their course. They consist partly of lacteals that proceed from the intestinal canal, and partly of ordinary lymphatic vessels. When filled by injection with quicksilver, they cover the vascular trunks, the veins for instance, completely. They unite in the anterior part of the body, and pour their contents by two trunks into the anterior, and partly also by several branches into the posterior, venæ cavæ. The main trunks (*ductus thoracici*) proceed from lymphatic sinuses near the cardiac orifice of the stomach, analogous to the *cisterna chyli*. Several lesser lymphatic branches would appear to lose themselves in venous ramuscules.

Peculiar *Caudal* and *Cranial sinuses* and a special *system of Lateral vessels* were recently discovered in Fishes, and seem to belong to the lymphatic system. Beneath what has been formerly described (p. 185) as the lateral or mucous canal of the integument, we find another sinus-like canal that is filled with a clear and limpid lymph, and communicates with a number of adjacent branches, all pursuing a subcutaneous course, and forming a ring of vessels around each scale, so that the body of Fishes is completely intersected by this net-work. This system of vessels communicates with a peculiar caudal sinus, that is placed in many Fishes, as the Eel, in the same situation as the caudal heart, which will presently be described. This sinus is double, the divisions lying close upon either side of the flat rays supporting the caudal fin; but both of them communicate by means of a transverse canal that passes through an opening in one of the fin-rays. The sinus varies in size, and passes into the caudal vein, being there provided with a valve. It is invested by a strong fibrous tunic, and contains a clear lymph; whether it is endowed with powers of expansion and contraction has not yet been determined. A similar sinus has been observed upon either side the cranial cavity external to the jugular veins; it is pear-shaped, smaller than the caudal sinus, and appears to be contractile. The occurrence and position of these reservoirs remind us very much of the lymphatic hearts of the Amphibia.

The *Blood* of Fishes is, with one single exception, of a red color, and contains almost always oval, flat, and slightly biconvex *corpuscules;* those in the Plagiostomi are distinguished by their great size, and in this respect, as well as in their form, agree with those of Frogs; in the Osseous Fishes they are smaller. The Cyclostomi, at least Petromyzon, have, however, circular biconcave corpuscules resembling the human, but larger.

The greatest departure from the circulatory system of the rest of

Fishes is exhibited by the Amphioxus or Lancelet. The blood is quite colorless, and has not as yet been found to contain any corpuscules. The hearts, however, are numerous. There is found, 1*st*. An *Arterial Heart*, a tube of uniform thickness placed below the branchial thorax in the middle line where the branchial artery in other Fishes is situated, but without any trace of a pericardium; it is continued for a short extent backward as far as the end of the œsophagus, where it makes a curve and joins the tubular hearts of the venæ cavæ. 2*d*. The *Bulbilli* of the branchial arteries, which, given off regularly from the arterial heart, are continued into the angles between each pair of branchial arches, and represent the commencement of the branchial arteries; in young individuals we find twenty-five, but in older specimens fifty, such branchial hearts on either side. The branchial veins probably bring the blood into the aorta that lies beneath the vertebral column, but in addition to these, the blood enters the aorta through, 3*d*. The *Cardiform aortic arches;* it is a double contractile *ductus Botalli* arising from the median heart. 4*th*. A *Portal heart*, long and tubular in form like a vessel, and contracted throughout its whole length, runs along the ventral side of the intestine, and extends to the extremity of the cæcum. 5*th*. A *heart of the vena cava*, which lies on the opposite or dorsal side of the intestine, and is also tubular in form. Both venous hearts contract alternately. This structure of the vascular system obviously reminds us of that in the Annelida, where numerous pulsating heart-like vessels also occur.

The Cyclostomi are also characterized by many remarkable peculiarities in their vascular system, but to describe them in the present work would be entering into too great detail; one distinguishing feature, however, is the want of a muscular or contractile *bulbus arteriosus*, the trunk of the branchial artery exhibiting a uniform structure. In Lepidosiren annectens we find a *bulbus arteriosus*, and a singte auricle and ventricle. In L. paradoxa we meet with a right and left auricle imperfectly separated, the former receiving the pulmonary vein, the latter the venæ cavæ.

Among the Osseous and Cartilaginous Fishes the number of hearts is occasionally found to be also increased. Thus in Chimæra an elongated fusiform *accessory heart* is always developed upon the two axillary arteries destined to supply the pectoral fins. Similar axillary hearts also occur in Torpedo, but not in Raia.

