygon, Narcine, Torpedo (*T. californica* and *T. marmorata*), Raia (*R. ocellata*), Uraptera, Syrrhina, Rhinobatus, Somniosus, Chlamydoselachus, Heptabranchias, and Cestracion (Zygæna); also for sketches of Chimæra, Callorhynchus, and Pristiophorus; and for the outlines and sketches of such as had been drawn by Mr. Roetter.

With a few exceptions the names of the canals are those adopted by Professor Agassiz.

The structures to which attention is here directed are those on the Selachia and Holocephala, which correspond to the lateral lines of the Fishes. On the individual they form a system of branching canals, or tubes, tubules, and branchlets, which has received a variety of names at the hands of different writers: slime canal, mucous tube, water canal, lateral line, etc. To avoid confusing with the unbranched hyaline mucous ducts of the ampullæ of Lorenzini, the term canal will in this paper be applied exclusively to the organs comprised in the system under discussion. The manner in which the tubes branch and connect, and the fact that they are sometimes represented by mere furrows in the skin, make this designation the more appropriate. In addition, since it has been pretty well established that their function is that of very delicate tactile organs, receiving and carrying the slighter vibrations of the water, noting changes of density, currents, etc., a special name, Tremognosters, to be applied to these particular canals, distinguishing them from the many other canals of the body, is introduced as likely to prove still more convenient.

These canals, or tubes, lie in or under the skin on both body and head. They open externally either as furrows or by means of pores, that in some cases enter the tubes directly and in others are approached by tubules. The inner layers of their walls are furnished with series of nerve-endings, which, as also the external openings of tubular canals, are segmentally arranged. In different parts, the structure of the walls varies from fibro-cartilaginous, on the top and sides of the skull, to very delicate transparent tissue, under the snout. Granulation, apparently resulting from calcification, occurs in the cephalic tubes of certain genera. There are no glandular attachments; the vessels are simply canals, open at each end, and more or less so along their sides. On the head they are innervated mainly from the fifth pair, and on the body by a branch of the vagus, the nervus lateralis.

The development of the system, as worked out by Balfour in Scyllium, coincides closely with that of the Teleostei. According to Beard the lateral line in the embryo salmon first appears opposite the hyoid arch,

a little behind the ear capsule, on the level of the notochord; and it is formed by the splitting off of some of the cells of the inner layer of the epiblast. From its point of origin, where it is broadest, it grows backwards along the body. This cord of cells, as Beard calls it, is no doubt what Balfour describes, in Scyllium, as a linear thickening of the mucous layer of the epidermis, or as a linear streak of modified epidermis. This linear sense streak is in Balfour's opinion the primitive structure from which the various forms of the line have originated. He says, further, that the thickened streak becomes a canal in Scyllium, not by the folding over of the sides, as in Teleostei, but by the formation of a cavity between the epidermic and the mucous layers of the epiblast, and the subsequent enclosure of this cavity by the modified cells of the mucous layer of the epiblast constituting the lateral line. The cavity appeared first at the hinder end of the organ, and thence extended forwards. After formation the canal gradually recedes from the surface, retaining its connection, however, at a series of points corresponding to the segments, points at which the segmental openings are afterward formed. As compared with the open canal on Chimæra, the tubular canal is a secondary form. In regard to the innervation on the trunk by the lateral branch of the vagus, the nerve was found to originate as the other nerves, and, pushing its way backward, to follow the course of the lateral line. Originally the line is supposed to have been restricted to the anterior part of the body, and thence, extending farther and farther backward, it carried with it the lateral branch of the vagus, until ultimately the latter was prolonged far beyond the position it originally occupied. Beard says of this nerve, in Salmo, that it originates far from the epiblast and growing backward approaches the skin so as to lie between the two muscle plates just below the epiblast, never fusing with the lateral line, but always separated from it by the cuticular basement membrane of the epidermis.

Balfour found the canals of the head and the ducts of the ampullæ to be formed from the mucous layer of the epidermis, very much as the lateral line; but their innervation is effected by simple branches of the fifth and seventh pairs, which reach them in various places without following their courses, unlike the nervus lateralis and the lateral line.

Primarily the openings at the ends and along the sides of the tubes appear to have been in close relationship with the segments of the body, both in regard to position and number. The relations are still apparent in the numbers and in the positions of the tubules at their points of

junction with the main tubes. But in many species, through the descent of the canals below the skin, the consequent elongation of the tubules, and the multitudes of branchlets by which they communicate with the surface, the primary arrangement has come to be greatly obscured. Alopias illustrates this to some extent in the Galei; and in the Batoidei instances are numerous in the Trygonidæ, the Myliobatidæ, the Zygobatidæ, and the Ceratopteridæ.

The tubes contain a thin mucilaginous liquid. This is probably for the most part an excretion, and not an absolute necessity in connection with the function of the system, except, it may be, in so far as it serves the purpose of lubrication. Its retention is hardly possible in the open grooves of various genera, on which the office of the organs is undoubtedly the same. In discussing the purpose of the liquid, one must bear in mind those Teleosts in which the sense bulbs open directly on the epiderm, without either groove or tube, and the likelihood that they represent the primitive condition of the system from which the furrows and the tubular canals have been developed.

Absence of the mucous secretion on the skin of species well provided with canals precludes consideration of the opinion that the object of the latter is to cover the surface with slime.

Series of the follicles in immediate connection with the subrostral canals of certain species lead to the conclusion that the nerve follicles of Savi are really obsolescent tubes of the canal system, in which the section that forms the enclosure or follicle owes its persistence to the presence of the contained nerve. In other words, the follicles represent vanishing and rudimentary tubes. From this it would seem as if Potamotrygon, Disceus, and Urolophus, among others, may be on the way to lose the canals of their ventral surfaces, as has already happened in the cases of Torpedo and Narcine.

The hyaline mucous ducts of the ampullæ are unbranched, have but a single aperture, are closed at the inner end, where entered by the nerve, and are filled by a jelly-like mucous. Plate XXVIII. fig. 1, represents a portion of those of *Raia lævis*, and their distribution as compared with that of the principal canals, fig. 2.

GALEI.

On the Sharks the canal system consists of a vessel on each side of the vertebral axis, extending from the snout to the tail, connected with a similar vessel on the opposite side by a transverse branch near the

occiput, and sending another branch between the eye and the spiracle toward the mouth. Between the lip and the eye, on the lower aspect, the latter branch sends another backward past the angle of the mouth, and, farther on its way forward, sends still another behind each nostril, itself usually joining the main canal at the end of the snout. Commonly a branch from that passing the angle of the jaws extends under the jaw, behind the mouth, toward the middle of the chin; in some cases this branch is disconnected; in others it does not appear; occasionally it is continuous across the symphysis. The branch behind the nostril passes toward a similar one from the opposite side of the head, either uniting with it or approaching it closely for a short distance under the base of the rostral cartilage, after which the two diverge slightly and continue forward to the end of the rostrum. On the top of the skull the tubes are more or less strongly attached to the cartilage, in troughs or depressions in which they are often deeply seated. Under the base of the rostrum there is also a firm attachment to the cartilage. Elsewhere the canals lie at varying depths in the skin or below it. Generally they are tubes with openings to the surface through simple to many-branched tubules. On species of Heptabranchias and on Chlamydoselachus they appear, in great part of their extent, as open dermal grooves. On one of the genera of the Holocephala they are open furrows, on the other they are tubes.

NAMES OF THE CANALS.

Plate I.

The most convenient designations for the different canals, or parts of canals, are those derived from the names of the portions of the body traversed by them, or from those of the organs near which they pass. The propriety of the names *cephalic* for all the canals of the head, and *corporal* for all those of the body, is at once apparent. Their position along the flanks makes the name *laterals* (*l*), by which they are generally known, a very appropriate one for the two main corporals. In the Batoidei there is a canal peculiar to them extending out upon the pectoral fin; this may be called the *pleural* (*p*). On the lower surface it becomes a *subpleural*. The areas enclosed by the pleural tubes are the pleural areas; those sometimes enclosed by scapular tubules on the shoulder are called the scapular areas.

Running longitudinally on the top of the head are the two principal cephalic tubes, the *cranials* (*cr*); anteriorly, on the rostrum they be-

come the *rostrals* (*r*), and after passing below the snout they are known as *subrostrals* (*sr*). At the end of each cranial, on the crown of the head, an *orbital* (*orb*) canal runs outward behind the orbit; below the eye, and below the disk in the flat-bodied Selachians, they become the *suborbitals* (*so*). A transverse tube from one lateral to the other, close to the external openings of the aqueducts, ear openings as commonly named, is the *aural* (*au*). A short *occipital* (*oc*) reaches from the aural to the orbital; or, in other words, from the lateral to the cranial.

On the ventral surface the canal passing lengthwise near each angle of the mouth is the *angular* (*ang*). The portion to which this name is applied is not a long one; farther back on the same tube, the name is supplanted by that of *jugular* (*j*). In some cases these canals are definitely limited by a branch, the *oral* (*o*), putting out transversely behind the mouth; but very often the oral is found to have lost its connection with the other tubes. Rarely the oral is continuous across the symphysis. In front the angular meets either the suborbital or a canal, the *nasal* (*n*), extending behind the nostril, between the latter and the mouth; sometimes the one is met, sometimes the other; whichever it may be, it marks the anterior limit of the angular. The two nasals meet in front of the middle of the mouth, in most cases, and, uniting, form a short *median* (*m*), from which two other tubes, the *prenasals* (*pn*), diverge and run forward to the end of the snout. On a few forms the nasals do not meet. In some instances there is a junction of subrostral and nasal; in others, the subrostral joins the suborbital; in one species the angular and the nasal join, in another it is the angular and the suborbital; but however the junctions may be arranged, a tube of less or more extent lies between the end of the orbital and that of the nasal. Its position is indicated in its name, *orbito-nasal* (*on*).

BATOIDEI.

If one of the round-bodied sharks were to be greatly depressed and flattened, extension taking place on both dorsal and ventral surfaces, the pectoral fin at the same time being expanded and applied to the side of the trunk, the arrangement of the main tubes of the system would be similar to that obtaining on the Batoidei. The subrostral, nasal, prenasal, angular, jugular, and suborbital would appear on the lower surface, as in the Skates and Rays. An important addition to what has been recorded in the Galei occurs in the Batoidei: a *pleural* canal (*pl*), which meets the lateral at the shoulder, runs outward on the pecto-

ral fin, then forward, descending near the head, and, after a backward course of varying extent on the lower surface, unites with the jugular. Or, reversing the direction and starting below, from the jugular, the canal goes out and forward under the pectoral, ascends at the side of the head, then turns out and backward, describing a circuit toward the margins on the top of the fin, and unites with the lateral at the shoulder. Most frequently it is the case that the pleural and the orbital are connected by orbito-pleural tubules; exceptionally these tubes meet directly without the intervention of the tubule. No doubt the pleural originated as a branch of the orbital. Besides this pleural canal on the pectoral, there are usually present several others, post-pleurals, from the scapular curve of the lateral toward the hinder part of the fin, which also are not represented in the Galei. Ordinarily the upper pleurals are abundantly supplied with tubules; sometimes on the lower surface tubules are entirely absent; and on the Torpedoes the ventral portion of the entire system is obsolete. Branches of tubules are generally in pairs; a tubule forks to form a pair; each of this pair forms another pair in similar manner, and so on. This dichotomous branching of the branchlets may be kept up, as in the higher Rays, until on reaching the outer layers of the skin a considerable space is occupied by the mat or rosette formed of the very small tubes and their pore-like openings on each of the tubules. Among the Torpedoes and the Skates the simple unbranched tubule is the common form.

The origin of the pleurals of the Batoids, or the manner in which the group became possessed of these canals, in addition to those possessed by the Galei generally, is a question of considerable interest. Our only clue to the solution of the problem is to be seen in Chlamydoselachus. If the head and body of this shark were depressed, and the pectorals expanded and applied, so as to produce the skate-like form, the spiracular canal would then extend back along the basal cartilages of these fins, they being attached above the gill openings, thus forming the pleural canal, the union of which with the scapular branch of the lateral is only a secondary matter, as shown by the variety in modes of junction, in the Rhinobatidæ, the Raiidæ, and such genera of Trygonidæ as Urolophus and allies. On the lower surface the subpleurals would be supplied by the gular and the canal lying between it and the lip, the oral being limited to the part anterior to their point of meeting. The fact that the additional canals would be acquired in this way, as a necessary consequence of the change of the form, leads, at the least, to a strong presumption that the Batoidei are indebted for their

pleurals and subpleurals to a Galeoid ancestor resembling Chlamydoselachus as far as the possession of spiracular and gular canals is concerned, if not further. And indirectly the tendency of such considerations is to confirm the claim elsewhere advanced that that genus is in great measure to be regarded as a persistent type.

HOLOCEPHALA.

The great differences between Chimæra and Callorhynchus in regard to rostral appendages and claspers, are in reality no greater than those obtaining in their canal systems. Greater divergence than occurs in these genera is not to be seen in the most dissimilar forms of the Sharks. On Chimæra the canals are furrows, as on the body of Chlamydoselachus, and the oral meets the angular; on Callorhynchus the canals are tubes, and angular, oral, and jugular meet the suborbital independently. At the first glance, the differences in the distribution of the cephalic canals in the two genera appear greater than they really are. On comparison, the positions of laterals, aural, occipitals, cranials, and orbitals are found to be similar. In both cases the oral and the jugular cross the median line as series of pores or short grooves, the suborbital extends to the end of the snout, the subrostrals unite under the rostrum to form a median, then separate to meet the nasals, and the nasals are in front of the nostrils, meeting across the middle without forming a median canal or prenasals. It may be added, that in both types the lateral descends, above the lower lobe of the caudal fin, to the lower edge of the muscles, as in certain of the lower Galei.

Affinities with the Sharks, through ancestry, are indicated by the correspondence in laterals, aurals, cranials, orbitals, angulars, and orals. Special points of disagreement are seen in the union of the jugulars, the prenarial location of the nasals, the absence of prenasals, the presence of a median in the subrostrals, and in the connections of the occipitals.

COMPARISONS.

Whether the canal system is a suitable basis for homology and classification, either alone or in connection with other parts of the anatomy, and its importance as such a basis, are to be determined by consideration of the extent of its development and the amount of its variability in the different types included in the class. An exhaustive investigation of the subject would naturally demand a study of the

system in its relations to the general structure and to the habits of the species, and, through the latter, to the surroundings and to their influence upon its evolution and variation. Direct opportunity for much of this is not within reach; but from the material at hand it may be possible to make approximations that at least will be tolerable.

Possession of the organ is quite general; no exception has yet been discovered either in the Selachia or in the Holocephala. A stage of development of the system that is comparatively simple exists on those forms usually called the lower, and on the course from them to the highest the amount of complexity is found to correspond well with the rank as indicated by the brain or other parts of the organization. Between Heptabranchias and Alopias of the Galei, and between Pristis and Dicerobatus of the Batoidei, each step is marked by variation in contour and in the extent and complication of the system of the canals. In the Holocephala a blow is apparently given to the idea that the groove is the lowest, the primitive form of canal, by the fact that Callorhynchus possesses tubes and not furrows like those of Chimæra. This may be no more than an indication that the former is the most differentiated type, the higher in rank. Bony Fishes, also, possess tubes. The fact remains that it is among the lower forms of the Sharks and in Chimæra that the grooves obtain. Furrows are unknown in the canals of the Batoidei; and it is in this order that the greatest degree of development is attained by the system. Dichotomization of the tubules appears in the higher, and becomes excessive in the highest, forms of either order. Types known to be sluggish in their habits are less abundantly supplied with tubules, and the system is not so complex as on the more active. It needs but a contrast of the Raiidæ and the Myliobatidæ to make this obvious. Forms which have changed their habits and become more addicted to resting on the bottom give evidence of the fact in the gradual deterioration and disruption of certain canals on the under portions of the body. That the canals are rather less subject to variation, that is, that they respond less quickly to its causes, than certain other organs, is intimated by the results of a comparison of the species of a single genus. Close genetic relationship is asserted by the canals of such species as *Dasybatus walga* and *D. nudus*, or by *Uraptera agassizii* and *Raia lævis*. Young specimens, or embryos, often serve better as guides to descent and affinity than old ones, since canals are present on the former which in some instances can hardly be found on the older ones. In the embryo the canal system takes on its generic

and specific peculiarities long before the characteristics of the outer skin are acquired, even before the shapes of body and fins, and the peculiar dentition, or the other features commonly relied upon to separate the forms and groups, have become available. Consequently, the various embryos may be recognized by means of the canals at periods when identification by the specific and generic characters ordinarily employed for the purpose of distinguishing them would be quite out of the question.

