bony projections, which arise from the bottom of the dental socket; this is the case with the incisor teeth of Balistes, that thus present a double gomphosis. There is frequently a slight anchylosis of the bases of the teeth to the walls of the alveolar cavity, as in Sphyræna, Acanthurus, and others. In the majority of cases an actual fusion of the bony substance of the jaws with the sockets of the teeth exists. Before, however, this anchylosis is completed, the tooth has been united to the jaw by ligament. Occasionally, as in the posterior teeth of Lophius, the teeth are fastened by elastic ligaments to the maxillæ, and so disposed that during deglutition they yield downward and backward so as to offer no obstruction to the passage of food, and again spring up into their usual erect position when the pressure is removed. The teeth of the Sharks, for the most part bifurcated inferiorly, are attached by ligaments to the partly ossified edges of the maxillæ. A very curious mode of attachment is exemplified by the teeth of the Eagle-Ray (Myliobatis), in which the flat hexagonal teeth are united by suture to a series of quadrangular pieces.

The form of the teeth is likewise very varied, being either conical as in most Fishes, flat, prismatic, or cylindrical. The conical kind are frequently very numerous, and in such cases so small as to appear like papillæ, and may possibly serve only as instruments of touch; in other instances they are longer, almost filamentary like bristles, and divided at their apex into two or three prongs; in many Fish, *e. g.*, in Trichiurus, they are provided at their points with hooks; they are frequently largely developed, for instance, the canine teeth of many Carnivorous Fishes, *e. g.*, the Sea-wolf (Anarrhicas Lupus). The incisor teeth also may be perfectly flattened like those of the human subject, as in Sparus sargus, L., and behind these stand short cylindrical teeth with rounded flattened crowns. Such flattened teeth differ both in form and size; their plates are cylindrical, elliptical, elongated, triangular or quadrangular, semilunar or falciform; the same flat, tessellated kind of teeth are found in the jaws of the Saw-fish. It is not rare for the teeth upon the two jaws to differ, as in the Sharks, where the teeth that are destined to rise up and replace the others when they fall out, form numerous rows lying like tiles one over the other upon the inner walls of the maxillæ.

The number of the teeth ranges from one to so many that they can be scarcely counted. Thus the Myxinoidæ (*e. g.*, Bdellostoma, Myxine) have only one single slightly-curved tooth on the palate.

The genera Ceratodus and Ctenodus have two teeth above and two below, while in Chimæra we find four superior and two inferior teeth.

The substance of which the teeth in Fishes is composed presents very different characters. The teeth of the Cyclostomi belong to the category of epithelial structures, or horn-tissue. The dental plate upon the occipital process of the Carp consists of a peculiar brown, semitransparent tissue, harder than the substance of the horny teeth of the Lampreys. In most Chætodonts the teeth are delicate, flexible, and elastic, and composed of a yellow transparent tissue, this being the case also in the labial teeth of Helostomus. In most Fishes, however, the teeth consist of Osseous substance, slightly denser than that of the jaws to which they are attached. Occasionally, as in Exocœtus and Echeneis, the substance of the teeth is uniform throughout, and not invested by a layer of denser texture. In others, *e. g.*, the Sharks, the tooth is covered by a dense transparent enamelloid substance; it is not, however, true enamel, but the proportion this substance bears to the rest of the tooth may be determined from the larger quantity of earthy constituents which it contains, the finer division and more parallel arrangement of its calciferous tubules. In Sargus and Balistes the peculiar osseous substance of the tooth is still harder, and covered by a thick layer of a denser substance, which differs little from the enamel of the higher Vertebrata. In Balistes also, and some other Fishes, we find a third layer superadded, that may be compared to the cementum of the Mammalia. In Scarus there is found even a fourth material, forming a very dense ivory-like layer upon the periphery of the tooth. In Fishes the small dental tubes (*canaliculi chalcophori*) are extremely distinct, and the microscopic structure of the teeth in general exhibits manifold modifications, which can not be further discussed in a work like the present.

The *Intestinal Canal* offers for consideration a number of diversities, which, like those of the teeth, can not be well described without entering into the anatomy of the several orders and genera.