In the Eel there is found, upon both sides of the last caudal ver-

tebra, a pulsating organ which receives the blood from the delicate veins of the end of the caudal fin and propels it into the caudal vein, thus constituting a *caudal heart*, that occurs too in Murænophis. It is a true blood-propelling organ, but occupies the same position as the already-described lymphatic reservoirs found in many Fishes, and conjectured to be contractile.

In Myxine the sac of the vena porta contracts rythmically, and so forms a heart; thus in the class of Fishes have heart-like expansions been found developed in different parts of the circulatory apparatus, and would appear to be the more necessary from the numerous plexuses of vessels through which the blood has to pass.

These plexuses, or *Retia mirabilia*, have been found of the most complex form and arrangement in very different organs. Thus they occur upon the hepatic, portal, intestinal veins, and cœliac artery in the Tunny and several species of Shark; in the choroid gland of the Bony Fishes, in the swimming-bladder, and the so-called pseudo or *Accessory branchiæ*. These latter organs, which occur in most Osseous Fish, were formerly, from their resemblance to the true branchiæ, regarded as such, although they differ completely from them in structure. They are situated mostly upon the palatal portion of the branchial cavity in front or external to the upper extremity of the branchiæ, like which they are pectinated and provided with cartilaginous strips for their support. The blood-vessels ramify upon their leaflets in a regular manner, like the barbs of a feather, and receive their blood, like the opercula of the gills and lingual bone, through a branch which proceeds downward from the first branchial vein. A second or glandular form of these accessory branchiæ also occurs, and consists of deep red vascular organs composed of several lobes, not presenting the shape of gills, although they are covered by the mucous membrane of the branchial cavity. The lobules themselves, however, appear like small feathers with cartilaginous shafts, the latter being provided with lateral leaflets. Such glandular pseudobranchiæ are found in the Carp, Pike, and species of Gadus.

In the Sturgeon we find two accessory branchiæ: a large one situated against the operculum is a true respiratory pseudobranchia; the second, very small, and situated on the anterior wall of the spiricle, consists of folds and transverse lesser folds, possesses the plexiform structure of the pseudobranchiæ, and obtains its arterial blood from a branch of the vein upon the first branchial arch, while

the respiratory accessory gill receives dark-colored blood from the branchial artery. A similar pseudobranchia is possessed by the Rays and Sharks upon the valve of the anterior spiracle.

ORGANS OF RESPIRATION.

All Fishes respire by means of branchiæ or gills, for the support and protection of which organs we find a very complicated framework of bone or cartilage developed, and exhibiting the greatest diversities of structure in the several orders and genera. The whole of this apparatus may be reduced to three principal divisions: 1*st*. The lingual bone and branchiostegous rays. 2*d*. The branchial arches. 3*d*. The opercula or gill-covers. A *fourth* division of this part of the skeleton may be regarded as formed by the upper and lower pharyngeal bones or maxillæ, from the resemblance they bear to branchial arches; but as they do not support branchiæ, but only teeth, they more properly belong to the organs of digestion.

In the Osseous Fishes the *Hyoid bone* consists of a large arch, situated behind the lower jaw in front of the first branchial arch, and formed of several bony pieces symmetrically placed upon either side of a single intermediate piece. The lateral branches of the hyoid arch are of very large size in the Osseous Fishes, and correspond to the great cornua; they are composed almost invariably of four pieces, the posterior of which, mostly style-shaped, is the medium for attachment of the hyoid to the bone that is analogous to the os quadratum; the several pieces sometimes coalesce into two or one, but are generally united by fibro-cartilaginous bands. In front the two lateral branches abut against and are united by a single intermediate ossicle (*copula*); this represents the body of the hyoid bone, and commonly supports in front an elongated ossicle, upon which the rudimentary tongue rests; this is called the *lingual bone*, and is frequently provided with teeth. To the two branches externally a series of mostly narrow and slender, or frequently broad and strong ossicles, are fastened by ligaments or moveable joints; they support the opercular membrane of the gills, and have been therefore called the *Branchiostegous rays;* their number varies according to the genera and species, or even sometimes the individual. In the true Cartilaginous Fishes, parts occur which correspond to the hyoid arch, but true branchiostegous rays are entirely absent.