Dichotomized tubules do not appear to any great extent on the lower surfaces of such as habitually lie on the bottom. The tubules which occur on the ventral canals of such species most often have their external apertures at the border of the disk. On the Torpedinidæ it is altogether likely that disuse has led to the loss of the entire ventral portion of the system. Types addicted to flights through the water at a distance from the bottom have the tubules and their branchlets more alike on the upper and lower surfaces, as may be seen in such as the Zygobatidæ and the Dicerobatidæ. These and similar Rays have a greater aggregation of the tubules and branchlets toward the hinder portion of the disk, a distribution which suggests liability to danger from behind, possibly while the creatures are feeding. The modifications in position and outline which the cephalic canals have undergone on these families, through changes in shape of head, snout, and pectoral fins, and through change in the position of the mouth, become very prominent when directly contrasted with the same canals on such as the Trygonidæ or the Raiidæ.

The extent to which the canals may be used in classification is best illustrated by comparing the systems on the various species or groups. Necessarily the comparisons instituted below have been made very much as if the genera were composed of the species under examination. Further investigation of other species will, no doubt, bring to light differences in matter of detail, serviceable in specific diagnoses, and possibly such as may compel modification of our ideas of the generic characters; but the attempt has been made here to use only such features as are least liable to the minor variations. As the vessels have not yet been studied on one sixth of the whole number of species in the class, and as those on which the system has been worked out do not include representatives of all of the genera, it follows that a synopsis constructed on the material here gathered could only be a temporary affair. For this reason a short summary of differences is to be preferred to a synopsis giving only a few of the more prominent ones.

A connection of the cranials, instead of the laterals, by the aural, and the passage of the jugulars across the chest, at once separate the Holocephala from both the Galei and the Batoidei. The Batoidei are separated from the Galei by the possession of the pleural canals.

Chimæra, in the Holocephala, is marked by the grooves, instead of tubes, and Callorhynchus by the tubes, instead of grooves.

Among the Galei, on the base of the tail the lateral canals descend to the lower edge of the muscles in Chlamydoselachus, Heptabranchias, Heterodontus, Pristiophorus, Acanthias, and Somniosus, as in the Holocephala. Open corporal canals resembling those of Chimæra appear on Chlamydoselachus, *Heptabranchias maculatus*, and, in part, on Acanthias. On other genera the laterals maintain their position near the vertebræ of the tail, and the canals are tubular. On Scoliodon, Mustelus, and the Hammerheads the lateral makes a decided bend below the second dorsal fin; and it ends at or near the end of the vertebral column in Scoliodon, Triacis, Mustelus, Odontaspis, Scylliorhinus, Chlamydoselachus, Ginglymostoma, Cestracion, and Somniosus, not reaching so far back in others. Disregarding the course of the column in Isurus, it passes directly backward, ending at the edge of the muscles just above the lower lobe of the caudal fin.

The aural is behind the "ear openings," and more or less curved back in the majority of the Sharks; it is in front of the openings in Chlamydoselachus, bisected in Heptabranchias, curved forward in the middle in Acanthias and Chlamydoselachus, and nearly straight in Mustelus, Scylliorhinus, Heterodontus, and Somniosus. Sometimes, as in Pristiophorus, it is deeply curved backward, much as in the Holocephala, or in Dicerobatus.

The occipitals appear like continuations of the laterals, so slight is their change in direction, in Acanthias, Rhina, Heptabranchias, and Chlamydoselachus; others have the tubes directed more or less obliquely outward.

Somniosus is peculiar in that cranials, orbitals, and occipitals do not meet on the crown.

On the frontal region the cranial curves are shallow in Prionodon, Alopias, Isurus, Heterodontus, Acanthias, Somniosus, and Pristiophorus; decided in Scylliorhinus, Mustelus, Triacis, Ginglymostoma, and Rhina; more decided in Chlamydoselachus and Scoliodon; and excessive in Cestracion (Zygæna).

A majority have the orbital bent forward in its lower portion; in Cestracion, Heptabranchias, and Chlamydoselachus it bends backward.

In the suborbital, Scoliodon and Prionodon have a curve that reaches upward in front of the orbit. This curve goes farther forward than the eye in the greater number of the Sharks; it lies under the orbit in Isurus, Alopias, Cestracion, and Acanthias; it is absent in Heptabranchias, Somniosus, and Chlamydoselachus; and it goes forward of the nostril in Ginglymostoma.

Between the nostril and the median, in much the greater number of cases, the nasal canal is bent forward; this bend is either absent or faint in Isurus, Odontaspis, Alopias, Heptabranchias, Chlamydoselachus, Scylliorhinus, and Ginglymostoma. On Isurus the nasals meet the angulars; on others, as on certain Batoids, they meet the subrostrals.

A union of the nasals in front of the mouth on most of the sharks forms the median; no such union takes place on Acanthias, Heptabranchias, Chlamydoselachus, or Pristiophorus.

No connection between prenasals and rostrals appears in Heptabranchias and Somniosus.

Most often the jugular is directed toward the middle of the first branchial aperture; Alopias differs in having this tube pass below the gill opening.

The oral is continuous behind the mouth in Ginglymostoma; it does not meet the angular in Scoliodon, Prionodon, Triacis, Mustelus, Scylliorhinus, Acanthias, and Rhina; and it was not found in Heptabranchias, Somniosus, and Pristiophorus.

A general characteristic of the Batoids is seen in the pleural canals. At once on passing from the Pristiophoridæ of the Sharks to the Pristidæ of the Skates these tubes become prominent features.

The Pristidæ are affected by an excessive elongation of the rostrals and prenasals. Their pleurals are comparatively short, extending but little on the pectorals. The scapular branches are few, but one, a post-pleural, being present in the species sketched.

On the Rhinobatidæ post-pleural branches are more numerous. In general there is considerable resemblance between this family and the preceding. The anterior cephalic canals are shorter, and there is a sternal canal below the coraco-scapular arch.

All the Raiidæ are marked by greater extension of the upper pleurals on the pectorals. A strong branch extending back on the middle of these fins is apparently common. The prominent narrow fold in the subrostral varies in the different species: in Uraptera the fold has been so much narrowed as to bring its sides together. On the ventral surface of *Raia ocellata* the pleurals are obsolete.

The Torpedinidæ have lost the canals of the lower surface. Remnants of the missing vessels are found in the follicles of Savi, present on some. The pleurals and the orbitals unite directly, without the intervention of tubules. In Narcine the entire extent of the system is much less than in Torpedo, owing to the reduction in number and length of the tubules. Yet in these respects there is not a little variation in the species of Torpedo, as is seen by comparison of *T. californica* and *T. marmorata*.

In the Trygonidæ, as, further along, in the Myliobatidæ and their allies, we see a disposition to enlarge the system by means of curves, tubules, and dichotomous branchings much beyond what has been noticed in the Skates. Through the increase in length of the main tubes the courses of orbitals and suborbitals have come to be crossed by the pleurals on both upper and lower surfaces. The presence of a small enclosure, or more than one, on each shoulder, formed by scapular branches, pre-pleural or post-pleural, or both, is somewhat general in this section of the Batoids.

Potamotrygones as well as Thalassotrygones have the tubules of the pleurals on the lower surface massed anteriorly, comparatively few appearing under the posterior half of the disk. An obsolescent condition of the subrostrals obtains in Disceus and Potamotrygon; where parallel with the prenasals these tubes are merely lines of follicles, without apparent connection by their cavities, marking the paths of the canals. On the lower portion of the pleural of Potamotrygon there are rather few tubules; the sections of the oral are elongate and sinuous; the nasal meets the angular, and apparently there is a short sternal canal. On Disceus the tubules are very numerous on the lower pleurals, the parts of the oral are short and separated by some distance, the nasal and the subrostral meet, and there is an orbito-pleural plexus containing a large number of small areas. Differences similar in character, but less pronounced, exist on the upper surfaces of these genera.

Urolophus has no orbito-pleural plexus on the lower surface, its pleural tubules are not massed in front, and the suborbital is not provided with a long loop pointing forward as in Potamotrygon. It has a short sternal tube.

Tæniura resembles Urolophus more than it does the Potamotrygons. Like the former it has the pleural tubules distributed along the tube, and it has neither orbito-pleural plexus nor suborbital loop. It differs from Urolophus in the multitude of its branchlets on the upper aspect, in its pleural areas, and in the union of subrostral and nasal.

Dasybatus has a considerable part of the anterior portion of the lower pleural close to and parallel with the anterior edge of the pectoral. Along this section the tubules are numerous. Backward they are distributed sparingly, if present. The features possessed in common by the various species are best seen on the dorsal surface, since the tendency toward variation has been much more active beneath the disk. The suborbital alone is sufficiently different to distinguish the three species figured: in *D. nudus* it is excessively elongate, it encloses a peculiar series of spaces, and twice, in a couple of long reaches, it comes abruptly to an end; in *D. dipterurus* it is rather short and somewhat sinuous; and in *D. tuberculatus* it is greatly lengthened by a complex series of zigzag folds or convolutions.

Pteroplatea differs greatly from the other genera in the distribution of tubes and tubules on the dorsal surface. They are arranged to reach the margins around the entire pectoral, and, though numerous posteriorly, the branchlets are matted in multitudes in front. On *P. valenciennii* the tubules are most plentiful, on *P. marmorata* less abundant, and on *P. hirundo* still more scattered. These species differ in the branchings and areas on the scapular region, as also in the general arrangement and abundance.

The Myliobatidæ, through narrowing the pectorals at the side of the head, have had pleurals, orbitals, and rostrals brought close together under the orbit. Those types which have the fins most reduced, or absent, in this location, have these tubes arranged almost vertically one above another on the side of the face. This family and the Zygobatidæ agree in this respect; they also agree in restricting the dorsal canals to about half the distance from the vertebræ to the outer angle of the pectoral, in the arrangement of the lower pleurals in pairs of lines along the anterior margins or along the branchial and the abdominal areas, and in having a large portion of the oral longitudinally extended, as if folded with compression of the head, among the more noticeable peculiarities. We might also have included the Dicerobatidæ in the majority, if not in all, of these agreements. These families are readily separated by means of the cephalic canals. Forward from the fontanelle in the Myliobatidae the orbitals cross the rostrals, a position they do not attain in any of the lower families. *Myliobatis freminvillei* has longer canals on the rostrum and a less number of pleural tubules than *M. aquila*, and it has the subrostral separate from the prenasal. *M. aquila* has the shorter anterior cephalic tubes, the greater number of tubules on either surface, and has the subrostral joining the prenasal

near the median. Aëtobatus agrees with *M. aquila* in regard to junction of subrostral and prenasal; it differs from both of the sketched species of Myliobatis in such characters as would be more likely to be induced by greater compression of the head, as is seen in the foldings of the oral, deeper curvature of the aural, etc.

Zygobatidæ. — In this family the mouth, as compared with that of the Myliobatidæ, has been drawn backward closer to the gill openings or the coraco-scapular, and the snout, through reduction, and retraction to follow the mouth, has arrived at a position beneath the skull. The process of the change is well written in the foldings, sinuosities, and contortions of the cephalic tubes. Besides these particulars of characterization there are others, apparently resultant from a shortening of the longitudinal axis of the body, equally peculiar in this group. Of these are the scapular and posterior pleural foldings. The species figured differ in the number of cephalic tubules, in the scapular areas, in the post-pleural folds, and in the oral, which is divided in one species, united in the other.

Between the Dicerobatidæ and the Zygobatidæ there are more points of resemblance than between the former and the Myliobatidæ. There is more of a disposition to mass the pleural tubules posteriorly than in either; and the connection of the laterals across the vertebræ has not before been noticed in any of the Batoids. A further peculiarity occurs on the inner anterior section of the lower pleural, on which the tubules turn backward, as in *Myliobatis freminvillei*. The latter is no doubt only a specific character. Of the cephalic canals, it is hardly necessary to say anything, the distinctions arising from the peculiar shape of the head are so excessively marked. Yet, as is noted in the description of *D. olfersii*, the affinities existing between Dicerobatus and Rhinoptera are shown by the canals of both body and head.

The subjoined synoptic list furnishes a condensed illustration of the availability of the canal system in classification. Being based exclusively on the species here described and figured, some of them represented by single specimens, it is to be expected that study of new forms will necessitate modification and rearrangement.

CHONDRICHTHYOIDEA.

With the nasal canals in front of the nostrils;
  cranial meeting the aural
    HOLOCEPHALA.
    canals sulcate *Chimæra monstrosa.*
    canals tubular *Callorhynchus antarcticus.*
With the nasal behind the nostrils;
  cranial not meeting the aural
    SELACHIA.
    without pleural canals **Galei.**
    with pleural canals **Batoidei.**

Galei.

Oral not connected with angular;
  median longitudinal;
    cranial curves abrupt, deep
      Scoliodon terræ novæ.
    cranial curves shallow;
      an upward anal curve;
        jugular reaching toward upper edge of gill opening;
          anal curve prominent
            Mustelus canis.
        jugular reaching toward middle of gill opening;
          anal curve low
            Triacis semifasciatus.
        jugular curved downward
          Scylliorhinus caniculus.
      anal curve indistinct;
        nasals not meeting
          Acanthias americanus.
        suborbitals and subrostrals on top of snout *Rhina squatina.*
  median transverse;
    anal curve absent *Prionodon milbertii.*
Oral connected with angular;
  divided at the symphysis;
    cranials folded over themselves
      Cestracion tiburo.
    cranials not folded;
      suborbital and angular meeting;
        median transverse;
          jugular passing below gill opening *Alopias vulpes.*
        median longitudinal;
          jugular passing toward middle of gill opening
            Odontaspis americanus.
          jugular short, passing toward upper edge of gill opening
            Heterodontus philippii.
        spiraculars and gulars present
          Chlamydoselachus anguineus.
  not divided at the symphysis
    Ginglymostoma cirratum.
    suborbital and subrostral meeting
      Isurus punctatus.
Oral absent;
  aural divided;
    nasals not meeting
      Heptabranchias maculatus.
  aural entire;
    nasals not meeting
      Pristiophorus cirratus.
    nasals meeting *Somniosus carcharias.*

Batoidei.

Subpleurals in front of gill openings;
  pleural descending on edge of disk
    Pristis pectinatus.
  pleural passing through disk;
    sternal divided;
      rostrals and prenasals long
        Rhinobatus planiceps.
    sternal entire;
      rostrals and prenasals short
        Syrrhina brevirostris.
Subpleural and other ventral canals absent;
  tubules very short *Narcine brasiliensis*
  tubules medium;
    aural tubules very short
      Torpedo marmorata.
  tubules long;
    aural tubules long
      Torpedo californica.
Subpleurals at side of gill openings;
  tubules simple; a long post-scapular tubule;
    orbito-nasal at right angles with pleural *Uraptera agassizii.*

orbito-nasal parallel with pleural
Raja lævis.
subpleurals partly obsolete
Raja ocellata.
tubules with dichotomous branchlets;
pleural tubules distant from lateral and hinder margins;
subpleural tubules massed in front of head;
subpleurals and suborbitals forming a network;
subrostral and nasal meeting
Disceus strongylopterus.
no subpleural network;
no lateral tubules on subpleural;
subrostral and suborbital meeting
Potamotrygon motoro.
lateral tubules on subpleural;
subrostral and suborbital meeting
Urolophus halleri.
subpleural and suborbital meeting, very tortuous
Dasybatus tuberculatus.
subpleural and suborbital not tortuous;
orbitonasal a mere point
Dasybatus dipterurus.
no lateral tubules on subpleural; tubules massed in front;
suborbital forming a series of four incomplete areas
Dasybatus nudus.
pleural tubules reaching outer pectoral angles;
areas included by pleurals wider than long;
lower pleurals emerge two sevenths way from the median to tip of snout
Pteroplatea valenciennii.
lower pleurals emerge two fifths way from median to tip
Pteroplatea marmorata.
lower pleurals emerge half-way from the median to the tip
Pteroplatea hirundo.
pleural tubules reaching little, if any, more than half-way to the outer angle;
laterals not united across the vertebræ;
anterior cephalic tubes reaching forward from skull;
subrostral and prenasal united;
median transverse
Myliobatis aquila.
median vertical
Aëtobatus narinari.
subrostral and prenasal not united
Myliobatis freminvillei.
anterior cephalic tubes not reaching in advance of skull;
oral not crossing symphysis;
no long tubules on the occipital
Rhinoptera brasiliensis.
oral crossing symphysis;
long tubules on the occipital
Rhinoptera jussieui.
laterals united by tubes across the vertebræ *Dicerobatus olfersii.*

DESCRIPTIONS.

