vertebræ, and opposed to each other; but the gelatinous column with its fibrous sheath that occurs in the Sturgeons and Chimæræ, and also in the Cyclostomi (as will be described further on), has a cellular structure, like the chorda dorsalis, quite different from cartilage.

In the Plagiostomi the formation is of a more perfect kind, and similar to that of the Osseous Fishes, for the upper and lower pieces of the vertebræ having become more complete, the gelatinous column is so enclosed that the conical facets of the vertebral bodies are alone left. The points of ossification in its interior are very complex. In some Rays and Sharks a hyaline cartilage rests upon the surface of the vertebral body (*e. g.* Spinax, Scyllium); in others the vertebral body, with cellular interstices, ossifies up to the surface, but in its interior there remains a cross of hyaline cartilage, the crura of which are directed toward the points of origin of the arches and transverse processes (*e. g.* Carcharias, Zygæna); or other varieties occur, as in many genera, *e. g.* Hexanchus, Heptanchus, where the whole vertebral column remains cartilaginous throughout life. As a rule, however, the vertebral bodies, the pieces forming the arches, the intercrural cartilages, and the laminæ forming the roof of the spinal canal, are always to be distinguished. In the Rays a large anterior portion of the vertebral column is not distinctly divided into vertebral pieces, these being blended together.

In Petromyzon the fibro-cartilaginous tube is found to be annulated, filled with gelatine, and surrounded by a fibrous tunic, which forms above it a tube for the spinal marrow. In the upper membranous tube cartilaginous crura are seen to arise, and may be viewed as rudiments of vertebral arches.

In Myxine, Ammocætes, and Bdellostoma, we meet with the lowest persistent condition of the vertebral column, and one which disappears at a very early period of existence in the higher Vertebrata; this consists of a chorda dorsalis, filled with gelatine, and surrounded by a fibrous tunic that forms above a tube for the spinal marrow; but all special divisions or rudiments of ossification in this tube are wanting. A similar chorda dorsalis, projecting as far as the snout, together with a fibro-membranous capsule for the spinal marrow, is found also in Amphioxus. Even in the Lepidosiren the vertebral column consists of a mere chorda dorsalis, without any indication of vertebral rudiments, and provided only with a ligamentous capsule and gelatinous substance.

Cartilaginous accessory spines occur in the dorsal and anal fins

of the Sturgeon as in those of the Osseous Fishes; in the Sharks and Rays several divisions of triangular and quadrangular cartilaginous laminæ occur; they correspond to the accessory spines and support the fin-rays.

Many of the Cartilaginous Fish, as the Rays, Sharks, Sturgeon, and the genus Lepidosiren, are provided with *Ribs*. The Cyclostomi, at least the Lampreys, possess a peculiar sternal series, formed of a number of ramified rib-shaped cartilages which are united together, and to an elongated sternoid cartilage; it encloses the gills, and may be therefore most properly compared with the branchial skeleton of other Fishes.

Among the Cartilaginous Fishes we meet with an entire absence of *Extremities* in the Cyclostomi, while in the Sturgeons, Chimæræ, Rays, and Sharks, they exist in the form of pectoral and ventral fins. The anterior extremities of the Sturgeon resemble those of the Osseous Fishes in being composed of several pieces, which correspond to a scapula and clavicle; the posterior extremities are a pair of small ventral fins. The Chimæra approximates most in this respect to the Plagiostomi.

Among the Plagiostomi the Rays present us with a surprising development of their *pectoral fins*, which correspond to anterior extremities, and are in some degree analogous to those of the Osseous Fishes. Their first portion consists of a scapular and a clavicular cartilage; frequently, however, of three cartilages that form a pretty broad arch, which in the Rays firmly unites with the anterior anchylosed section of the vertebral column, but does not reach the latter in the Sharks. To this first portion succeeds a second, which consist in the Rays of three or four very elongated cartilaginous pieces; next we meet usually with two rows of rays, the posterior of which may be perhaps likened to the metacarpus, while the anterior or external represents as fin-rays the digital phalanges. In the Rays the digital phalanges are somewhat dilated at the two ends.