In the above structures we meet with numerous diversities. The hyoid arch is very narrow in Muræna, Syngnathus, and others, and

in the latter genus it always consists of a single piece, but in Diodon and Tetrodon of two; in all these genera, as in Uranoscopus and Cyclopterus, the copula is wanting. The piece supporting the tongue is absent in Tetrodon, Diodon, Balistes, Muræ nophis, and others. The branchiostegous rays are very rarely wanting, as in Syngnathus. Polypterus has only one of these rays, while three are found in Cyprinus, Cobitis, and others; seven in Muræna anguilla, twenty-five in M. colubrina, and upward of thirty in Elops. The passage from the Osseous to the Cartilaginous Fishes is made by the Sturgeon, in which the hyoid arch consists of three pieces instead of four, and both copula and branchiostegous rays are entirely wanting. In the Sharks a cartilaginous arch is found upon either side, supporting some cartilaginous rays, divided simply in a digitate manner. In the Rays similar arches are found, supporting a pair of pseudobranchiæ.

Behind the hyoid bone is situated a system of bones or cartilages called the *Branchial arches*, very generally four in number, and which support the vascular fringes or leaflets of the gills. Each arch consists of several pieces, varying in number according to the species of fish and the several arches themselves. There are, however, never more than four pieces, mostly three, and rarely two; upon their convex side they are channeled out for the lodgement of the branchial vessels, while on their concave side, or that turned toward the cavity of the mouth, they are mostly beset with teeth, and the upper segments of the posterior arches are usually so strong, that they have been distinguished by the special name of *ossa pharyngea superiora;* the postero-inferior pharyngeal jaws are also intimately related, both by form and position, to the last and rudimentary branchial arches. In the direction downward the branchial arches are usually attached, like ribs to a sternum, to an intermediate chain of bones or cartilages, two to four in number, which are articulated in front with the copula of the hyoid bone; the posterior arches are frequently united to this central chain by fibrous ligaments only, for it is seldom that all the arches are directly continued and connected to it by bone. Superiorly the branchial arches are generally attached by muscles and cellular tissue, or by true ligaments, to the basal surface of the skull, or sometimes further backward to the first vertebræ. The teeth are usually disposed in two rows upon the inner side of the branchial arches, and are rarely absent, as in Cyprinus, Muræna, Murænophis, Lophius, Fistularia, and others. The median chain of ossicles uniting the

branchial arches below are seldom wanting, as in Murænophis, Syngnathus, and Lophius. The Cartilaginous Fishes possess similar branchial arches, only they are cartilaginous, and five instead of four in number, of which, however, the most posterior corresponds to a pharyngeal maxilla; the arches abut, in the Sharks, against some intermediate cartilaginous pieces, and consist themselves of several segments; the branchial arches in the Rays resemble in general those of the Sharks, and are united inferiorly by one or two very broad sternoidal cartilaginous plates. In most Osseous Fishes the branchial arches are situated beneath the skull, but in Fishes of the Eel kind, *e. g.* Muræna, Murænophis, they are situated further back beneath the first vertebræ; in the Rays and Sharks they are united still further back to the commencement of the vertebral column. In the Cyclostomi we find a very peculiar branchial skeleton, formed of narrow arch-shaped cartilaginous rays that surround the gills.

The gills, which in the earlier stages of development of Fishes were freely exposed and unprotected, are always concealed at a later period of existence beneath the skin, and protected also by special covers or opercula; these are most evolved in the Acanthopterygians, and form for the most part a large bony apparatus, seldom inferior in size to the branchial, but which is superseded in the Chondropterygians by another contrivance. There are most frequently four, or if we regard, with many anatomists, the præoperculum as the quadratal bone, three bony pieces, composing the opercula of the gills. The *Præoperculum* is of a semilunar form, and bounds posteriorly the series of bones belonging to the articulating or quadratal portion of the temporal bone. To this succeeds, in the direction upward and backward, the true *Operculum*, a flat and more or less quadrangular bone, the largest in size, and presenting upward and forward a socket that articulates freely with a capsular head upon the uppermost quadratal bone. Upon the posterior and inferior edge of the operculum is situated the *Postoperculum*, and between this and the præoperculum, behind the lower jaw, is placed the *Interoperculum*. This opercular apparatus serves as a valve, whereby the fissure leading from without into the branchial cavity, and placed between the posterior edge of the operculum and the anterior girdle of the pectoral fins, may be opened or shut. The position, but more especially the size of the opercular bones, varies; one or other of them is frequently ill-developed, as in the Eel family. Among the true Cartilaginous Fishes we find, instead of this appa-

ratus, narrow, digitiform, cartilaginous plates, the analogues of the branchial rays, and which are fastened to the quadratal cartilage. The peculiar disposition of the branchiæ themselves in the Sharks, Rays, and Cyclostomi, renders a true operculum unnecessary.