Chimæra.

Chimæra monstrosa (Plate II.) has open grooves throughout both corporal and cephalic portions of the canal system. The delicate membranes of the inner part of the furrows are protected by closely set scales which overhang from each edge. There are no tubules. On the snout the canals present a

peculiarly scalloped appearance, caused by the rising of short sections of the edges as prominent rounded flanges supported by ribbed cartilaginous expansions. At the end of each pair of these flanges the walls are lower, which gives an appearance of rounded holes into the grooves. Between the holes the edges are somewhat zigzag.

On the scapular region the lateral (*l*) makes a moderate curve upward; on the flank it is slightly sinuous; and on the anterior portion of the tail, near the forward end of the lower lobe of the caudal fin, it descends to the lower edge of the muscles, a position retained to the extremity. In its middle the aural (*au*) is bent back, forming an angle from which a short post-aural branch reaches toward the dorsal spine; the canal crosses behind the aqueducts. Aural and cranial (*cr*) are joined; they are connected with lateral and orbital (*orb*) by an occipital (*oc*) of moderate length passing downward and backward. The cranials converge to some extent on the forehead; on each side of the frontal holder they turn out a little, but approach again on the snout. Below the posterior border of the orbit the orbital meets the jugular (*j*) and the suborbital (*so*). From this point the suborbital passes forward to join the rostral (*r*) at the end of the snout, rising well up in front of the eye in an open loop, somewhat inclined forward. An individual variation appears in each of two specimens at hand: in one the angular (*ang*) unites with the jugular, in the other with the suborbital. At first the angular passes downward to the oral (*o*); thence it goes forward to the nasal (*n*) and the subrostral (*sr*). The jugular runs obliquely backward and continues across the throat in a broken line. Beneath the back part of the eye the oral leaves the angular, and may be traced across the chin in a series of dashes or dots. The nasal lies in front of the nostril; it bends forward and meets its fellow in advance of the nares, but forms neither median nor prenasals. From the suborbitals the subrostrals extend toward each other and unite in a median; a short distance posteriorly they diverge to meet the angulars. The second specimen differs from that just noted in having the angular united with the suborbital, and the jugular less noticeable on the throat. The first of these features is an approach to the condition in Callorhynchus, where angular, oral, and jugular connect with the suborbital, but not with each other.

Callorhynchus.

Callorhynchus antarcticus (Plates III., IV.) differs from Chimæra, and agrees with the majority of the Sharks, in possessing canals that are tubes, instead of furrows. On the flank the lateral rises a little in the scapular region; thence it is sinuous to the end of the dorsal; and thence stralght to a point above the lower lobe of the caudal fin, where it makes an abrupt downward bend to the lower edge of the muscles, which position it retains to the end.

In the middle the aural is much turned back; but it forms no angle and sends off no branch. Forward from the aural the cranials are gradually con-

vergent, more decidedly so in advance of the frontal holder (♂), and they approach each other closely on the thin portion of the proboscis. As in Chimæra, the occipitals connect the laterals and the orbitals with the aural and the cranials, instead of connecting the aural and the laterals with the orbitals and the cranials as in the Selachia. Orbitals and jugulars meet below the pupil of the eye. The suborbitals are very long; they pass quite to the end of the snout, and there meet the rostrals as the latter pass to the lower surface of the rostrum. A row of short pieces of canals across the throat serves to unite the jugulars. Under the fore part of the pupil the oral leaves the suborbital; it curves forward on the cheek and the chin, and backward behind the corners of the mouth. On the cheek it has what appears to be a more slender tube just in front of itself. Not far in front of the oral the angular descends toward the mouth from the suborbital. As it nears the lip it takes more of a forward course, and, following near the border of the rostral flap, finds its way down and backward to the edge of the lower surface, where it turns under and inward to cross the wing and meet the angular of the opposite side. After meeting the suborbital each rostral in its backward route approaches very close to its fellow, under the end of the rostrum, if it does not unite with it. Farther back they diverge, and each turns up a side of the snout, curving back as if to unite with the nasal. The union of subrostral and nasal has not been traced. In the adult specimens the oral and the jugular show tendencies to obsolescence.

Although there are great differences in the shape of the head in this genus and in Chimæra, in the arrangement of the canals in the two cases there is a great deal of similarity. One has only to suppose the snout of Callorhynchus shortened, so that the flap may be applied against the head, and the union of subrostral and nasal, if not already existing, to produce an arrangement essentially the same as that of Chimæra.

Scoliodon.

Scoliodon terræ novæ (Plate V.) represents one of the subdivisions of the genus Carcharias, as arranged by Müller and Henle. Comparison of this species with *Prionodon milberti*, a representative of another of these subdivisions, will give an approximate idea of the range of variation within that genus.

A small amount of curvature only is to be noticed in the thoracic portions of the laterals. Below the second dorsal they make a slight descent, then they rise rather higher than before, after which the canals retain the same relative height as regards the vertebral axis till they reach their terminations at its end.

In its middle the aural has a shallow backward bend; and it has one of similar depth in the opposite direction near each end. The occipitals are comparatively long; they are extended obliquely out toward the eye. A short distance from these canals, each cranial makes a short but decided outward

bend; in front of this, and between the orbits, it runs abruptly toward the middle of the crown, before reaching which it makes a broad deep curve, carrying the tube outward to a point opposite the hinder margin of the fontanelle, whence it passes in a nearly straight direction toward the tip of the snout. Before it reaches the latter, it descends to the lower surface. Soon after leaving the cranials, the orbitals sink deeply into the tissues of the side of the head; approaching the skin again, each makes a broad curve around the orbit, rising in front above the middle, after which it goes downward to meet the angular, nearly half-way from the eye to the nostril. The angular is rather elongate; its continuation, the jugular, ends in front of the middle of the first branchial aperture. The sections of the oral are disconnected and detached; the space separating them from the angular is about equal to that separating them from each other; their length is about two thirds of that of each mandible. At its forward extremity the short orbito-nasal meets the subrostral and the nasal; posteriorly it meets the suborbital and the angular. The nasals are nearly transverse, and would be quite so if not for a decided curve forward at the inner edge of each nostril. A short longitudinal median connects the nasals and the prenasals; the latter have a moderate degree of divergence, and unite with the rostrals.

Very prominent cranial curves, long occipitals, a shorter suborbital fold in front of the eye, and a more pronounced nasal curve, are among the most patent differences to be noted on this species as compared with *Prionodon milberti*. An approach toward the conditions existing on Cestracion is to be seen in the cranial, rostral, subrostral, and nasal curves, and in the great depth to which the orbitals have sunk in the tissues behind the eye at the side of the head.

Prionodon.

Along the trunk, the laterals of *Prionodon milberti* (Plate VI.) deviate but little from a right line. There is a small degree of curvature behind the occiput. Opposite the anal the downward bend is hardly perceptible. On the tail, above the anterior portion of the fin, the canal descends hardly half-way to the lower edge of the muscles; it keeps the same relative position as far back as to the hindermost of the vertebræ.

The aural is transverse, turned back a very little at each end. The occipitals reach toward the side, behind the eye; they are rather short. In the coronal region each cranial makes a long shallow curve inward. From the fontanelle they are nearly direct, converging somewhat; and they descend some distance behind the end of the snout. Depression of the head has brought orbitals and angulars close together, on the cheek. In front of the orbit, the suborbitals rise higher than the middle of the eye; the loop formed by them extends more than a diameter in front, and it is about half as far from the orbit to the junction with the angular. The subrostral is long, with a shallow curve around the nostril; the angular is long; the jugular is me-

dium; the orbito-nasal is short; the nasal is transverse, with a broad curve; the median is very short; and the prenasals are long and connected with the rostrals. There is a short disconnected oral behind each side of the mouth. In their principal features, the canals represented in this form are intermediate between those of Mustelus and Scoliodon.

Cestracion (Klein).

Forward, the laterals of *Cestracion tiburo* (Plate VII.) are nearly straight; backward, they have a pronounced curve, between anal and second dorsal, but do not descend much below the middle of the tail, and they stop near the end of the vertebral column.

The flatness of the head, the expansion of the snout, and the positions of nostrils and eyes at such great distances from the occiput, have caused some very peculiar contortions of the cephalic tubes. A small amount of backward convexity is presented by the aural. The occipital is elongate and turned toward the side. Between the eyes the cranial is very tortuous, turning upon itself several times before taking its way toward the rostrum, where it again makes a backward run before passing through. From the occipital the orbital goes outward and backward a short distance, then passes through, behind the lateral cartilages of the skull, to the ventral surface. Below the head the subrostrals tend laterally near the edges until about half-way from the snout to the eyes, where they ascend and run for a similar distance on the upper surface before descending again just in front of the eyes, thus passing around the nostril, and finally going with much directness to meet the nasal about half-way from the eye to the median. A great bend out in the direction of the eye is made by the suborbital on the way forward to its junction with the angular, the entire length of the tube being about three times the distance between the point of appearance on this surface and that of the meeting. The orbito-nasal is very short; it lies at right angles with the angular. Angular and jugular are about equal in length. Near the corner of the mouth the oral is bent toward the thorax; it is connected with the angular, but does not cross the symphysis. Were it not for a long narrow loop putting out toward the nostril the nasal would be described as nearly transverse. This loop has parallel sides, is slightly bent back, and has a tubule from its extremity. A median of moderate length gives rise to a pair of prenasals, which are somewhat curved, and which meet the subrostrals a little toward the side from the points at which the latter make their appearance.

An arrangement of canals such as that here described might be developed from a form like *Scoliodon terræ novæ* by crowding the snout back toward the skull and expanding the head at the sides. To push the long cranials back toward the occiput would bring about the identical curves appearing on the Hammerheads; in fact, the curves on Scoliodon are just what would naturally lead to such a result. Expanding the head would necessitate the appearance

of the subrostral on the upper surface to retain its position outside of the nostril, the latter being on the edge. And the orbitals, being behind the expansion, would sink deeper into the tissues; this also is simply going farther in the direction already partially traversed by the orbitals of Scoliodon.

Mustelus.

Anteriorly on *Mustelus canis* (Plate VIII.) there is hardly any departure from a right line in the lateral. Over the anal fin the canal rises; farther back, it descends to its former level, and, not going below the middle of the caudal muscles, it stops at the last of the vertebræ.

Comparatively little curvature is apparent in either aural or occipitals. The latter are short and diverge toward the cranials. In front the cranials converge; opposite the fontanelle they turn directly toward the side of the head for a short distance, then they run forward, almost straight, somewhat convergent, and pass through the snout before reaching the tip. At first the orbitals are transverse, but with a gradual curve they sweep below and about half its diameter in front of the eye, where they turn back and downward to meet the angular beneath the anterior third of the orbit. The angular is of medium length; the jugular is short, ending near midway from spiracle to gill opening. A short horizontal orbito-nasal connects with a long subrostral, in which there is but a slight bend at the side of the nostril. A prominent curve appears in each nasal, between the nostrils. The median is long and longitudinal. The prenasals are rather long; they connect with the rostrals. Behind each angle of the mouth there is a short detached oral.

The canal system of Mustelus closely resembles that of Triacis.

Triacis.

On *Triacis semifasciatum* (Plate IX.) there is hardly any curve in the scapular portions of the laterals. As in Mustelus, the anal curve is a broad one; the canal does not descend to the edge of the fin, and it stops at the end of the column.

There is a slight forward bend in the middle of the aural, otherwise it is almost straight. The occipitals are of medium length, and are divergent. In their coronal portions the cranials are nearly straight. At the sides of the fontanelle the bend is abrupt, but not deep. The rostral sections of these canals vary in outline, converge, and descend before reaching the end of the rostrum. Passing outward, the orbitals bend back slightly; they sink deeply into the tissues behind the eye, and extend in front of the orbit more than its diameter. A much more open loop is made by these tubes as they turn to join the angular than in Mustelus. The angular is of moderate length; the jugular is short and turned up toward the superior edge of the gill opening, as in Ginglymostoma, Scylliorhinus, and Mustelus. The orbito-nasals are short, convergent

forward. The subrostrals are moderate in length and slight in curvature. The nasals are transverse, broadly curved forward between the nasal valves. Approaching the symphysis, behind the corners of the mouth there is a pair of detached orals. A short median and moderate prenasals, the latter connected with the rostrals, complete a system closely resembling that of Mustelus and with remote likenesses to that of Scylliorhinus.

An embryo of two and a half inches agrees so well with the adult that it is readily identified by means of the canals. Without the aid of the system identification would hardly have been possible.

Isurus.

Isurus punctatus (Plates I., X.) by the fusiform shape of its body compels the laterals to diverge considerably along the middle of the flanks. With this exception they are tolerably straight, there being hardly any deflection above the anal, and but a scarcely noticeable upward turn on the tail. In reality the laterals cross the muscular portion of the tail, not following the course of the vertebræ, and they end at the lower (hinder) edge of the muscles close behind (above) the lower caudal lobe in front of the concavity in the posterior margin of the fin.

The aural is long, without prominent curves. The occipital is short, and nearly transverse. Both coronal and rostral curves of the cranials are long and shallow. The rostrals are short. In its downward course the orbital is waved a little; as a suborbital it joins the subrostral below the forward margin of the orbit. By its connections the short orbito-nasal would appear to be reversed in direction. In one specimen the angular bends downward behind the angle of the mouth to meet the oral, and the jugular makes an upward turn, then goes half-way to the gill, to bend up still farther at the end; in another case the angular and jugular form a single nearly straight line. The oral is connected with the angular, and runs but little beyond the corner of the mouth. At less than a quarter of the distance from the eye to the rostral tip, the subrostral appears on the lower surface; from this point it is longitudinal, faintly curving above the nostril. No nasal curve appears in the nasals. The short median is nearly transverse. About one third of the prenasal is bent abruptly to the side to meet the rostral.

Prominent among distinguishing characters are the caudal portions of the laterals, the reversed orbito-nasal, the transverse median, the curveless nasal, and the attached oral.

Odontaspis.

Odontaspis americanus (Plate XI.) exhibits neither scapular nor anal curves in the laterals. The canal remains near the middle of the tail, and stops a little forward of the last of the vertebræ.

The aural bends back in the middle a very little. The occipital is of mod-

erate length, and puts out directly toward the eye. On the crown the cranials are straight until opposite the fontanelle, where they make a shallow outward curve. The rostrals descend near the end of the rostrum. Starting down and backward, the orbitals make a broad curve around the eye until beneath it, where they become longitudinal and run more than a diameter forward from the orbit, before turning down and back, parallel with themselves, to join the angular. Both angular and jugular are long. From the angular the oral bends back around the mouth; it is not continuous across the symphysis. The long orbito-nasal bends down under the fore part of the eye before becoming longitudinal. Above the nostril the subrostral turns abruptly toward the nasal, in which there is no perceptible curve. The median is elongate and longitudinal. At the median the rather short prenasals bend outward, then turn forward to join the rostrals.

The type is characterized by absence of anal or caudal bends, by an elongate occipital, a slight curvature in the cranials, a longitudinal loop in the suborbitals, a prominent curve in the subrostrals, absence of a nasal curve, and by the junction of oral and angular.

Alopias.

Alopias vulpes (Plates XII., XIII.). A very great development of the canal system obtains in this Shark. There is no great difference in the main tubes from what may be seen in allied genera; it is in the enormous number, the length, and the amount of branching of the tubules, that unusual features are most patent.