In the Plagiostomi and Chimæræ the arrangement of the *posterior extremities* is rather more perfect than in most Osseous Fishes. An iliac cartilage is here present as a rudiment of the pelvis, and to this follows a series of more elongated cartilages, which may be regarded as tarsal, while arranged upon these are the rays or pedal phalanges supporting the ventral fins. In the male Rays and Sharks a pair of long, slender, cartilaginous appendages are united to the iliac cartilage; they are hollowed out by a groove above for

the passage and exit of semen, and thus perform the function of external generative organs.

The genus Amphioxus, like the whole order of Cyclostomi, is devoid of all extremities. In Lepidosiren there are found externally, in the situation of the pectoral and ventral fins, two pairs of inarticulate filaments. The first pair rest upon a bone or cartilaginous girdle forming their support; and for the posterior rudiments of fins there exists likewise a pelvic piece.

MUSCULAR SYSTEM.

The Muscles of Fishes are characterized by their slight degree of separation from each other, by the absence of long tendons (which occur only in some anomalous muscles of the cranium, *e. g.* in the Electric Ray), and by the softness of their fibres. The color of the muscles is generally pale, being either white or having a tinge of yellow; occasionally, however, as in the Tunny (Scomber thynnus), they are red like the flesh of Mammalia. Their microscopic structure does not differ from that of the other Vertebrata, nor are the characteristic transverse striæ wanting even in the whitest fibrillæ.

Peculiar muscles of the integument do not appear to exist; still the small superficial muscles which move the several rays of the dorsal and anal fins are obviously analogous to the muscles that act upon the feathers in Birds, and upon the ventral scales in Serpents. Each fin-ray is constantly provided with a single superficial muscle upon either side (right and left) of its basis; they arise from the integument, and wave the fin to and fro so as to maintain the act of swimming. Besides these, there are other muscles more deeply seated, and of some length, which cover the interspinous bones. Each fin itself is provided with a pair of protractor and a pair of retractor muscles, those that correspond upon either side being separated by the interspines, and covered by the great lateral muscles of the body. By means of these muscles the dorsal and anal fins can be elevated and depressed. Those Fishes which, like Gasterosteus, Silurus, Lophius, and Balistes, are furnished with certain strong but loose spines or fin-rays as instruments of defence, present greatly developed and isolated fin-muscles.

By far the largest portion of the fleshy mass of Fishes is made up by the large *lateral muscles* of the body; they consist of longitudinal fibres, which are interrupted by numerous tendinous undulating lines passing from the dorsal to the ventral aspect, and extend from

the head and scapular arch to the base of the caudal fin. This mass of muscle is not, however, so simple as it appears, but divided into numerous parts. We may distinguish an upper layer where the tendinous strips are directed obliquely backward, and then a second and third, the last of which is situated beneath the lateral line. The tendinous transverse strips here alter their direction, but correspond to the number of vertebræ. These layers of muscle arise from the skull itself, from the occipital and mastoid bones, in which situation they correspond to the nuchal muscles; also from the scapula and clavicle, then from the lingual bone, the vertebræ and their spinous processes, clothe the ribs, and are inserted by short tendons into the base of the caudal fin. Below them lies another layer upon the belly, which corresponds to the abdominal muscles, while the upper layers are analogous to the dorsal muscles of the higher animals, especially the *m. m. spinalis*, *semispinalis*, *multifidus spinæ*, *longissimus dorsi*, and *sacro-lumbaris*. The symmetry displayed by the dorsal and ventral portions of the lateral muscles, upon a perpendicular section, is most striking, and we are in this way best enabled to see the peculiar infundibuliform arrangement of the several muscular layers.

Each lateral muscle bends the body toward its own side, at the same time producing powerful lateral inflexions of the rudder-like tail; movements so necessary in the act of swimming. The head can be also moved to a slight degree, when its freedom of attachment to the vertebral column admits of it. By the co-operation of the two lateral muscles upon either side at their anterior part, the compression of the swimming-bladder may be also affected.