The *Cavity of the Mouth* in the Osseous Fishes opens externally upon either side through the branchial fissures. Peculiar tooth-like processes stand out upon the internal edge of the branchial arches, and protect the fissures between the latter from the intrusion of food. The pharynx commences in the Osseous Fishes immediately behind the pharyngeal teeth, and there is found surrounding it in this situation a strong sphincter-like muscle; an œsophagus may be

continued from it as a short infundibular tube, but frequently only its commencement, or the pharynx, is developed, which then forms an extremely short canal, which is surrounded throughout its entire length by an annular layer of muscular fibres. There being no larynx in Fishes, the œsophageal intestine is attached to the vertebral column and pericardium by cellular tissue. A dense mucous membrane, frequently beset with tubercles and papillary projections, lines the œsophagus, and is usually disposed in coarse longitudinal folds, that are frequently continued into the stomach.

There are Fishes in which the intestinal tube is continued from the pharynx without any indication of a gastric enlargement or of convolutions, and with which no organ of secretion is connected, except the liver. It is interesting to commence with such simple structures and ascend to the more complex.

The greatest departure from the structure of the Vertebrata generally, and also from that of Fish, is furnished by the anomalous genus Amphioxus. Its internal branchial cavity is prolonged into a narrow canal, the œsophagus, which is continued into a much wider intestine. The latter is always of a green color, as is also a cæcum that is developed from it. The green fluid or gall is secreted by a glandular layer situated in the parietes of the intestine, and which, as in many Annelides, has not yet freed itself from the intestine in the form of a more highly organized parenchymatous liver. The green-colored portion terminates by an abrupt line, and then the walls of the intestine present, as do those of the cæcum also, their natural translucency and delicate texture. The intestinal sac exhibits, upon the whole of its internal surface, a glistening epithelium and an active vibratory or twinkling movement that hitherto has not been observed in any other vertebrated animal. This remarkable fish appears to be nourished simply by swallowing the microscopic animalcules met with in the sea-water. Nevertheless, excrements are extruded from the body of a dark color and stringy form.

Devoid of convolutions, and without any special dilatation for the stomach, if we except a slight increase in its width at one particular part, the intestine runs straight from the mouth to the anus in the Cyclostomi, *e. g.*, Petromyzon, in Myxine, where, however, it is wider, in Syngnathus, and in Chimæra, so that such is its condition in the most different orders. In many other Fish, as the Cyprini and Labri, in which the intestinal canal is long and spirally contorted, a special gastric dilatation is also absent, while in others that are furnished with smaller and insignificant convolutions, we meet with a well-defined stomach, as in Gasterosteus, Gobius, and some species of Blennius and Pleuronectes. In other instances the stomach is not developed directly in the course of the intestine, but to the side of the latter, and forms either an oval or spherical dilatation, as in Cobitis and Blennius viviparus, or passes from this form into that of a retort, examples of which may be seen in the majority of Bony Fish, *e. g.* the Salmon. The cardiac portion of the stomach is frequently extended into a more or less elongated cæcum, *e. g.* in the Eel, in Gadus, Scomber, Clupea, and many other Fish, but more especially in Ammodytes tobianus. To the stomach, when present, succeeds the intestine properly so called; it makes either few or many convolutions, and is not unfrequently continued backward to form a thicker portion that may be regarded as the large intestine, the limits of this being defined frequently by a cæcal valve, as those of the pylorus are by a constriction. Beyond this point, however, the intestine frequently narrows toward the cloaca, as in many Carps and Salmons, and it is not rare for the valve to be wanting. Occasionally a valve is found upon the cardiac orifice of the stomach. Anomalies also occur of a peculiar kind, *e. g.* in Lepadogaster biciliatus; for here to a short narrow pharynx succeeds a dilatation from four to five times wider, which occupies the greatest part of the ventral cavity, and represents at once both the stomach and the small intestine, while after it comes another bag of a more oval form, the large intestine. Applicable as they may so far appear, we shall find that in other cases the names of divisions borrowed from those of the intestinal canal in the human subject are not applicable to Fishes any more than they are to some of the naked Amphibia, and that it is better to adopt the terms oral, meso, and anal intestine, as expressing the regions of the body to which the portions of intestine may happen to belong. An equal amount of variety is displayed also by the mucous membrane lining the canal; thus it is often simply disposed in longitudinal folds, as in Pleuronectes, Silurus, Blennius, Cyclopterus, Petromyzon, or in zigzag folds, *e. g.* in several Cyprini, while in other Carps, and in Gasterosteus, transverse folds are observable, that are particularly developed in the Salmon-tribe, in the terminal portion of the intestine. Most Fishes, however, exhibit a very varied net-work formed by confluent longitudinal and transverse folds of mucous membrane. It is more rare for true papillæ, or tongue-shaped prolongations of the folds, to be met with, as in the Pike, and many species of

Salmon, Perch, and Flounder. Still, however, papillæ similar to those of the human subject have been found upon the smooth mucous membrane, *e. g.* in Mugil cephalus. The mucous membrance lining the stomach is usually soft as velvet, forms delicate reticulations, but is rarely provided with papillæ and projecting folds. Occasionally, as in Uranoscopus scaber, we meet with clusters of secerning follicles within the intestinal cæca.