Forward the lateral bends upward a little; at the base of the tail it follows the vertebral axis, keeping its position near the middle of the muscular portion, and ends a little in advance of the notch in the hinder extremity. Throughout the entire length the tubules are closely placed on the sides. Anteriorly, on the thorax, they are directed toward the back. Nearly all of those on the abdominal region are extended toward the belly. From the base of the ventrals to the end of the anal the tubules have numerous branches, some of which pass upward and others downward. On the tail the tubules are sent toward the lower edge of the fin.

The aural is long; in prominent curves it bends back in the middle and forward at each end. The occipitals are short. In the cranials the curves are shallow. At the crown the orbital starts back and down ; as a post-orbital it is vertical; and in the suborbital it sinks below the eye. Slightly in advance of the eye the suborbital turns back, and not far from the centre of the orbit, over the front edge of the mouth, is the union with the angular. The latter is of medium length. An uncommon arrangement of the jugular is seen here: the tube is long and passes below the gill apertures. The oral is elongate and connected with the angular; it makes a sharp bend around the corners, and is divided by a narrow interspace in the middle, behind the symphysis. At the

angular the orbito-nasals make an abrupt drop, beyond which they are longitudinal. The nasals are long, and have but a small amount of curvature. The median is short, and placed longitudinally. The prenasals are long, and abruptly bent to the sides to meet the rostrals. Opposite the nostrils there is a decided outward bend in the subrostrals.

A great number of long tubules exist on the laterals, and on some of the cephalic tubes. Those from the aural reach directly back. Those from the suborbital extend backward or downward; some of them connect with the angular or its tubules; all are more or less branched. Above the mouth the branches of the angular turn upward; behind the oral a few of them go downward, where, by meeting others from the oral, and by uniting among themselves, they form a network. On the upper side of the jugular the branches are much more numerous, but have not so many branchlets. Behind the angle of the mouth the tubules of the oral are longer and more branched.

There is a striking similarity in the canals of Alopias and those of Odontaspis. This may be seen in cranials, aurals, orbito-nasals, suborbitals, subrostrals, prenasals, nasals, angulars, and orals; and it appears fully to warrant placing these genera side by side in a systematic arrangement of the Galei.

Heptabranchias.

Heptabranchias maculatus (Plate XIV.). On the flanks of this species the canals are shallow furrows, protected by enlarged overhanging scales of the shagreen on the edges. In front the grooves commence above the forward portions of the bases of the pectorals; all the canals farther in front are tubes. Another specimen shows alternation in the lateral, between the aural and the continuous lateral furrow, of irregular lengths of tube and groove. Over the anterior lower lobe of the caudal the furrow bends downward in the direction of the fibrous portion, which it approaches more gradually backward, and it ends at the notch between the lower and the hinder sections of the fin.

The aural is divided by an interspace, behind the openings of the aqueducts, as in *H. pectorosus*. A small amount of outward curvature marks the elongate occipitals. At each side of the fontanelle the cranials bend out in a broad curve toward the side of the head. In front of the nostrils the rostrals turn back toward the subrostrals, but apparently without meeting them. These tubes seem to be separated, just above the nostril, by a short interspace. On the top of the head, again, the orbital is directed outward and a little forward; on the side it goes down and backward, without forming a suborbital, to join the angular and orbito-nasal. The latter is very long, and takes the place of the suborbital. Jugular, angular, and orbito-nasal form a single longitudinal line; the first is short, ending in front of the middle of the first gill cleft, the second is of moderate length, and the third is as long as both of the others. The nasal is of moderate length, curves strongly toward the median line, but does not meet its fellow, from the other side, to form a median. The pre-

nasals bend out toward the rostral, without approaching closely, then pass forward and end blindly near the tip, at a considerable distance apart. Above the front edge of the mouth the subrostral meets the nasal in a sharp angle. The nasal curve is comparatively slight. Traces of an oral were not detected.

Excessive thinness of the skin, by bringing the canals so close to the surface, favors the presence of furrows rather than tubes, or, to go still further, leads to the disappearance of the canals altogether, as in case of the orals of this and other species.

Characteristic features of the system on this shark are the isolation of the prenasal, the length of the orbito-nasal, the suppression of the suborbital, the direction of the orbital, the bisection of the rostral, the division of the aural, and the open lateral tubes. Several points, in occipitals, cranials, orbitals, and orbito-nasals, recall similar ones in Chlamydoselachus; the latter, however, is widely withdrawn by consideration of its lack of division in aural and rostrals, the position of its prenasal, and its possession of oral, gular, and spiracular canals.

H. pectorosus is, in most particulars, similar to *H. maculatus*. Its laterals end about two fifths of the length of the tail in advance of the extremity, making a decided and broad curve downward to the fibrous part of the caudal.

A specimen of *H. cinereus* has closed corporal canals, or tubes, of similar position and outline as the two species of this genus already noticed, but reaching a little farther toward the caudal notch than in *H. pectorosus*.

Chlamydoselachus.

Chlamydoselachus anguineus (Plate XV.) has the laterals open throughout their whole extent, with the exception of less than an inch immediately behind the aural. From each edge enlarged scales overhang the groove, enclosing it in a measure and protecting it. Along the flanks the canals are nearly straight. The caudal curve is very gradual in one specimen, more abrupt in another, and on one side of the second descends, then rises to repeat the curve. On the body, the canal lies a little above the crease between the muscles of the back and those of the flank. On the tail, its track lies a little below the middle of the muscular portion; it continues thus, with a few slight breaks posteriorly, to within an inch of the end of the vertebral column, where it stops.

In the sketch the courses of the closed cephalic tubes are indicated by lines of dots, each of the larger of which marks the opening of one of the short tubules. The aural is closed. It has no tubules. Contrary to what obtains in other Galei, it lies in front of the so-called ear openings. These openings, however, are at the ends of tubes the inner extremities of which are in front of the canal. The canal is nearly straight, bending slightly forward in the middle and a little backward near each end. The occipitals are long and

extend forward with a very slight trend outward. On the crown the cranials are parallel. At the sides of the fontanelle they bend abruptly outward, and, as rostrals, run near the edge of the snout for some distance before going to the lower surface. From the cranials the orbitals run outward and somewhat forward; near the side they turn backward and downward toward the corner of the mouth. They end some distance behind the eyes. A long angular joins the short jugular and the very long oral, which reaches almost to the symphysis. At the end of the jugular near the middle of the first branchial aperture, there are two branches not found in any other of the Sharks examined: a *spiracular* (*sp*), turning upward and forward toward the spiracle, and a *gular* (*g*), turning down and forward near the median line, and finally uniting with the oral a short distance from the inner end. Below the eye, in the position usually occupied by the suborbital, lies a very long orbito-nasal. The nasal is of moderate length, and curves broadly in its posterior half. The subrostral is a little shorter than the nasal; it bends upward over the nostril. Apparently the prenasal is reversed in direction, meeting the nasal in front and running backward to join the subrostral. Like the corporals, oral, gular, and spiracular are open grooves. In the spiraculars and gulars of this Shark are found the nearest approaches to the pleurals of the Batoidei.

Distinguishing peculiarities of the system on this type are seen in the possession of spiracular and gular canals, in the position of the prenasals, and in that of the aural, with regard to the ear openings. Similarity in the orbito-nasals occurs in Heptabranchias. Somniosus by the same canals is intermediate between these genera and others of the order.

Ginglymostoma.

Ginglymostoma cirratum (Plate XVI.). Over the shoulders the laterals have little outward curvature; in the anterior part of the tail they drop somewhat abruptly from the middle to the lower portion of the muscular band, near the edge of the fin, where they continue, ending with the vertebral column.

This form has a short broad head, and a very short snout. If compared with one of the long-snouted species, it will be seen that there is a tendency toward the transverse in the cephalic canals, which in those forms are nearly or quite longitudinal. The aural is long, bending backward a little in the middle, and as much forward toward each end. The occipital is of medium length; it runs obliquely outward, with a slight curve toward the spiracle in the middle. From the end of this canal the cranial turns rather sharply toward the crown; it then passes forward, diverging a little from its fellow until opposite the fontanelle, where it turns outward with less curvature than in Scylliorhinus. Approaching the edge, the rostrals run parallel with it until near the tip, where they descend. The orbital is rather short. The suborbital is much longer and passes forward more than three times the diameter of the orbit; above the nostril it turns back, forming an angle, and meets the subrostral a short distance forward from the eye. Angular and jugular are short; they are directed up-

ward some, toward the top of the first branchial aperture. Behind the corner of the mouth the oral makes a strong backward curve; the tube is a long one; it crosses the symphysis and meets with the angular. Posteriorly the orbito-nasal curves upward to meet the angular; the tube is elongate and nearly horizontal. The nasal is long, sinuous, and almost transverse. Contrary to what might be expected on a short snout, the median is long. As if reduction in the length of the snout had proceeded faster than in that of the tubes, the prenasals appear as if pushed back and folded on themselves; each is turned abruptly toward the side, and bent into two folds. They unite with the rostrals.

Prominent distinguishing features in this shark are the caudal canals, scapular curves, complete oral, long suborbitals and orbito-nasals, and the folded prenasals. Of the genera studied it approaches Scylliorhinus most closely.

Scylliorhinus.

Scylliorhinus caniculus (Plate XVII.) has scarcely any curvature in the laterals, and they end with the column, not going down to the fibrous portion of the caudal fin.

A slight sinuosity affects the aural. The very short occipital is directed toward the eye. Behind the fontanelle the cranials approach the median line in a broad curve: in front of this, they turn abruptly out toward the edges of the snout. Just before it joins the prenasal, there are several curves in the rostral: in descending it runs forward, downward, inward, backward, and outward. At the side of the nostril there is a prominent curve in the subrostral. The suborbitals are longitudinal below the orbit; at its forward edge they pass down and backward to meet the short orbito-nasals. The nasals are almost straight and transverse; the median is short; and the prenasals, sinuous and moderately long, unite with the rostrals. From the angular the jugular curves up toward the upper edges of the gill opening, which it does not reach. Behind each angle of the mouth there is a short disconnected oral.

Heterodontus.

On *Heterodontus philippi* (Plate XVIII.) the laterals diverge a little, behind the occiput; farther back they are straight, without a curve over the anal fin, until they reach the tail, above the lower lobe of which they descend to the lower edge of the muscles. As it nears the end of the column, the canal becomes a furrow.

Lateral and aural form a continuous curve, and are connected with the cranial and orbital, which form a similar curve, by a very short occipital. The cranial bends are broad, but not at all deep. This is true also of the suborbital, which reaches nearly a diameter in front of the orbit, then drops vertically on the subrostral. Angular and jugular are both very short. The oral joins the

angular, but does not cross the symphysis. The orbito-nasal is long. In passing the nostril, the short subrostral makes a decided curve. Behind the nostril the nasal is bent toward the mouth. The median is very short. From the median the short prenasal goes directly to the side, joining the rostral.

By the canals either Odontaspis or Ginglymostoma shows more affinities with Heterodontus than does Acanthias. The differences in dentition between the latter genera are scarcely greater than those apparent in the canal systems.

Acanthias.

Acanthias americanus (Plate XIX.). Backward from the shallow scapular curve, the laterals of this species are nearly straight. Above the widest part of the lower lobe of the tail, the tube makes a slight bend upward; it does not follow the vertebral column, but gradually approaches the lower edge of the muscles, and stops in front of the last vertebra.

In the middle, towards the ear openings, the aural is bent forward. A continuous longitudinal line is formed by the elongate occipital and the lateral. At the orbitals, the cranials make a rather sharp curve; opposite the fontanelle, they make a broad and shallow bend. The upper portion of the orbital is sinuous; behind the eye it is thrown backward; and beneath the orbit it goes but half-way before turning back in a sharp angle to join the angular. Jugular and angular together are short. The orbito-nasal is long, and is bent downward from the suborbital. By the side of the nostril there is a decided bend in the subrostral. The nasals are long and bent so that the curves in each approach the outlines of a Z; they do not meet to form a median, but run close together as in Pristiophorus. Near the end of the snout the prenasals converge, without seeming to join; they are located some distance from the rostrals. The tubes are of large calibre, and the tubules are numerous and short. A short oral lies close to each angle of the mouth, entirely disconnected. On the tail, for a short distance from the end, the canal is open. Figure 6 shows the arrangement of the scales and the form of the portion of the canal included between the dotted lines.

An embryo of two and a quarter inches has tubes similar to those of the adult, but the tubules are shorter or absent.

Somniosus.

Somniosus carcharias (Plate XX.) has tolerably straight tubular laterals. They extend on the middle of the muscular portion of the tail, running as far back as the hinder edge of the anterior lower lobe of the caudal fin; thence they descend to the lower edge of the muscles, above the fibrous portion, where they continue to the end of the column.

Among the cephalic canals a very peculiar arrangement occurs on the occiput: the aural is transverse, and has its ordinary position; from its ends the occipitals curve forward and inward, and end anteriorly without connecting with

other tubes; a short distance in front of their ends are those of the orbitals, also disconnected; and still farther in front are the posterior extremities of the cranials, like the others, making no connections. The orbitals pass directly outward, then downward and forward, meeting the angular below the hinder portion of the eye. At the start the cranials are transverse, they soon bend forward, and, making very open curves around the fontanelle, becoming rostrals, converge toward the end of the snout, before reaching which they pass through to the lower aspect. As subrostrals they go back and outward, making a loop on the side and top around the nasal chamber, and pushing farther back to meet the nasals. In comparison with that of other genera, the orbito-nasal is rather long; it extends below the greater portion of the orbit. A prominent curve toward the nostril marks the middle of each of the elongate transverse nasals. From a median of more than ordinary length the prenasals diverge and run forward, ending abruptly, under the tip of the snout, without joining the rostrals. The angulars are of moderate length. The jugular is short. An oral could not be found. The tubules are numerous, short, and provided with large apertures.

Especially noticeable among the peculiar features met with in this species are the separation of the orbitals and the cranials from the occipitals, the isolation of the prenasals, the supranarial curve of the subrostrals, the length of the orbito-nasal, the lack of the oral, and the caudal curve of the lateral. The coronal arrangement of the cephalic canals, and the subrostral curve, distinguish the genus from any of the other genera noted here. The orbito-nasal and the disposition of the lateral on the tail are intermediate between sharks like Heptabranchias and the majority of those of higher rank. In Cestracion (Zygæna) only of the other Galei have we seen the subrostral return to the top of the snout.

Rhina.

Rhina squatina (Plate XXI.). With the great depression of the body of this Shark, the lateral has to some extent been carried outward on the thoracic and the scapular regions. Excepting slight waves in the outline, there is hardly a deviation from a straight line in the tubes on the sides of the tail. The canal does not reach quite to the hindmost vertebra. Above the thoracic region near the aural a few of the tubules reach toward the median line. Elsewhere along the whole length of the laterals the tubules are short and directed out.

In consequence of the anterior position of the mouth and the shortness of the snout, the canals of the front part of the head are greatly reduced in length. Subrostrals, prenasals, and other tubes that in the balance of the Sharks are confined to the lower surface, have been brought to the top by depression of the head. The aural is long, curves backward slightly, and has a few tubules extending toward the shoulders. The occipitals are long, and divergent forward. On the frontal region, the cranials curve toward each other;

their tubules, as those of the occipitals, start out, but turn and cross the tubes toward the middle. Opposite the fontanelle the cranials make a broad open bend, from which the short rostrals pass about half-way to the middle of the mouth. From the front end of the rostrals the subrostrals turn back, around and behind the nostril, to meet the nasals on the sides of the face. The prenasals lie on the upper surface; they are nearly transverse, and turn back at the ends as if to join the rostrals, but without making a junction. Apparently the very short median is vertical. The orbitals are entirely on the upper surface. From the cranials, they go obliquely outward until past the orbit, then, turning forward at a right angle, the suborbitals run a short distance beyond the eye, where they turn out and backward, making a deep loop, convex in front. They meet the angular opposite the eye. Both angular and jugular are on the top of the disk. The orbito-nasal is on the side of the face; it is comparatively elongate, running from opposite the middle of the orbit to within a short distance of the nostril. The orals and the nasals belong to the lower view. The former are elongate, disconnected, and do not reach the symphysis; the latter are moderate and transverse, with a shallow curve forward toward the middle. The tubules from the suborbitals are rather long and pass outward; they, like the others, are unbranched.