In the majority of Fishes, but particularly in those of the Osseous kind, a double row of pointed lanceolate leaflets project, like the teeth of a comb, from the convex side of each of the four branchial arches; they are mostly separate as far as their base, where they coalesce, but are sometimes united higher up; each leaflet is provided in the middle with a thin fibro-cartilaginous plate, that keeps it stiff and straight. Upon these leaflets we find a number of thin membranous transverse ridges, which contribute to increase the respiratory surface, and the plexuses of blood-vessels further expand upon peculiar siliquose elevations; it is rare for only three of the branchial arches to support such pectiniform leaflets, as in Lophius, Batrachus, Diodon, Tetrodon; and very rarely do three, or only one row of branchial leaflets rest upon an arch. The branchial leaflets in Syngnathus and allied genera forming the group of Lophobranchii are of an unusual form, being lanceolate, but very broad and short, so as to form tufts. All these branchial combs are lodged in a common cavity situated behind the opercular apparatus, and communicating with the mouth by the slits between the branchial arches, and externally by a single large or frequently very small slit between the edge of the operculum and the girdle of the pectoral fins. The arrangement of these parts is somewhat different in the true Cartilaginous Fishes; upon the middle of each of their branchial arches we find a dense cellular plate, which attaches them to the external integument; in front and posteriorly the mucous membrane of the mouth is prolonged over this plate, and forms upon it elevated folds standing perpendicularly upon the cartilaginous arches, like the branchial leaflets of the Acanthopterygians; externally the mucous membrane is continuous with the external integument; each branchial arch is furnished with an anterior and posterior row of such branchial folds, but the anterior arch has only the posterior set, so that only four and a half gills are to be counted. From the branchiæ being united externally to the integument, five (and in other genera, as Hexanchus, Heptanchus, six to seven) branchial fissures are found both internally and externally, between which the integument forms narrow bridge-like strips. The Cyclostomi present a still more peculiar structure. There are here from six to seven pairs of branchiæ present; each pair forms a flat

sac or pouch, upon the internal walls of which strongly-developed folds project, as in the Plagiostomi; each sac opens externally by a round aperture, and in the inward direction by a canal into the œsophagus, or even into a special membranous tube or *bronchus*, situated beneath the œsophagus, and opening anteriorly into the pharynx, where it is closed by a membranous valve, and terminates blindly posteriorly.

The movement of the branchial arches, and also of the operculum and branchiostegous membrane of the Osseous Fishes, is effected by numerous muscles, which are absent in the Cartilaginous Fishes with fixed gills. By their action the branchial arches are separated or approximated, the branchiostegous membrane spread out, and the operculum flapped to and fro so as to open or shut the external branchial fissure. Smaller muscles move the double row of branchial leaflets against each other. Similar muscular fasciculi are found in the Cyclostomi, and serve to expand the branchial sacs. The water taken in at and streaming through the mouth, is driven by the movement of the branchial arches and hyoid bone between the gills, where it bathes the leaflets with their superimposed plexuses of vessels, and is again expelled through the external branchial fissures.

In many Osseous Fishes, *Branchial follicles*, as they are termed, that secrete a copious mucus, are found at the posterior commencement of the branchial cavity.

In addition to this mode of respiration by branchiæ, we find that in many Fishes this function is performed by pulmonary organs. The Amphibioid Fishes, like Proteus among the true Amphibia, possess a pair of truly-developed *Lungs* near to the gills. In Lepidosiren annectens a partly single, partly double row of branchial filiments project from the six branchial arches with the exception of the second and third, and in the vicinity of the anterior extremity we find the single branchial fissure. Besides these gills, however, a double sacciform lung is present, each portion being divided into several lobes; it is situated behind the kidneys against the ribs, and is internally cellular like the lung of a serpent; anteriorly it opens by a tolerably long, narrow, and membranous tube into the œsophagus. Each lung receives a branch of the pulmonary artery which arises from the branchial arteries.

Among even the true Bony Fishes we meet with *Accessory or pulmonic organs of respiration, e. g.*, in Silurus fossilis of Bloch, and among Fishes of the Eel kind in Amphipnous Cucia; they consist of vascular hollow sacs, which are either situated within the bran-

chial cavity, or extend thence to beneath the lateral muscles; they receive branches from the branchial arteries, and their veins enter the aorta.