The structure of the intestinal canal in the Plagiostomi, or Rays and Sharks, merits a separate consideration, though an extremely near approach to it is made by the Sturgeon. They have a short but wide œsophagus, continued into a large oval stomach that is furnished with muscular layers; to this wide gastric cavity succeeds a narrow intestiniform canal, which may be viewed either as the cardiac portion of the stomach or the duodenum; in its place we find, in the Sturgeon, a larger loop of intestine. In some instances; and perhaps these are very rare, there would appear to occur, *e. g.* Squalus maximus, a more compound kind of stomach than is usually observed in the class of Fishes. In this Shark the stomach is parcelled out by constrictions and inversions into several divisions, the first of which is separated from the œsophagus by two large triangular valves, and the fourth division by a strong internal pyloric projection from the remainder of the intestine. This latter, in the Sturgeon and Plagiostomi, is very wide, and (with some modifications peculiar to the different species that can not be considered in this work) distinguished by a singular structure that is developed in its interior. The mucous membrane here projects in the form of a plate that winds spirally like a staircase as far as the very anus, and in this way the extent of the absorbent surface of the intestine, which throughout its course is very short, becomes much increased. Posteriorly where it is continued into the cloaca the intestine narrows, and presents to our notice, as in Squalus canicula, a small cœcal appendage.

We have yet to consider, as occurring in many Osseous Fishes, a peculiar set of cæcal canals developed from the pylorus, and that are known under the name of *Pyloric appendages*. These cæca were formerly viewed as the analogues of the pancreatic gland, which is actually absent as a true parenchymatous viscus in many Fishes. The propriety, however, of thus interpreting the pyloric appendages is rendered doubtful by the fact, that these organs have been found in Fishes, *e. g.* the Trout, in which there exists also a compact pancreatic gland. The pyloric appendages are invariably absent in

those Fishes that do not possess a perfectly-formed stomach, as in the Cyprini, Gobii, and Syngnathi, but they are wanting also in other Fishes with that organ properly developed, *e. g.* the Pike. As a rule, however, they are present in the latter instances, and vary exceedingly in number. It is very rare to meet with a single cæcum, as in Ammodytes tobianus; there are sometimes two, as in several Plaice (Pleuronectes), while other species of this genus have, like the River Perch and Common Loach, three of them; four occur, *e. g.* in Mugil cephalus and Cottus gobio, five in Salmo spirinchus, six in Perca lucioperca and in Sargus annularis, seven to eight in Trachinus Draco, ten to thirty or more in many Salmons and Herrings, and from eighty to ninety in the Salmon; but these appendages are most numerous in Gadus and Scomber, for in the Mackerel about two hundred may be counted. These cæcal appendages either encircle the pylorus, or occupy longitudinally a greater or less extent of the commencement of the intestine. In some of the Fishes already named, as in the Herring and Mackerel, the cæca begin to divide, and two of them open by a single aperture into the intestine. In Gadus Lota two or three of the twenty cæca unite to form a common trunk; in the Tunny (Scomber thynnus) they divide so as to form tufts; in Cyclopterus, Gymnotus, and others, those of the second row are further subdivided. In the Sword-fish (Xiphias gladius) the finely-divided cæca are united by cellular tissue, and invested externally by a common membranous covering, so that the whole organ resembles a gland. In the Sturgeon, indeed, the pyloric appendages, by being still more subdivided and again united, acquire the form of a true parenchymatous pancreas. The mucous membrane lining the pyloric appendages exhibits a reticulated appearance similar to that of the intestines. No nutritive matter is found in these cæca, but only some slimy fluid; chyme, however, has been frequently observed in them. Their function is in other respect highly problematical, though it is possible they may secrete a fluid analogous to the pancreatic juice.

In the Osseous Fishes, *e. g.* the Eel, Pike, Trout, we constantly find a true compact and glandular *Pancreas* of a yellowish-white color, which sends from two to three excretory ducts into the intestine; these are frequently accompanied by the biliary ducts, but are so closely attached to the latter as to be easily overlooked. In the Sturgeon a second kind of pancreas has been described as also existing. The Rays and Sharks possess a lobulated and reddish-yel-

low pancreatic gland, more analogous to that of the higher Vertebrata.