The appearance of all the tubes, except orals and nasals, on the top, looks as if resultant from depression that had caused great expansion of the ventral portions of the body, and but little of the dorsal. This peculiarity alone would serve to distinguish the genus from the other genera. There is nothing in the canal system that favors the idea of close affinity with the Batoidei.

Pristiophorus.

Considerable uncertainty exists in connection with several points on the sketch of *Pristiophorus cirratus* (Plate XXII.), because of the bad condition of the specimen, a dried skin.

Back of the head the laterals turn outward somewhat; on the tail they appear to lie near the middle of the muscular portion, stopping at the end of the column.

The halves of the aural meet in a sharp angle at the middle; behind the openings of the aqueducts they form a V, from the apex of which a short tube extends directly back. A low inward sweep is made by the cranials, on the crown. Beneath the eye the orbital does not quite reach the front edge of the orbit; turning backward, it descends to join the angular on a vertical from the centre of the pupil. The angular is longer than the jugular. Apparently there is no oral. The orbito-nasal is rather long; and, with the angular and the subrostral, it forms a longitudinal line. In front of the mouth the nasal is turned back; it has a moderate nasal curve, and does not connect with its fellow to form a median. Prenasals and subrostrals are very long. In the specimen they cannot be followed near the end of the rostrum.

There are marked resemblances between this Shark and Acanthias, which

are at least suggestive of closer affinities in the distant past. These are brought prominently forward in comparisons of such tubes as the medians and suborbitals of the two forms.

Pristis.

Posteriorly the laterals of *Pristis pectinatus* (Plate XXIII.) are straight. On the tail there is a slight downward tendency, and the canals end near its extremity, at the lower edge of the muscles. Anteriorly, above the thoracic region, they are drawn toward each other; at the shoulder each makes an outward bend, from which the scapular and the post-scapular branches extend. A comparatively small area is enclosed by the pleural; from the shoulder the tube runs out and backward, then it turns forward, along the inner edge of the pectoral fin, to meet some of the tubules from the orbital, near the hinder part of the orbit, after which it makes a sharp bend and goes back a short distance parallel with its former course before passing down the side to the lower aspect, about opposite the aural. One or two post-scapular branches, together with the posterior pleural tubules, form a network of branchlets on the pectoral. Lateral, pleural, and suborbital possess slender tubules. Similar ones on the rostral have delicate branchlets.

On the ventral surface the pleurals run toward the gill openings, in front of which, about one third of the distance to the mouth, they meet the jugulars. The space included by these tubes is small.

The aural is deeply bent backward. A short occipital connects it with the orbital. The latter goes close below the eye and in front of it, about half a diameter, passes to the lower surface around the edge. Near the fontanelle the cranials diverge slightly, making a shallow bend; near the end of the rostrum they converge, but diverge again at the tip; in general, their course is tolerably direct. These, as the other tubes of this surface, are beset with a great many very fine short tubules.

Angular and jugular are moderate. The orbito-nasal is short; in front it meets the suborbital and the subrostral. Only a small portion of the suborbital is to be seen from below. The subrostral is much elongated, has a waved course, and is bent prominently forward in front of the nostril. The nasal is transverse, and waved in outline. The median is longitudinal and short. From it the prenasals turn abruptly outward, toward the nostrils, before taking a course of tolerable directness toward the rostral extremity. Close to the latter they appear as if crowded back, so as to make a fold directed toward the median line. Behind each side of the mouth there is a disconnected oral; toward the middle the tube bends forward, at the outer end it is turned back in a hook.

Although there is much resemblance between the majority of the canals of *Pristis* and those of *Pristiophorus*, the presence of the pleural and the scapular branches fixes the position of the former in the Batoidei.

Rhinobatus.

Rhinobatus planiceps (Plate XXIV.). From the shoulder girdle to their ends on the tail the laterals of this species are nearly straight. At the pectoral arch the scapular curves carry them outward, and back of the head they approach each other. Posteriorly they send numerous tubules outward; anteriorly others are sent inward and backward. Behind the scapular there are four post-scapulars, each of which has two or more tubules near the end. There is more lateral curvature in the pleurals in this genus than was seen in Pristis; there is also a more intimate connection between them and the suborbitals, by means of four or more of the tubules. Opposite the forward part of the orbit, about half-way between it and the margin, the pleurals pass through the disk, after sending numerous tubules on the pectoral. These pleural tubules are of two kinds, one stronger, longer, and straighter; another finer, shorter, and crookeder, distributed among the first. The course of the pleurals on the lower surface is short; they meet the jugulars in front of the first branchial aperture.

The aural curves back in the middle. A slight divergence obtains in the short occipitals. In front of the eye the cranials curve outward sharply; they approach each other nearest along the middle of the rostral cartilage. At the end of the suborbital a branch is sent backward; in front of the eye its tubules extend both inward and outward; and still farther in front they are sent toward the margin. Instead of going around its edge, the suborbital passes through the disk very near the border. On reaching the lower surface this tube makes a broad curve back, and joins the subrostral opposite the nostril. A short orbito-nasal connects it with angular and jugular, both of which are short. The nasal is bent back behind the nasal valves. The median is very short. Near the middle of their length the elongate prenasals are curved toward each other. The oral crosses the median line behind the mouth, but is disconnected from the angular. Around the anterior border of the abdominal chamber, beneath the coraco-scapular arch, there is a sternal canal, which differs from the others in being more open; it does not cross the middle. This canal was not seen in Pristis.

Syrrhina.

Syrrhina brevirostris (Plate XXV.). A description of the canal system in this species would duplicate that of the preceding, excepting that rostrals, subrostrals, and prenasals would be found to be greatly shortened. Other points of difference, less important, are seen in the smaller number of branches of the tubules and the undivided condition of the sternal. A study of the canals of this species discloses little that favors separation from *Rhinobatus*, since it differs less from species of that genus than some of them do from each other.

Uraptera.

On *Uraptera agassizii* (Plate XXVI.) the upper surface is pretty well covered with tubes and tubules. On the ventral aspect the main tubes are all present, but the tubules are few and short. There is nothing in the canals that will distinguish this genus from *Raia*.

On the shoulders, the laterals are thrown decidedly outward; farther forward, they make a broad curve toward the vertebræ; and they converge toward the base of the tail. Their tubules are of medium length and are most numerous above the abdominal region. The pleurals reach far out on the pectorals, enclosing an area, convex forward, somewhat lenticular in shape. At the angle opposite the shoulder they send back a strong branch with many tubules on its outer side. The most of the pleural tubules pass forward; a few, especially of those near the anterior border, turn back. Opposite the eye the pleural is connected with the suborbital by several tubules; thence it bends toward the margin and descends about half-way from the orbit. A strong postscapular goes to the hinder angle of the pectoral; the greater number of its tubules are directed outward.

The occipitals are short and greatly divergent. Between the eyes the cranials curve toward each other; in front of the orbits they bend apart; and on the rostrum they converge gradually to their points of descent, near the end. Outward from the curve in front of the orbit a tuft of tubules extends from each. The suborbitals take a tolerably direct course to the end of the snout, but pass down some distance before reaching it.

On the lower surface, the pleurals bend out opposite the first gill cleft and inward opposite the shoulder girdle, in both the backward and the return courses. They neither reach back behind the middle of the abdomen, nor out to the middle of the pectorals.

The orbito-nasals are elongate, converging in front. The lower suborbitals are only of moderate length, diverging backward. On the greater part of the length of the snout the subrostrals are parallel with the prenasals; leaving the latter finally, they pass outward and then forward to make a close fold on themselves before taking a transverse direction in which they meet the suborbitals. At the inner edge of the nostril the nasals make a sharp bend, then, converging forward, they unite to form a short longitudinal median. From the median the prenasals at first bend outward rapidly, then converge gradually toward the tip, near which they end without connections.

The following peculiarities are among the more likely to prove characteristic: the shape of the pleural area, the short occipital, the length of the tubules, the closeness of the fold in the subrostrals, and the longitudinal median.

Raia.

Raia lævis (Plates XXVII.–XXIX.). Some resemblance is seen in the shape of this species and that of Uraptera, and there is still more in the arrangement

of the main canals. If these vessels alone were taken into consideration, more than specific distinction would not be accorded the two types.

In comparison with the preceding the laterals on the smooth Skate approach each other more gradually behind the shoulders and more abruptly in front of them. Over the gills the branchial area is wider, and in general it is more irregular in outline. The majority of the tubules on the hinder branch of the pleurals run forward or outward, and on the post-scapular, toward the hinder margin, a number of them turn backward.

The occipital is rather long. At the side of the eye a branch, from the suborbital, turns back in the direction of the branchial area. Three or four tubules connect the orbitals with the pleurals; the latter go down near the margin, more than half the length of the snout in front of the skull.

Beneath the disk the subrostral is parallel with the prenasal more than half the distance to the mouth; it then turns outward, and returning makes a sharp curve and fold, not quite as close and complete as that of Uraptera, after which it goes back obliquely, instead of transversely as in that genus, thus bringing about a shortening of the orbito-nasal. The pleural lies close by the side of the angular and orbito-nasal; opposite the mouth it bends outward a short distance, then stretches back almost directly toward the posterior angle of the pectoral; and about as far back as the middle of the abdomen it turns to the coraco-scapular arch to meet the jugular. The space included is narrow in front, and much broadened at the shoulder girdle. There is a moderate amount of curvature in the nasal. The median is transverse. At the median the prenasals make a broad bend; they are not connected in front. The oral is disconnected, and is in two sections.

Plate XXVII. shows the tubes and tubules of the upper surface; Plate XXVIII. gives (fig. 1) the hyaline mucous ducts of the "ampullæ of Lorenzini," and (fig. 2) the main tubes of the canal system of the same surface; and Plate XXIX. contains a view of the lower side of the head in fig. 1, and a sketch of the upper surface in fig. 2.

Raia ocellata (Plate XXX.) is one of the species with shorter snouts. In consequence of the rostral shortening, the lengths of the prenasals and of the rostrals have been decreased so much as to bring their forward extremities almost back to a transverse line from the end of one suborbital to that of the other.

Above the thoracic region the curves of the laterals are shallower, and the scapular bends are less prominent, than in *R. lævis*. The pleural areas are subtriangular, broader posteriorly. The posterior branch of the pleural is the longer. A strong post-scapular extends from the shoulder obliquely out to the posterior margin. This tube is provided with tubules on its outer half. Laterals, pleurals, and orbitals also have tubules, which are more or less irregular in regard to length.

The occipitals are of moderate length. The cranials have a prominent curve opposite the fontanelle, and another near the orbitals; their tubules are short, with the exception of several in front of the orbit.

On the ventral surface the pleurals are entirely absent, from the posterior jugular extension. A moderate length obtains in the orbito-nasal. The curve in the subrostral is very prominent, and a trifle more open than that of *R. lævis*. A decided curve appears in the nasal. It is difficult to determine whether the median is longitudinal or transverse, it is so very short. Near the mouth, the prenasals separate widely; forward, they are convergent but not connected. An oral appears behind each half of the lower jaw.

Torpedo.

Torpedo californica (Plate XXXI.) goes much beyond the following species in respect to the amount of surface covered by the tubes and tubules. On the shoulders, the curve, or, better, the scapular angle of the laterals, extends farther out, and, the batteries occupying a larger portion of the disk, the pleurals are carried nearer to the margins. As in that species, pleurals and suborbitals seem to form a continuous tube.

The aural is longer and straighter and in front of it the cranials converge more. The rostrals extend farther toward the border, and are better provided with tubules than in *T. marmorata*.

At the sides of the suborbitals, and the thoracic portions of the laterals, long tubules pass out upon the batteries, nearly across them. A marked contrast is presented by this distribution when compared with that of the following, or of Narcine, in both of which the tubules venture little if any over the surface of the batteries. A number of long tubules put out from the aural toward the shoulders. Behind the angles on the pectorals formed by the pleurals, there is a strong tubule with several branches; elsewhere the tubules are simple.

There is much irregularity in the cephalic tubes, and it is probable that there is considerable variation between individuals of the species in regard to suborbitals and rostrals. In fact, there is great variance in the tubes of opposite sides of the head of a single specimen. This is well illustrated by dissections of the head of *T. occidentalis*.

Torpedo marmorata (Plate XXXII.) accords substantially in the arrangement of the canals with *Narcine brasiliensis*, but the tubes are longer and more crooked, and the tubules are of much greater length. On the back over the branchial region the laterals are considerably curved. Surrounding the large batteries the pleurals approach very near to the front margins of the disk. These tubes unite directly with the suborbitals. The occipitals are long. The cranials make a rather sharp curve in front of the eye, and they disappear before reaching the end of the rostrum. Among the longest tubules are those situated posteriorly on the pleurals and the orbitals, and anteriorly on the laterals.

This genus agrees with *Narcine* in the absence of the canals on the lower surface.

Absence of post-scapulars, or, better, the backward position of the pleurals

where joined to the laterals, is an approach toward the Trigonidæ rather than toward the Raiæ.

The lack of canals on the lower surface and the junction of pleurals and orbitals sufficiently distinguish the Torpedoes from other families.

Narcine.

Narcine brasiliensis (Plate XXXIII.). Apparently there are no traces of the canals on the ventral surface. On the back there is a very simple arrangement of the system. The lateral passes directly to the end of the vertebral column. Only a moderate degree of prominence is given the scapular curve. Rather widely separated at the shoulders, the laterals converge toward the back of the head. The tubules are short and not many. At the outer edges of the batteries the pleurals encroach but little on the pectorals. Half-way from the eye to the margin they unite directly with the suborbitals.

The occipitals are long. About midway from the eye to the end of the snout the cranials dwindle and disappear, after sending off a group of short tubules in front of the eye. The curve around the eye described by the orbital is somewhat regular, and the canal ends near the margin. It sends out a couple of short branches near the spiracle, and some shorter ones in front of the junction with the pleural. A strong tubule reaches backward from an angle in the pleural, opposite the scapular bends. From the lack of branchlets, the small size of the tubules, etc., the total length of the system is much below the average of the order.

Potamotrygon.

Potamotrygon motoro (Plate XXXIV.). Upon the shoulders of this species the laterals bend outward in a variety of curves. The anterior of these, the greater ones, are concave, the posterior convex. A very little behind the girdle the pleurals are met. There are two pre-scapular tubules, which do not enclose an area. Behind the pleural there are several post-scapulars more or less disposed to unite soon after leaving the main tube. The pleural starts from several branches which form scapular enclosures. Backward from the aural the laterals describe the outlines of a goblet, with the bowl extended forward, and closed by the aural. The occipital tubules are not far behind the ends of the latter. At the fontanelle the cranial curves are but moderate. Tubules are numerous on the head, and backward; in general they branch two or more times. From the laterals the pleurals pass backward and outward, rather more than in the sketch, until well out on the fin, where they form a somewhat sharp angle and turn forward in a broad curve; in front of the eye they turn inward, and, passing under the orbital, they descend at the fore part of the skull. Long tubules, with small groups of branchlets at their ends, extend laterally toward the margins. Two or more tubules join the pleural and the orbital. A branch goes back from the orbital at the eye, and, in front of the

orbit, five or six long tubules reach toward the anterior border. The orbital goes down at the side of the rostral, not half-way from the skull to the end of the snout. Nearly or quite all of the tubules on this surface are branched.

On the lower aspect the pleurals pass toward the front margin, and, running parallel with it, send out a number of simple tubules; afterward, along the middle of the fin, they take a course of some directness to the posterior extension of the jugular, a little distance forward from the pelvis. A single tubule marks the turning point. Bending around and back, as far as the mouth, in a waved course, the suborbitals make a long loop forward. Behind this loop they extend toward the gill apertures; in front of the latter they turn toward the nostrils and meet the subrostrals opposite the mouth. The orbito-nasals are of medium length, the nasals are long and moderately curved, the median is short, and the prenasals are elongate and close together. Between the nostrils each subrostral makes a deep bend, on the nasal valve; they end, at the side of the prenasals, in a series of rings or capsules connected with each other by thin transparent tissue, which only near the mouth presents the semblance of a tube. These rings are closed follicles, which do not appear to be connected with the surface; they seem in most respects identical with the follicles of Savi, and trace their origin to obsolescent canals, of which portions surrounding certain nerve endings have persisted and become closed sacs. Rings and enlargements also are seen in the front portions of the prenasals. On each side of the symphysis, near the teeth, a crooked oral reaches about half-way to the first gill cleft. A short sternal crosses the middle in front of the pelvic spine.