With the above organs we may also include the hollow arborescent tufts of accessory branchiæ which lie, in Heterobranchus anguillaris, behind the true gills, as also the labyrinthine accessory gills of Anabas, Osphromenus, Ophiocephalus, and others; a part of the upper pharyngeal Maxilla is here divided into a greater or less number of leaflets, from between which cells arise, wherein water can be retained for a long time. These fishes form a peculiar family, the Pharyngii Labyrinthiformes, and are able by this structure to live a long while on dry land; the arteries of these organs proceed from those of the gills; the veins enter, after the analogy of the branchial veins, into the aorta.

THE SWIMMING-BLADDER.

Frequently as it has been compared with the lungs of the higher Vertebrata, and certainly, from its mode of development, position, and internal structure, reminding us exceedingly of these organs in the Amphibia, still the disposition of its vessels forbids our regarding the *Swimming-bladder* as an instrument of respiration, and thus we are still in doubt as to its precise functions; it occurs only in the Bony Fishes, but not in all the genera, and among the Cartilaginous in the Sturgeon alone, which forms the transition-link to the Osseous Fishes. The swimming-bladder must, however, exist in connexion with definite modes of life in several Fishes, since it is frequently absent in different species of a genus, or in nearly allied genera, *e. g.*, Scomber scombrus, Polynemus paradiseus, and the genera Pleuronectes and Lophius.

In ordinary cases the swimming-bladder is situated beneath the spinal column, to which it is firmly attached by cellular tissue, and, covered by the kidneys, overlaps the intestinal canal. It consists of two coats; of an external, which is very tough, fibrous, and glistening, and an internal or soft vascular mucous membrane. It is invested upon its lower surface, or that facing the viscera, by peritoneum. The swimming-bladder in some instances, as in Esox, Gadus, Holocentrus, Cepola, is of very great length, extending through the whole body; in others, as in the Eels, it is very short. Its longitudinal dimensions usually predominate over the transverse, the reverse, as in Silurus and Orthagoriscus oblongus, being of rare occurrence. As a rule, the swimming-bladder contains only a single cavity; frequently, however, two, one placed behind the other, and separated by a deep constriction, as in the Carps and many Salmons; in Blennius Phycis we find three, and in Polypterus two such divisions; in Trigla hirundo there are also three, but they are arranged side by side. Pimelodus filamentosus is furnished with two completely-separated swimming-bladders lying one behind the other. The swimming-bladder is sometimes provided with cæcal pouches, varying in size, form, and length, *e. g.*, in some species of Gadus; but they are most distinct in the family of Sciænidæ, as in S. umbra, in Johnius, Pogonius, Corvina, and Otolithus, where the appendages are divided in a digitate manner. It is rare for cells to be developed upon the internal surface of the swimming-bladder, in which case that organ greatly resembles the lung of an Amphibian; this is exemplified in many Erythrini, and in several genera of Siluroidæ, *e. g.*, Bagrus and Arius, where the swimming-bladder is divided into several intercommunicating chambers by imperfect partitions; in Platystoma we meet, in addition, with a pair of cellular wings or appendages. The very long swimming-bladder of Lepisosteus, which extends from the pharynx to the anus, is provided superiorly with two blind appendages, but is in other respects simple, except that a part of its internal cavity is furnished with smaller cavities or pouches upon the floor of which the mucous membrane forms a network of parietal cells. In many Fishes the swimming-bladder is peculiarly situated. Thus in Cobitis fossilis it is completely enclosed in a bony capsule formed by the transverse processes of the third cervical vertebra. In Heterobranchus it is situated transversely within a conical bony capsule opening by a fissure inferiorly, and formed by an expansion of the transverse processes.

The swimming-bladder is either entirely closed, or provided with a tube, as in most of the Ventrales, while in the Pectorales and Jugulares this is usually wanting. The tube consists of the same coats as the bladder, and is either short or long, narrow and tortuous; it runs in the direction downward and forward, and perforates the œsophagus in different situations, and in some cases the commencement, or what is more rare, the bottom of the stomach. In the genus Salmo the tube arises from the anterior extremity of the bladder, or from its second division, as in Cyprinus, where it is very narrow and tortuous; in the Pike, however, it is short and wide, and in Clupea it enters the base of the stomach. This opening of communication of the swimming-bladder with the intestine has been