The *Salivary glands* appear to be very generally absent in Fishes, or their place to be occupied by an increased development of the mucous glands of the mouth. A small cylindrical and lobulated gland has been found in Lophius piscatorius, lying immediately beneath the integument posteriorly to the wide branchial opening; it would appear to be analogous to a salivary gland, from the fact of the branchial cavity of this Fish serving as a receptacle for its prey.

The *Liver* is in general of large size, and colored in different shades of red, brown, or yellow. It is frequently very simple in form, and alobular, or often tongue-shaped, *e. g.* in Petromyzon, Syngnathus, Esox, Salmo, and, in a word, in the most different families. It is bilobed in Silurus, Blennius, Perca, Cobitis, and the Sharks, but trilobed in Gadus, Clupea, many species of Cyprinus, and in the Rays. In other species of Cyprinus, *e. g.* C. barbus, carassias, it is divided into a number of lobes united by narrow bands, and placed between the convolutions of the intestine. The biliary ducts do not usually unite into a single tube, but proceed together into the gall-bladder, or into the vesical duct. The gall-bladder is seldom wanting, as in Petromyzon, Cyclopterus Lumpus, and in Scomber Leuciscus. Its form is either elongated and pyriform, cylindrical, or spherical. Occasionally it is completely imbedded in the liver, and in many cases, as in Uranoscopus scaber and Orthagoriscus Mola, is of very large and disproportionate size compared to that of other Vertebrata. The gall-dust (*d. choledochus*), generally single, opens mostly in the vicinity of the pylorus, but sometimes at a part of the intestine remote from the latter, as in the Pike.

The *Spleen* appears to be either absent in several Fishes, or so small as to be readily overlooked, *e. g.* in the Cyclostomi and Lepadogaster. It is mostly of a reddish-brown color, small size, and very varied form; thus it is elongated in Blennius, triangular in the Pike, large, irregular, and slightly lobular, in Cyprinus and the Sturgeon, very large in many Sharks, and divided into lobes of unequal size, but united together. The liver and spleen do not exhibit the same symmetrical and regular position in respect to each other that they do in the higher Vertebrata; the greater portion of the liver frequently lies to the right, but very often to the left side, while the spleen is usually placed upon the right side, but often in the middle line above or behind the stomach.

The *Peritoneum* in Fishes invests the whole intestine, and is attached above to the pericardium, so as to form a kind of diaphragm or partition, though not one of a muscular texture; it also completely clothes the sexual organs, but not the kidneys. In some Fishes, as in the Plagiostomi, the Sturgeon, and Salmonidæ, a pair of openings are situated upon either side of the anus which lead into the cavity of the peritoneum, and allow the ingress of water to the cavity and its contained viscera. The intestine is seldom secured by a perfect mesentery, as is the case in the lower Fishes, *e. g.* Myxine, but this is usually effected only by some thin filaments or vasiferous bands. It is remarkable that during the embryonic existence of all Fishes a mesentery appears to be fully formed, but disappears at a later period by absorption. When a swimming-bladder is present, it usually opens into the œsophagus, but sometimes by a second orifice into the stomach.

In the genus Lepidosiren several peculiarities occur in the organs of digestion, and both spleen and pancreatic glands are absent.

ORGANS OF CIRCULATION.

To give a general description of the organs of circulation in the class of Fishes is attended with much difficulty, from the many peculiar varieties of structure which they present in the several genera and families. Still, however, we may attempt a general survey of the vascular system by first selecting a normal example of the Osseous Fishes, such as the Common Perch, and a Shark or Ray, as types of the Chondropterygians.