Distinguishing peculiarities appear in the presence of both pre- and post-scapulars, in the isolation of the subrostrals, in the groups of tubules on the front sections of the ventro-pleurals, and in the oddly shaped loop in the suborbitals.

Disceus.

Disceus strongylopterus (Plate XXXV.). One of the most peculiar canal arrangements to be found in the order occurs in this genus. Pre- and post-scapulars are both present, and, outside of the prominent scapular curve in the laterals, there is a pre-scapular area included by the pre-scapulars. The post-scapulars are short; by uniting among themselves or their branches they form an irregular plexus. First passing back from the laterals, the pleurals then turn forward at a sharp angle, and, in their course through the middle of the pectorals, send toward the margin a large number of long tubules, each of which bears a small group of branchlets at its end. Connecting with the orbitals by means of a couple of tubules, the pleurals bend back toward the forehead, whence they run forward a little more than half the distance to the tip before descending.

The aural is long and transverse. Starting outward from the aural, the elongate occipitals turn forward, after sending out the occipital branches. In

front of the eye, the short cranials have a very sharp and prominent bend; on the rostrum they are close together and nearly parallel. From the branch sent back of the spiracles the orbitals incline a little outward, and proceed thus until more than half-way to the edge, when they turn inward; close to the rostrals they again take a longitudinal course for a short distance, and find their way down, in front of the pleurals, after sending out upon the fin ten or a dozen long tubules.

On making their appearance on the lower surface the pleurals pass directly forward; nearing the margin they turn and follow it around, gradually receding from it, to a point opposite the mouth, where they turn toward the abdominal chamber. Back of the shoulder girdle they turn slightly outward; and when opposite the pelvis they turn toward it abruptly, meeting the extension from the jugular at the edge of the abdomen. On the transverse posterior portion, near the pelvis, there are a few tubules of medium length; on the portions anterior to the gills there is a multitude of tubules that reach to the edge of the disk. The suborbitals emerge a little in front of the pleurals, which they cross, to run obliquely back until not far in front of the gills, where they take an inward and forward course to meet the angulars a little back of the mouth. As they pass backward they send off nine or ten branches which by repeated forkings and fusions form networks, the outer limits of which are the pleurals, and in which the inner areas are large and elongate polygons and the outer small and short ones. The orbito-nasals are of moderate length, connecting, as in the majority of the Sharks, with the angular and suborbital posteriorly, and with the subrostral and nasal anteriorly. Each subrostral makes a very prominent bend in front of the nostril; it does not return far enough to reach the nasal valve; and it ends at the side of the prenasal, near the skull, in a series of four or five swellings or follicles. No great amount of curvature appears in the nasals. The median is very short. The prenasals are close together and nearly parallel; they have several irregularly placed rings or bunches along their sides. Not far from each angle of the mouth there is a short disconnected oral.

The sketches were made entirely from the left side of the specimen.

This genus is well distinguished from its allies, the Potamotrygons, on the one hand, and the Thalassotrygons, on the other, by the disposition of the tubes on the shoulders, and the orbito-pleural plexus beneath the pectorals.

It is quite possible that the appearance of the follicles on certain of the canals of the ventral surface, attended by deterioration and disappearance of the tubes themselves, in this genus and Urolophus, and in species of other genera, points toward a change made from habits similar to those of the typical Thalassotrygons, in which the lower canals possessed great utility, to others leading the individual to remain habitually on the bottom, where the lower vessels may be comparatively useless, which if persisted in lead to disuse and ultimate obsolescence of the tubes, as in the Torpedinidæ. It is not far to the conclusion that, through their ancestors, Torpedoes, as well as Potamotrygons, were more closely related to the Thalassotrygons.

Urolophus.

Urolophus halleri (Plate XXXVI.). A striking feature in this ray is the absence of the post-scapulars. Their position is occupied by the pleurals and by the pre-scapular branches. In the genera Raia and Rhinobatus the pleural met the anterior of the scapular branches; in this genus it is the posterior. From the anterior part of the scapular curve there is a pre-scapular branch which connects with the scapular, enclosing a small pentagonal area. Behind the aural the laterals converge in a gradual curve until rather close together. The aural is transverse. The occipitals are elongate and diverge forward. At each end of the aural, on the laterals, there is a small occipital tubule with a number of branchlets. The pleurals run forward a little way outside of the basipterygium of the fin; they pass under the suborbitals and go through close in front of the skull. One or more tubules connect these tubes with the orbitals. Laterally long tubules extend more than half the distance to the border. At the fontanelle, the cranials make deep curves outward; beyond this they approach each other until nearly in contact at the tip of the snout. The orbital sinks deeply into the tissue; at the outer edge of the spiracle a tubule is sent backward, farther forward others pass out laterally, one or more uniting with the pleural, and in front five or six long ones reach toward the front edge of the disk. The tube passes down about midway from the fontanelle to the end of the rostrum.

Beneath the disk, on their appearance the pleurals run forward as far as to the middle of the snout; thence they turn laterally and describe an arc of a circle having a radius of about the distance between the first pair of gill openings. This carries them back to a point opposite and near the coraco-scapular, a point from which they pass directly to join the jugular extension. Radiating from the outside of the circle there are two- or four-branched tubules of medium length. Emerging on the lower surface the suborbitals make a broad sweep laterally, then turn back until behind the mouth, and then forward toward the nostril till they meet the subrostrals. The connections of the short orbito-nasal are similar to those of Isurus and the Holocephala, and not to those of the majority of the Sharks. The angular is short, and reaches toward the inner edge of the gill cleft. The jugular bends outward before running back along the branchial apertures. No union is apparent between the rostrals and the subrostrals. From the orbito-nasal the latter are transverse in general course; they make a prominent bend forward in front of the nostril, and another back upon the nasal valve, thence they pass forward at the side of the prenasals, growing more and more delicate and transparent, and vanish before reaching the middle of the snout. Individuals show the peculiar enlargements or swellings in the tubes, in front of the median, that are seen in Potamotrygon. These rings or swollen portions closely resemble the follicles of Savi They seem to be connected with the prenasals by the tissue of the walls, but communication with the chambers of the tubes could not be discovered In the nasals the curves are not very pronounced. The short median is hidden

by cartilage. The prenasals diverge little from the parallel; they are disconnected forward. Behind the mouth, on each side, is a disconnected oral.

The tubules of the back are more or less dissected into fine branchlets, which form small groups about the ends. On the head the branchlets are close together. Only the principal ones were sketched, but, when possible, they were followed to their terminations.

Urolophus torpedinus differs from *U. halleri* mainly in matters of detail, in tubules, etc. The specimen at hand has five of the enlargements, at the side of the prenasal, in the subrostral; the tube ends with the fifth, seemingly without other anterior connections, excepting by tissue from the walls.

The junction of the pleurals to the anterior scapular branches in Rhinobatus, and to the posterior in Urolophus, indicates that both may have been secondary attachments; in other words, that the attachment of origin in the pleural is that with the orbital

Tæniura.

Tæniura lymma (Plate XXXVIII.) possesses both pre-scapular and post-scapular branches. What is called the pre-scapular area in Urolophus and in Dasybatus becomes, by the junction of the pleural tube to the middle of the outer boundary, a scapular area in this form. Three of the long tubules on the hinder part of the pectoral diverge from a single short stem, which connects them with the pleural. After connecting with one or more of the orbital tubules, the pleurals go downward near the forehead. Immediately in front of the prominent scapular curve the laterals approach each other closely. They send out the occipital branch near the end of the aural. Along the greater portion of their lengths they are studded with short tubules, the majority of which are branched two or more times, making four or more of the branchlets. On the skull the extremities of the dissected tubules interfere with each other so much, and become so confused, that it is not possible to present more than an approximation in the sketch.

An arrangement of the pleurals on the under surface intermediate between that of Urolophus and Dasybatus is presented by this specimen. The lateral curve of the tubes is not so round or so regular as in the former genus, and the tubules are more massed along the anterior edge. Compared with the latter, the lateral sweep is more regular, and the tubules are much less crowded along the anterior margin. From their point of appearance near the median the pleurals describe curves which are entitled to rank as intermediates between those traced by the same tubes in the genera cited. At each end the suborbital is bent so as to form a hook; it meets the angular. Forward from the nostril there is a deep fold in the subrostral; the tube does not return quite to the nasal valve, and it cannot be traced beyond the base of the snout. The nasal is moderately curved. There is a very short median, apparently transverse. Behind each side of the mouth there is a short oral, which has the appearance of being affected by the swellings elsewhere seen in subrostrals

or prenasals, possible precursors of the follicles of Savi, evidences of the action of causes tending toward disruption and destruction of the canals. Below the disk the tubules are rather short and are somewhat separated, but not so much so as in Urolophus.

The great difference of the canal distribution as compared with that obtaining on the Potamotrygons is evidence to be added to that advanced by the writer in 1877, of the necessity of separating the river Trygons from the species properly belonging to the genus Tæniura.

Dasybatus.

Forward on the thoracic region of *Dasybatus nudus* (Plate XXXIX.) the laterals are nearer to each other than they are above the abdomen. On the shoulder the curve is moderately prominent. There is a pre-scapular branch, and also an area. There are no post-scapulars. The pleurals do not extend much farther out than the basipterygia of the pectorals; their tubules reach more than half-way to the margin of the disk, and end in small groups of branchlets. The pleurals descend rather close to the forehead. The aural is moderate; the occipitals are longer; and the occipital branches may spring either from the occipitals themselves, or from the laterals, or from both, as may happen, though most often they appear on the first. Posteriorly the cranials converge; the orbital curve is pronounced; and the canals seem to end on the snout. The orbitals cross the pleurals twice; they then go through to the lower face of the disk, more than half the length of the rostrum from the forehead. Their tubules are long and are branched at the ends. One only joins the pleural.

Under the disk the figures outlined by the tubes are still more characteristic. Within the subrostral loop, in front of the nostril, the pleural makes its appearance. From this point it sweeps out and forward toward the tip of the snout, crossed by the subrostral once and by the suborbital three times. Before reaching the extremity it turns, and, running close along the anterior margin, sends forward a great number of fine short tubules. Near the outer angle of the pectoral it bends across the fin toward the pelvis, in front of which it meets the post-jugular extension. All of the tubules on this surface are along the pleural in front. Four areas are outlined by the suborbital. Only one of them is completely circumscribed by it, from the fact that two of its branches end without connections. With the aid of the pleural, in front, the otherwise open areas one, two, and four are enclosed. The first goes back as far as the nostrils, the second as far as the mouth, the third as far as the middle of the space between the mouth and the gills, and the fourth area ends opposite the second gill opening. Suborbital and subrostral meet at the short orbito-nasal. Angular and jugular are both crooked in irregular flexures. The subrostral is very much bent and folded; a prominent loop extends forward in front of the nostril, and another upon the nasal valve. This canal disappears, without visible connections, at the base of the snout. The nasal has not a

great deal of curvature. The median is short. The prenasals are long. On each side of the middle behind the lip is an oral that extends but little farther than the corner of the mouth.

Marked variation in the branches of the suborbital occurs on the specimen sketched. Of species similar in shape, *Dasybatus walya* resembles this one very much in the patterns described by the orbitals, but *D. zugei* is even more simple than *D. dipterurus* in respect to the same tubes. In the first case cited the similarity is so close as to raise doubts of the specific distinction of the two.

Dasybatus dipterurus (Plate XL.). Compared with the preceding, this species shows less prominent scapular curves, sharper bends in the cranials, more connections between orbitals and pleurals and less distance between their points of descent, and a larger number of tubules. On the lower surface the differences are a great deal more pronounced. The pleurals do not reach so far laterally, and they bear tubules toward the sides and posteriorly as well as in front. The suborbitals traverse a comparatively direct course, though affected by many small flexures, till they reach a point opposite the mouth, where they turn toward the nostrils, parallel with their former route, and meet the subrostrals directly in advance of the first gill cleft. The subrostrals also are sinuous; they form a prominent loop in front of the nostril, and, apparently, vanish near the base of the rostrum after advancing very little on the nasal valve. There is little doubt that the subrostrals and rostrals join; the latter pass to the lower surface, and may be traced back half the length of the snout before the walls of the tubes become so thin and delicate as to be undistinguishable from the surrounding tissue. The condition of the orbito-nasal in this specimen is one of uncertainty: on one side the subrostral and the orbital meet, on the other side the subrostral and the nasal join.

Dasybatus tuberculatus (Plates XLI., XLII.). Differences between this species and the preceding are numerous, and very noticeable. But a moderate degree of prominence is to be seen in the scapular bends of the laterals. The scapulars and the pre-scapular area are separated. The occipital branch is situated at the end of the aural. An intricate orbito-pleural plexus is formed, in which the spiracular branch of the orbital is concerned, with the usual anteorbital tubules. The tubules are abundant, elongate and branched; the posterior one on each pleural is forked. Toward the forehead the cranials diverge gradually; opposite the fontanelle the curves are strong and sharp. Half-way from the eyes to the end of the snout the orbitals pass to the lower surface. On the same transverse line, below the snout, are the points of emergence of both the orbitals and the pleurals, the latter being a trifle farther from the prenasals, although on the top they started down close to the skull.

Considerable resemblances are seen in the outlines traced by the pleurals on the ventral aspects of the three species sketched, from this genus. There is the same outward prenarial curve, the same course along the anterior border with the great number of short tubules, and a similarly crooked route across the pectorals in the direction of the pelvis. The suborbitals connect with the

subrostrals, as in both of the preceding, but do not reach them by a comparatively simple course, as in *D. dipterurus*, or through complex areas, as in *D. nudus*. At the start they run forward to turn sharply back and to the side, before reaching the pleurals; then they commence a series of perplexing and seemingly erratic turns, doublings, and zigzags, that ultimately bring them opposite the second gill clefts and thence forward to the short orbito-nasals. Equally crooked is the course of the subrostral; it makes two prominent loops at the side of the nostril, one in front of it, and another at its inner side upon the nasal flap, before making its way directly to meet the rostral at the tip of the rostrum. The nasals partake slightly of the tendency toward sinuosities, as also the prenasals, orals, angulars, and jugulars. The median is short.

No attempt has been made in the drawing to follow the tubules of the head or back. The laterals continue along the sides of the tail throughout the whole of its great length. Under the snout the subrostral is difficult to trace, so much so that the connection with the rostral may yet be considered an open question.

Pteroplatea.

Plates XLIII.–XLV.

Nowhere else in the order, so far as it has come under our notice, does the development of the canal system attain such a degree as in this genus. So great is the number of tubules and branchlets that the larger portion of the upper surface is a tangle of minute vessels. They are most closely grouped in a broad band along the anterior margin, and on the head; posteriorly they are not nearly so much crowded. A space entirely unoccupied by them is found on the middle of each pectoral, whence it extends upon the branchial area. Smaller spaces, quite as free from them, appear in the scapular areas, and above the abdomen behind the scapulars. On the ventral surface the extent of the canals is not so remarkable; it is not much greater on this side of the disk than in species of Dasybatus. The only cause that suggests itself for such an extraordinary development of the system on forms that seem so poorly provided with means of progression, of defence, or of procuring subsistence, is a greater dependence on vibrations in the water for knowledge of the presence of enemies or of prey.

Pteroplatea hirundo (Plate XLIII. fig. 1). Resemblances in shape of disk between this species and *P. valenciennii* are accompanied by similarities in the figures outlined by the main canals. The pre-scapular area is large, and lies in front of a scapular network, in the formation of which the post-scapular is also con d. Anteriorly the smaller canals are less numerous and much more loosely arranged than in either of the following species. Posteriorly, also, the vessels are less abundant, and their general appearance is more straggling and scattered than the case on the same locality in those forms. The pleural appears on the lower surface about half-way from the median to the tip of the snout.

Pteroplatea marmorata (Plate XLIII. fig. 2). Greater length of disk and less lateral extension naturally bring about differences between this species and the following, in regard to shapes and outlines of areas, etc. For instance, the curve in the pleural behind the shoulder is comparatively deeper and shorter, and the finger-like area, projected toward the outer angle, stretches obliquely backward instead of nearly straight outward.

A pair of strong pre-scapular branches are situated close together on the forward portion of the scapular curve. These are not connected with the scapular area, which is at some distance from them and close to the pleural canal. An elongate post-scapular branch lies near to, and for some distance parallel with, the pleural. The masses of tubules and branchlets are more compact than in the preceding, and less dense than in the following. On the lower surface the pleural emerges two fifths of the distance from the median to the tip.

Pteroplatea valenciennii (Plates XLIV., XLV.). Neither of the other species figured possesses so great a number of tubules as this one. Forward, the tubes are completely hidden. The laterals may be traced without removing the smaller vessels, except close to the back of the head. In the scapular section the curves are extensive, though not very prominent toward the pectoral. Near the aural the tubes are rather close together; from their bends in this vicinity long tubules, with two or more branches, extend back beyond the shoulders. Long tubules, also, put out from the sides of the laterals over the abdominal chamber, beyond which the main canals continue to the end of the tail. A couple of pre-scapular areas lie in front of the scapulars; the latter originate in a plexus of scapular and post-scapular branches, in which it is difficult to trace the main line. A broad shallow bend, toward the hinder margin, brings the pleural behind and outside of the middle of the pectoral; there it turns forward and slightly inward till in front of the middle, where it turns directly toward the outer angle, making a deep notch, open backward. Some distance from the angle of the fin the tube turns toward the eye, nearly parallel with the margin, and, after meeting four or five of the suborbital tubules, descends near the forehead between the suborbital and the cranial. Anteriorly the tubules are numerous, branching into a thicket; posteriorly they are not so many or so short, and do not present such a confused mass of branchlets. Occipital branches occur on both laterals and occipitals. Opposite the orbits the orbitals make a prominent bend outward. On this bend are the tubules connecting with the pleurals; behind it are several long branches; and in front of it are a number of long tubules reaching forward. The orbitals descend in advance of the pleurals, and much nearer the rostrals. On the cranial the ante-orbital curve is sharp and produced.

Ventrally the pleurals extend near the front edges of the pectorals, for more than two thirds of the length of the latter, before turning toward the abdomen and meeting the jugular extension a little backward from the scapular arch. They emerge in the posterior third of the distance from the median to the tip of the snout; not as shown in the sketch, where the median is too far back and the pleural too far forward. The orbito-nasal is a mere point, as if the tubes

crossed each other at right angles. For about half the width of the pectoral, the suborbital passes directly outward, parallel with the pleural. From its outermost point it goes to the orbito-nasal. The subrostral lies close to the side of the prenasal, connects with the rostral, and does not reach the nasal valve. The median is short. The prenasals are moderate, disconnected in front. The pleural tubules of this surface, the lower, are most numerous on the anterior section of the tube; they are not long, and have no branches

Myliobatis.

Plates XLVI.-XLVIII.

Above the disk the canals and their branches extend only about half-way from the vertebral line to the outer angles of the pectorals. Within these limits the surface is closely occupied. There is a great tendency to form rosettes or mats of branchlets, at the ends of the tubules. From the forehead back to the base of the tail on each side of the vertebral column, the groups are dense, and so large as to be nearly continuous as a single one. The pleurals range close to the borders of the branchial areas.

On the lower surface the pleurals run outward and return near the anterior border of the pectoral, and they then pass backward very near the basal cartilages, thus merely skirting the fin. Elongate tubules pass outward on the base of the fin, hardly covering a fourth of the length, and others pass from the jugular extension inward upon the abdomen. In great part the orals are longitudinal. A continuous tube has, in each of the species drawn, taken the place of the separated sections of the oral, as apparent in the majority of the Batoidei.

Myliobatis aquila (Plates XLVI., XLVII.). Tubules and branchlets are numerous, above the abdomen, on both inner and outer sides of the laterals, in this species. The scapular curves are not very prominent; the scapular angle is sharp. A pre-scapular enclosure, of moderate size, lies in front of the scapular, and, by union of pleural and the elongate post-scapular branch, a small scapular area is enclosed. The branchial area is somewhat well covered by mats of branchlets, from the occipital and from the pre-scapular tubules. The occipital is elongate, and in some cases it bears the occipital branch; in others, this branch rises behind the aural. Tubules are very plentiful on the cranials. The ante-orbital bend in these tubes is moderate, and their rostral portions are short. Near the spiracle the orbital crosses the pleural, and it traverses two thirds or more of the length of the snout before going to the lower surface. In front of the eye the pleural rises upon the forehead; it makes its appearance on the under side near the nostril. Pleurals, orbitals, and cranials are thickly beset with tubules on or about the skull.

Beneath the disk the outward course of the pleural lies near the anterior margin, for two thirds of the length of the latter; the tube then turns back, making a sharp angle, to take a backward course close to the jugular. It does not extend as far back as to the pelvis, and the spaces enclosed by it, with the jugular and suborbital, are very narrow and elongate.

Behind its junction with the orbito-nasal the elongate suborbital makes a prominent loop. A similar loop occurs in the subrostral in advance of the nostril, and a second appears between the nostril and the median. The nasal is not greatly curved; it joins the subrostral, which in turn unites with the prenasal. Median and prenasals are short. The oral is crooked and branched; it extends back between the branchial clefts of the first pair. Tubules of moderate length, more or less branched, reach out upon the abdomen from the jugular, and upon the posterior areas of the pectoral fin from the pleural.

Myliobatis freminvillei (Plate XLVIII.). Compared with the preceding this Ray has a greater number of the pleural tubules massed together opposite the spiracles, and fewer of them reaching out upon the body of the fin; and it has longer rostrals, orbitals, and prenasals. The scapular enclosure appears incomplete on its outer boundary. The occipital branch is connected with the long occipital, and also with the lateral, possibly an individual peculiarity. Beneath the disk the areas enclosed by the pleural are more irregular, but the oral is curved much more regularly. The nasal joins the subrostral, which unites with the rostral. The orbito-nasal is short, being little more than a crossing of nasal and angular. Subrostrals and prenasals are not united.

Aëtobatus.

Aëtobatus narinari (Plate XLIX.) has but slight scapular bends in the laterals, and, apparently, has neither pre-scapular areas nor pre-scapular branches. A post-scapular branch or two enclose a very small space. On the pleurals there are few branches; those that exist are long, reaching beyond the middle of the fin. The branchings of the tubules are similar to those of Myliobatis and its allies. Opposite the end of the aural on each side is an occipital branch. The occipital is long. A spiracular branch was not discovered on the orbital. For a short distance this tube unites directly with the pleural, without the intervention of tubules, as in most Batoids; it crosses the track of the cranial twice, in front of the skull, and it descends not far from the tip of the rostrum. The pleurals descend much nearer the fontanelle.

The arrangement of the lower pleurals is similar to that of Myliobatis, though the canals extend farther outward or backward; they are hardly so close together in front, but are closer to the jugulars along the branchial clefts. From both of the transverse lines of the pleurals, near the forward edges of each pectoral, the tubules run toward the front; from the longitudinal portions of the same tubes they pass outward, and from the hinder part of the extension from the jugular they reach inward. The suborbital and the angular meet below the posterior edge of the orbit, whence a long orbito-nasal connects them with the nasal and the subrostral. Both of the curves in the subrostral, that in front of the nostril and that on the nasal flap, are sharp and prominent; the tube joins directly with the prenasal a little way in front of the median. As is generally the case in the group, the median is rather short; the point at

which the nasals unite is vertically above, or a little in front of the mesial forward bend, formed by the junction of the prenasals with the median. Consequently the median may be described as nearly or quite vertical. The prenasals are elongate; they unite directly with the subrostrals, forming with them a single tube on each side of the rostral cartilage, as in *Myliobatis aquila*. In *M. freminvillei*, which more closely resembles Aëtobatus in shape, these tubes are closely applied, but remain separate. At each side of the median line the oral of Aëtobatus sends forward a sharp curve, and on the outside of each of these a similar loop is sent outward; the tube goes some distance backward from this second bend before turning outward and forward. It ends without joining the angular.

The closeness of the relationships existing between this genus and the preceding are asserted in the characteristics of the canal system with as great emphasis as in any other portion of the anatomy.

Rhinoptera.

Plates L., LI.

So far as the general features of the canal system are concerned, this genus resembles both of the preceding. At the same time there are respects in which it differs decidedly from either of them. The majority of these are due to difference in the structure of the head, yet the divergences are not wholly confined to this portion. Again, on comparison with Dicerobatus the indications of close affinities are very conspicuous on the trunk, but on the head the relationship becomes apparent only on closer study, being masked by the dissimilarity in shape.

Rhinoptera brasiliensis (Plate L.). Abrupt bends give the scapular fold in this type more prominence than it would attain by a gradual curve, as it departs but little from the main course of the lateral. This fold bears a pre-scapular and also a post-scapular branch, and between them an elongate pre-scapular and a much smaller scapular inclosure. Behind the end of the aural, on the lateral, there is a strong forked occipital branch with a multitude of branchlets. Leaving the scapular area the pleural goes back and outward a short distance, where it has the appearance of being crowded back upon itself in a number of folds; from these it extends with tolerable directness to the side of the head. Its branches are few and long; their ends are much dissected. The two tubules in front of the posterior one are forked near the middle of their length; the hinder one branches a greater number of times.

All of the anterior cephalic canals are affected by many flexures, as if in compensation for the short distances between the extremities of the tubes. Bringing the mouth so far back toward the gill-openings, and ending the snout below the forehead, gives the rostral canal a vertical direction, and carries orbital and pleural under the anterior part of the skull. The tubules of the orbital pass forward on the inclined portion of the forehead. No distribution of the canals occurs on the upper surface of the rostral fins; the tubes seek the

lower face, going between these fins, and there become more sinuous and make broad and sweeping bends.

At the side of the head, opposite the angle of the mouth, angular, pleural, and suborbital are close together and paraHel. Below, the pleural emerges farther back than its point of disappearance on the top. It passes to the side of the face, thence to the pectoral, where, in its outward and its inward course, it traces a pair of lines along the greater part of the anterior border of the fin. Returned from this it runs back nearly parallel with and not far from the jugular extension toward the pelvic region. The tubules of both the anterior lines are directed forward; of the two posterior lines those of the outer line are extended outward, and those of the inner toward the abdomen, inward. Passing around on the rostral fin, near its border, the suborbital reaches a point on the side of the head, near the corner of the mouth, where it accompanies the pleural while making a long loop outward; coming back from this, it unites at once with the angular. The orbito-nasal is long, curving toward the oral. The nasal itself is neither long nor greatly curved. Two great loops occupy the whole of the subrostral: one turning forward in front of the nostril, and the other backward upon the nasal valve. Both the median and the prenasals are short. The latter are not connected with the rostrals. Behind each side of the mouth there is an oral of moderate length, in which the ends extend transversely in opposite directions from a median longitudinal section.

Rhinoptera (*Zygobates*) *jussieui* (Plate LI.). Prominent among the features in which this species differs from the preceding are the increase in the number of tubules on the cranials, the presence of a group of tubules immediately behind the orbital on the occipital, the extension of the prelateral branch between the spiracle and the cranial, the shapes of the scapular and the pre-scapular areas, the augmented number of branches on the posterior scapular tubule, the more regular curves in the suborbital and the subrostral, and in the union of the oral across the median line. Besides these there are other particulars of variance, more or less important, as a smaller amount of curvature in the pleural tubules of the ventral series, and greater parallelism in the prenasals, seen on comparison of the drawings. A close relationship of these species is indicated by the many points common to both.

Dicerobatus.

Dicerobatus olfersii (Plates LII., LIII.) presents a distribution of the corporal canals that, in the main features, bears much resemblance to that of Myliobatis, Aëtobatus, or Rhinoptera. There is a similar nearly parallel arrangement of two sections of the lower pleural near the front margin of each pectoral, and of two others, closer together, along the basipterygia of the same fin. On the dorsal surface the likeness to Rhinoptera is the greater. At the shoulder there is a single large pre-scapular area. Near the scapular arch the sinuous folds of the pleural are less prominent than in the preceding, but the branchlets of the tubules are even more massed toward the posterior angle of the fin. A post-

aural branch on the anterior extremity of the lateral recalls the same feature in Rhinoptera. Apparently the number of branchlets and openings is greater in Dicerobatus than in either of the other genera cited, and they form closer aggregations along the laterals or over the head. Connection between the laterals, across the vertebral line in the vicinity of the shoulder girdle, has not hitherto been observed. Still greater differences exist in the cephalic canals. If a specimen of one of the species of Rhinoptera were to have the pre-oral fins separated along the median line, and their inner edges carried upward and outward so as to be united to the skull along the edge below the eye, the mouth being at the same time much widened, an arrangement of the canals might be brought about that would present a somewhat near approach to that obtaining in Dicerobatus, so far as the distribution of the main vessels is concerned. The affinities between these genera are well indicated in the canals.

Laterals. — From the aural each lateral passes obliquely outward to the post-aural branch; thence it takes its way toward the point of junction of shoulder girdle and vertebral column. Nearing the latter, it sends a couple of tubes across it to the lateral of the opposite side, and immediately behind them turns inward and around, under itself, so as to make a rounded loop just in front of the pre-scapular enclosure. This may be an individual peculiarity. Behind the area the pleural is met, and farther back numerous tubules are sent out toward the median line. Half-way to the tail, or farther, some of the tubules pass to the outer side of the canal. In front of the shoulder seven or eight tubules are sent inward toward the vertebræ. The greatest branches are the post-aural and the scapular branch, by which the scapular area is enclosed.

Pleurals. — Each pleural encloses a branchial area of moderate size, that is widest near the middle of its length and pointed toward each end. Twenty-four branches pass outward from the canal, in the specimen at hand; the median reach little more than half-way from the middle of the back to the tip of the pectoral. The posterior of these tubules are more branched than the anterior, the latter being short, confused, and irregular. To make its descent to the lower surface the pleural passes through the edge of the disk, a short distance behind the spiracle, and drops downward, meeting on the way several tubes connecting with the orbital, until below the level of the eye, where it turns forward nearly parallel with, and a short distance below, the suborbital. With the latter it is connected at narrow intervals by short tubes, a half-dozen or more in number. Below the pleural, in the suborbital region, there are about a dozen short tubules with numerous fine branches, the openings of which appear as thickly strewn dots on the surface. Some of these tubules originate in the pleural, the majority, however, belong to the suborbital. A little distance in front of the eye the pleural passes obliquely backward and inward to the lower surface, making its appearance a very little in front of the nostril. From this its course is somewhat irregular backward and outward to a point below the spiracle, whence it turns still more outward and upward toward the lower side of the pectoral near the anterior border. Oppo-

site the angle of the mouth three or four tubules are sent downward and forward toward the lower border of the cephalic fin; a couple are sent inward behind the mouth; and several short ones are extended inward just before the tube enters its outward course along the border of the pectoral. Toward the anterior margin of this fin the canal puts forth a large number of short tubules, and near the outer angle, at the point of turning back on itself, two elongate branches are extended toward the tip. Each of these branches bears tubules. Returning toward the mouth the course of the pleural is not much farther from the edge. At first after making the bend it sends several tubules forward, then, near the middle of the fin, a number turn backward; nearing the first gill opening, some start forward, but turn and cross the canal, and still nearer, before turning back by the side of the extension of the angular, a few irregular branches are pushed forward. In their backward track the two inner sections of these sub-pleurals lie close together. The outer of the two has by far the greater number of tubules; from the shoulder girdle, anteriorly it sends these outward; near the girdle they are turned inward to cross the inner tube and reach the abdominal region. Opposite the middle of the abdomen, near the end of the course, the majority of the branches turn out and backward; a few only turn in to cross the tube; and at the turning-point of the tube an elongate tubule goes back upon the ventral fin. As the canal goes forward toward the jugular, it bears several branches turning toward the ventral region, then a few that cross the other section of the tube outward; but after leaving a point opposite the middle of the belly, it bears no others.

Aural. — This tube is elongate and strongly bent back in its middle, behind the openings of the aqueducts. Near the median line it sends back three or four tubules.

Occipitals. — From the aural, each of these tubes extends toward the eye, at the same time making a broad curve toward the branchial area, and sending several irregular branches in the same direction.