The principal or only heart in many Fishes is a *branchial heart*, in other words, a heart that is placed between the trunks of the branchial veins which it receives, and the trunks of the branchial arteries, which it gives off; it corresponds therefore to the right heart of Man and the higher Vertebrata, and is traversed by venous blood alone. The heart consists of one auricle and one ventricle, both of which are lodged within a pericardium, to the inner surface of which the heart is frequently attached, as in many Amphibia, by special filaments. In the Plagiostomi the pericardium communicates by openings with the peritoneum, so that it is bathed by the water brought through the apertures in that membrane, and already described as being situated near the anus. The heart is placed be-

tween the pharyngeal jaws and the girdle supporting the anterior extremities, and is small and angular in the Bony Fishes, but broad and flat in the Plagiostomi; it varies in size, and considerably also in weight relatively to the entire body, in different genera and species; thus Meckel has calculated the weight of the heart in the Ray at about $\frac{1}{300}$th, that of the Carp $\frac{1}{500}$th or $\frac{1}{600}$th, and in other Fishes $\frac{1}{1000}$ of the weight of the body. The auricle is generally much wider and its parietes thinner than those of the ventricle, above and somewhat behind which it is placed, while between the two cavities we find mostly two, more rarely three, as in the Sturgeon, muscular valves. The thick and very muscular ventricle is characterized in most fishes by a peculiar structure, for it is composed of two muscular layers so loosely connected to each other, that the external consisting chiefly of longitudinal fibres, may be separated, like a shell, from the internal, which is formed principally of transverse fibres. The contractile trunk of the branchial arteries arises from the anterior part of the ventricle by a strongly-developed oval enlargement, called the *bulbus arteriosus*, which is formed of very powerful annular muscular fibres, and is likewise situated within the pericardium. Between it and the ventricle we usually find two valves, as in the Osseous Fishes and in Petromyzon; in the Plagiostomi and in the Sturgeon, however, several, from two to five, rows of semilunar valves are met with lying one above the other.

The ventricle discharges its blood through the aortic trunk into the gills. This trunk of the branchial arteries usually divides upon either side into four, as in most Osseous Fishes, or into five branches, as in the Plagiostomi; these becoming gradually more slender, run in a groove on the convex side of each branchial arch, and ramify upon the branchial leaflets. Delicate ramuscules return the blood into the trunks of the branchial veins, which are lodged in the same groove behind the arteries, being usually single, but rarely double; they run upward to the base of the skull and the commencement of the vertebral column, and here form a large circle of arterial vessels (*circulus cephalicus magnus*) which receives the branchial veins and gives off the arteries; posteriorly the single aorta arises from it, which sends first branches to the muscles of the branchial arches, to the mucous membrane of the mouth and pharynx, and to the upper end of the kidneys; very near to these branches and to each other arise a cœliac and mesenteric artery, the two branchial arteries for the pectoral fins, and some renal arteries. In front, or, as it were, from the most anterior branchial veins, the two large posterior and two

smaller anterior carotids arise from the arterial circle; slight varieties and peculiar arrangements of these vessels occur, but can not be investigated in this work. The posterior carotid supplies chiefly the opercula of the gills, the pseudobranchiæ or retia mirabilia, and muscles of the lower jaw, with blood. The brain receives its arteries, which are very small, from the anterior and posterior carotids.

After the aorta has supplied the liver, the intestine, the organs of generation, and the swimming-bladder, it runs within the canal formed by the inferior spinous processes of the vertebræ to the tail, and there gives off branches to the kidneys, the muscles of the trunk, and the pelvic extremities. The substance of the heart receives its blood directly from the branchial vein. The blood returning from the viscera enters partly into the inferior or posterior trunk of the vena cava, which lies below the aorta, and is usually single in the Osseous Fishes, but double in the cartilaginous; partly also into the hepatic veins, and from the two into a large sinus-like expansion or contractile sac of the vena cava that opens into the auricle (being frequently of larger size than the latter), but is situated external to the pericardium. The blood also from the head enters the same venous sinus by two anterior venæ cavæ, which are expanded into sinuses upon the cranium; they also receive the blood from the branchiæ and anterior extremities. Between this sac of the vena cava and the auricle are found a pair of valves. The number of hepatic veins is subject to variety.

A large proportion of the venous blood of the posterior half of the body passes in Fishes from finer ramifications into trunks, that are again subdivided to form a portal system. We find, as in many Amphibia, a double portal system; one for the liver, which obtains its blood from the stomach, spleen, intestinal canal, and sometimes from the generative organs; the blood from these viscera usually entering by several smaller branches into different parts of the liver, but rarely uniting, before entering that gland, into a common portal vein. The second portal system belongs to the kidneys, which organs receive venous blood from the tail, partly also from the sexual organs and swimming-bladder; blood is also sent from this system to the venæ cavæ. The arrangement, however, of the two portal systems varies greatly, according to the species and genus.

Lymphatic vessels appear to be generally present in Fishes, and in some number; their parietes are thin and membranous; they are very wide, and form even large sacs and reservoirs, but are destitute of valves, and have no conglobate glands or plexuses developed in