Cranials. — A cranial goes forward from the end of each occipital directly toward the tip of the outstretched cephalic fin, without passing beyond the skull. Posteriorly each bears a number of tubules reaching toward the median line, but beyond a third of the distance forward they all reach outward to the supraciliary prominence, where they end in a band of thickly set punctures. Anteriorly the tubules are more numerous, more slender, and more crowded.

Rostrals. — The rostral turns rather abruptly back and inward from the end of the cranial. It runs near the front edge of the snout until about half-way to the median line, where it passes to the lower surface. On the under side of the snout it curves broadly in the direction of the prenasals, then, taking a lateral direction before reaching the mouth, crossing and recrossing the nasal, and making a bend forward in front of the nostril, it crosses the pleural before meeting the orbito-nasal, which it joins opposite the corner of the mouth. One of the rostrals (*sr*), that on the right side of the specimen dissected, appears to be abnormal; it crosses the pleural, and a short distance behind it stops abruptly, making no connection whatever.

Orbitals. — The junctions of orbitals and cranials are deeply buried in the tissues of the top of the head. The orbital is directed obliquely out toward the eye. In front of the spiracle it passes through the cartilage to the side of the head; there it makes a shallow backward curve and meets three or four tubes connecting it with the pleural. Eight or ten similar connections are made from the suborbital, behind the point at which it is crossed by the pleural, as the latter passes to the lower (inner) surface between the fin and the skull. The majority of the branches uniting with the pleural below the suborbital in reality originated in the suborbital, but in crossing the other tube have become joined to it. After being crossed by the pleural, the suborbital, on its way forward, makes a number of sinuous windings, and sends forth a number of strong many-mouthed tubules, which are nearly parallel as they reach ahead. Anteriorly the tube divides. One section of it passes the edge of the fin to take a course on the inner side along the margin toward the tip; near the latter it turns back, in a slightly sinuous track along the middle of the inner surface of the fin, crossing the pleural, and meets the angular some distance behind its junction with the subrostral. The other section of the suborbital turns toward the rostral, running between it and the edge of the snout. Apparently it connects with the rostral, not far from the cranial, and descends, without going as far toward the median line as the former, to meet the extremities of the prenasals. The connections and extent of this portion of the suborbital are subject to a little uncertainty on account of the number, excessive delicacy, and confused condition of the tubules, and the preclusion of injections by the preservation of the specimen. The openings of the branchlets of the suborbital form an elongate band of pores extending below the eye forward to the upper edge of the fin.

Nasals. — These are strong transverse tubes; they become calcified as they approach the median.

Median. — This tube is elongate, transverse, and, like the nasals, enclosed in a calcified envelope.

Prenasals. — These are of moderate length, calcified posteriorly, delicate and slender anteriorly, and, apparently, connected in their front extremities by a very slender vessel from the suborbital and rostral.

Orbito-nasals. — The orbito-nasals are of considerable length, and turn outward posteriorly.

Angulars. — Each angular makes a broad outward curve toward the front margin of the pectoral.

Orals. — Excessive fineness and delicacy in these vessels makes it very difficult to work them out. They were first sketched from the low ridges formed by the canals on the outer skin. The terminations and finer branchlets, of course, could not be marked in this manner. On removing the skin, however, some of the tubules were lost, and it was found better to give the sketch as taken from the surface.

HISTORY.

The mucous ducts and the canals were more or less confused by the earlier writers. Usually both systems were treated as apparatus for the secretion of mucus, and for distributing it over the skin. It was a long time after the structural differences were pointed out before the difference in function was recognized. On account of the confusion, the list of authors treating of the canals is made to contain also those treating of the ducts, as there are in most instances contrasts with the canals, or references to them, even in such writings as are most exclusively devoted to the ampullæ of Lorenzini. And, further, to make the literature approximately complete on the embryogeny, the innervation, and the general homologies of the system, it is found necessary to include studies of similar organs on the Fishes, the Batrachia, and the Insects. Consequently a few works are cited which have indirect connection only with the subject of this paper.

As early as 1664 the outward openings of the ducts on the skin of the Skate were noted by Stenonis. Those on one of the Sharks were described by him in 1669. The information given by Blasius, in 1681, was drawn from the publication of Stenonis.

Lorenzini, 1678, in observations on the Torpedoes, recognized the existence of the two classes of vessels, and distinguished them by their distribution and by their branchings. Following the ducts he discovered their swollen inner terminations, now called the "ampullæ of Lorenzini."

Monro, 1785, in his book on the "Structure and Physiology of Fishes," figured both ducts and canals. Plate V. of his work traces the canals on the head and shoulders of a Cod. Plate VI. exposes the ventral ducts and the canals of a species of the genus Raia; and Plate VII. shows the ducts of the upper surface of the same Skate. According to this author each system formed part of "a very elegant structure for the preparation of the mucus."

Geoffroy, 1802, published his opinion that the mucous ducts of the Skate were the analogues of the electric apparatus of the Torpedo. His conclusions did not meet with ready acceptance among his contemporaries.

Jacobson, 1813, put out a short paper, entitled "Extrait d'un Mémoire sur un organe particulier des sens dans les raies et les squales," in the "Nouveau Bulletin des Sciences, par la Société Philomatique de

Paris," VI., p. 332, in which he announces the discovery that the ducts are organs of sense, carrying vibrations from the surrounding water to the nerves. He also pointed out that these vessels could hardly be the analogues of the batteries, both being found in the Torpedoes. Treviranus, Knox, and others followed, agreeing more or less completely with his conclusions. Delle Chiaje, Savi, and other observers, still claimed that the ducts were to be regarded as "organi mucipari," distributing the slime over the surface.

Blainville, 1822, and others of his time and later, among them Müller, looked upon the canals as apparatus for the secretion of mucus.

Savi, in 1840, announced his discovery of the "appareil folliculaire nerveux" to the Scientific Congress at Florence, and a year later it was published in the "Atti della terza Riunione degli Scienziati Italiani in Firenze."

Mayer, 1843, arrived at conclusions similar to those of Geoffroy, 1802, and held that the mucous ducts of the Raiæ were the analogues of the electric batteries of the Torpedinidæ.

Savi, 1844, sent out his "Études anatomiques sur le Système Nerveux et sur l'Organe électrique de la Torpille," in Matteucci's work, "Traité des Phénomènes Électro-physiologiques des Animaux," of which it forms an appendix. Here he gives a detailed description and figures of series of follicles on the Torpedo, which are apparently of the same character as those sketched in the present work, on Discens, Potamotrygon, and Urolophus, and which are here proved to be part of the canal system.

Without mentioning all the writers who may have touched upon, or referred to either canals, follicles, or ducts, we may simply call attention to Wagner, 1847, to whom is to be credited the hypothesis that the function of the follicles of Savi is to excite the activity of the electric organs, and then proceed to several of the more important contributions toward an understanding of one or another of the organs.

H. Müller, 1851, makes three groups of the vessels, the greater part of which are to him organs of sensation instead of secretion. To quote his words, "Unter der Rubrik 'Schleimkanäle' sind bei den Knorpelfischen verschiedene gebilde zusammengefässt, von denen nur ein Theil den Schleimkanalen der Knochenfisch analog ist. Ein grosser Theil der Kanäle bei Knorpel- wie bei Knochenfischen hat bestimmt nicht Secretion sondern Sensation zum Zweck."

Leydig, 1852, also makes three classes of the vessels, one class including the ducts, another the canals, and another the follicles of Savi. He characterizes them thus: —

"1, als verzweigte Röhren, die in oder unter der Haut liegen. Sie setzen zusammen das System der Seitenlinie also die Seitenlinie selbst und ihre Ausläufer;

"2, als nicht verzweigte Röhren, welche mit einer erweiterung — Ampulle — blind geschlossen beginnen und sich auf der äusseren Haut öffnen;

"3, als geschlossene Blasen, die also nicht in der Haut ausmünden.

"Mit der ersten und zweiten Classe sind sämmtliche Rochen und Haie versehen, mit der ersten, zweiten und dritten zusammen bloss die Zitterrochen."

Kölliker, 1856 and 1858, and Max Schultze, 1862, showed the existence of a sensitive epithelium within the follicles.

Leydig, 1868, brought forward one of the most important contributions to knowledge of the organs under consideration. It was entitled "Ueber Organe eines sechsten Sinnes," and it deals with the matter in the most comprehensive way. The three classes of vessels are accepted as organs of a sixth sense.

Boll's monograph, "Die Lorenzinischen Ampullen der Selachier," appeared in the same year, 1868. As its name indicates, it was devoted to the ducts, but references to the canals are included.

A valuable addition to the literature, and very exhaustive so far as the follicles themselves are concerned, is the monograph, "Le vesicole di Savi della Torpedine," 1875, by the same author. He is able in this work to give no additional light on the physiological function of the vesicles. The idea that they are a form of the canals has little in it that is seductive to him, since it involves, as he says, ascribing one office to two organs of very different structure in the Selachia generally, or to three diverse organs in the Torpedinidæ alone. The hypothesis of R. Wagner, that the follicles provoked, in reflex manner, the activity of the electric organ, he claims to have shown in 1873 to be without foundation; and he maintains that the opinion that the follicles of Savi represent an organ of electric sense may only be discussed when the presence or absence of analogous organs is established in the other electric fishes.

To Balfour, 1878 and 1881, more perhaps than to any other one, we are indebted for knowledge of the origin and innervation of the canals. He first found the lateral nerve to originate as the other nerves, and to push backward, following the lead of the canal and sending branches to connect with it in the successive segments that were traversed. His conclusions disagreed with those of Semper and Goette, who claim that the lateral nerve originates directly from the epiblast of the lateral line, but the results of more recent study favor his opinions rather than theirs.

In connection with the embryogeny, segmental distribution of the nerve-endings, etc., it is found necessary to refer to a number of publications relating mainly to other organs of the Selachia, or to similar organs in other classes of animals. Semper, Goette, Eisig, Dercum, Van Wijhe, Hoffmann, Wright, and others, have all put forward contributions which may not be overlooked, though not in most cases directly connected with the subject of this paper.

Solger, 1878–80, is the author of a number of papers relating to the microscopical anatomy in Selachia, Holocephala, and Fishes.

Sappey, 1880, in his "Études sur l'appareil mucipare et sur le système lymphatique des Poissons," did some work on the Selachia, the results of which are indicated on several plates illustrating the courses and connections of the canals, as well as of the mucous ducts, of a Skate, probably *Raia clavata*, and of a Shark, probably Galeus. This is the nearest approach to a delineation of the canal system since the attempt of Monro, nearly a century previous. Some peculiarities are to be seen on the plates in Sappey's publication, which apparently make the species dissected for the drawings to differ greatly from others of their genera. A number of the items of greatest variance are evidently the consequences of incomplete observations. The most questionable points on his Skate are these: (1) the connection of prenasal and subrostral; (2) the absence of connection between subrostral and rostral; (3) absence of junction of suborbital and orbital; (4) the disunited condition of upper and lower sections of the pleurals; (5) the ending of the upper pleural near the orbit; (6) the presence of a transverse canal between the cranials in front of the orbital; and (7) the absence of the aural. On his Shark neither aural, orbitals, nor orals would appear to have been discovered.

De Sède, 1884, in his "Recherches sur la ligne latérale des Poissons osseux," details the results of a number of essays toward a determination of the uses of the organ. In this work he also instituted a number of comparisons for the purpose of ascertaining its value in classification. He occupies the position of a pioneer in the directions of his study. From his experiments he decides that the line is a tactile organ of extreme delicacy. In the Selachia the canals demand higher rank as aids in classification than he accords them in the Teleostei, and his conclusion that the apparatus is more necessary to the least migratory fishes is directly opposed to what is seen on such Sharks as Alopias, or such Rays as Dicerobatus.

Beard, 1885, has made one of the most recent and important contri-

butions to the literature of the subject. In the main, his conclusions agree with those of Balfour.

Though the distinctions between the canals, the ducts, and the follicles had by a number of writers been kept prominently in sight for many years, Professor Agassiz was the first to attempt the use of the canal system as a basis for homologies, as an aid in classification, or as a means of tracing affinities, purposes for which it is admirably adapted.

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ABBREVIATIONS.

ang.	Angular.	*n.*	Nasal.	*pp.*	Post-pleural.
au.	Aural.	*o.*	Oral.	*r.*	Rostral.
cr.	Cranial.	*oc.*	Occipital.	*sc.*	Scapular.
g.	Gular.	*on.*	Orbito-nasal.	*so.*	Suborbital.
j.	Jugular.	*orb.*	Orbital.	*sp.*	Spiracular.
l.	Lateral.	*p.*	Pleural.	*sr.*	Sub-rostral.
m.	Median.	*pn.*	Prenasal.	*st.*	Sternal.

PLATE

I. *Isurus punctatus* sp. DeKay. With the names and abbreviations. Fig. 1, top, 2, front, 3, lower, and 4, side view of head.

II. *Chimæra monstrosa* Linné. Fig. 1, side, full length; 2, top, 3, front, 4, side, and 5, lower view of head.

III. *Callorhynchus antarcticus* La C.; Cuv. Fig. 1, side, and 2, back, full length; 3, lower view of head.

IV. *Callorhynchus antarcticus.* Fig. 1, side, 2, top, and 3, lower view of head.

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VI. *Prionodon milberti* (Val.) M. & H. Fig. 1, side, full length; 2, lower, 3, front, and 4, upper view of head.

VII. *Cestracion tiburo* L.; Dum. (*Zygæna* auct.) Fig. 1, lower, and 2, upper view of head.

VIII. *Mustelus canis* Mitch.; DeKay. Fig. 1, side, entire; 2, lower, 3, front, and 4, top view of head.

IX. *Triacis semifasciatum* Girard. Fig. 1, side, entire; 2, lower, 3, front, and 4, top view of head.

X. *Isurus punctatus* sp. DeKay. Fig. 1, side, entire; 2, lower, 3, front, and 4, top view of head.

XI. *Odontaspis americanus* Mitch.; Abb. Fig. 1, entire side; 2, top, 3, front, and 4, lower view of head.

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XIII. *Alopias vulpes.* Entire view of side.

XIV. *Heptabranchias maculatus* Girard. Fig. 1, side, and 2, top view of head.

XV. *Chlamydoselachus anguineus* Garman. Fig. 1, side, and 2, top view of head.

XVI. *Ginglymostoma cirratum* Gmel.; M. & H. Fig. 1, entire side; 2, lower, 3, front, and 4, top view of head.

XVII. *Scyliorhinus caniculus* sp. Linn. Fig. 1, entire side; 2, lower, 3, front, and 4, top view of head.

XVIII. *Heterodontus philippi* La C.; Blainv. Fig. 1, entire side; 2, lower, 3, front, and 4, top view of head.

XIX. *Acanthias americanus* Storer. Fig. 1, entire side; 2, half of lower, 3, half of upper, and 4, front view of head; 5, side of tail; 6, section of canal at side of tail.

XX. *Somniosus carcharias* Müller; Garm. Fig. 1, top, and 2, lower view of head.

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XXV. *Syrrhina brevirostris* Müller & Henle. Fig. 1, top, and 2, lower view.

XXVI. *Uraptera agassizii* M. & H. Fig. 1, lower, and 2, upper view.

XXVII. *Raia lævis* Mitchill. Upper surface, showing tubes and tubules.

XXVIII. *Raia lævis.* Upper view, showing (1) the hyaline mucous ducts of the "ampullæ of Lorenzini," and (2) the main tubes of the canal system.

XXIX. *Raia lævis.* Fig. 1, lower, and 2, upper view of head.

XXX. *Raia ocellata* Mitch. Fig. 1, top, and 2, lower view of disk.

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XXXII. *Torpedo marmorata* Risso. Upper view.

XXXIII. *Narcine brasiliensis* Oif.; Henle. Upper view.

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XLII. *Dasybatus tuberculatus.* Upper view.

XLIII. Fig. 1. *Pteroplatea hirundo* Lowe. Upper view. Fig. 2. *Pteroplatea marmorata* Cooper. Upper view.

XLIV. *Pteroplatea valenciennii* Duméril. Upper surface.

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LIII. *Dicerobatus olfersii.* Lower surface.