The several orders and genera of Fish naturally exhibit numerous muscular varieties. Beneath the lateral muscles, between the ribs, are found the *intercostal* muscles. In the interspaces between the two great lateral muscles, both upon the dorsal and ventral side, but chiefly upon the latter, two very slender muscular strips may be seen to pass, as in the Perca fluviatilis, and to be interrupted only by the dorsal and anal fins.

The *caudal fin* is moved chiefly by small thin muscles, which form two layers, a superficial and a deep, and are inserted, like those of the dorsal fins, into the rays composing it; occasionally there occurs, as in Perca, a third layer. The several rays of the caudal fin can be moved by means of these upward, downward, and laterally.

The *muscles of the anterior extremities* consist of two principal layers, upon each of the two surfaces of the antebrachial and carpal

bones. The superficial layer of the external side arises from the clavicle, and covers entirely that which lies beneath it; that also of the inner surface of the fin, or the one turned toward the trunk, exhibits similar relations. The latter draws the fin toward the body, while the external, as abductors of the fin, move and raise it outward.

The arrangement of the *muscles upon the posterior extremities*, or ventral fins, when the latter are present, is of a similar kind. Here we find proper elevators and depressors in a double series, which arise from the pelvis and are inserted into the fin-rays. The rudimentary pelvic bones obtain fasciculi from the lateral muscles, that correspond to an oblique abdominal muscle and a rectus.

The muscles of the anterior extremities, or pectoral fins, are particularly developed in Lophius and in the Flying Fish, *e. g.* Trigla, Exocætus, among the Osseous Fishes.

The *muscles of manducation* are very strongly developed, and form more or less a mass constituting what is called the cheek-flesh of Fishes, and which in the Trout has a particularly delicate taste. The whole depression occupying the external surface of the articular portion of the temporal bone is covered by this muscular mass; and it arises not only thence, but also from the anterior edge of the præoperculum, and is inserted partly into the upper, partly into the lower jaw. The disposition of these manducatory muscles is very different from that of the *masseter* and *temporal* muscles of the higher animals, to which, however, they correspond.

The muscles of the Cartilaginous Fishes exhibit more noticeable diversities. In the Plagiostomi, as the Rays, the dorsal and ventral muscles are more separated by a horizontal tendinous layer, that divides each lateral muscle into an upper and lower half. Several muscles are also given off for the cranium, so that the head can be slightly moved. Remarkably large horizontally expanded layers form, in the Rays, the muscles for the great pectoral fins, without, however, these admitting of a separation into superficial and deep layers, as in the Osseous Fishes. In the Electric Ray a pair of peculiar muscles with long tendons also occur; their fleshy part or bellies arise behind the skull from its lower surface, and are inserted into the anterior margin of the head in front of the electric organs; they have no analogue in other Fishes.

In the Cyclostomi the same numerous tendinous strips are found intersecting the lateral muscles, which are here much developed, and surround the body. In the Myxinoides we find superadded a

system of lateral ventral muscles, which, as a rule, is absent in other Fishes, and consists of an oblique and a straight ventral muscle; by means of these the powerful movements and vermiform deflections of these animals are effected.

NERVOUS SYSTEM.

The Nervous System also of Fishes, especially the Brain, exhibiting numerous diversities, it will be best to become first acquainted with the regular arrangement of these structures as they are found in the majority of Osseous Fishes, and then to describe their varieties in the several genera and families of that sub-class; lastly, their mode of formation in the remaining orders.

The ordinary type of structure in the Brain of Osseous Fishes is to be observed in many Acanthopterygians, *e. g.*, Perca fluviatilis, and Malacopterygians, as the Pike (Esox lucius), in both of which it presents a very close conformity; in the common Carp, however, which, from its frequent occurrence, has been chiefly recommended for the purposes of dissection, we already encounter peculiar cerebral anomalies; and other species of that genus, as Cyprinus barbus, are therefore better suited for examination.

The *Brain* in general does not nearly fill up the cranial cavity, so that between the dura mater that lines the internal surface of the cranium and the soft membrane which very closely invests the brain itself, we find a free space filled up by a quantity of loose cellular tissue, interrupted throughout by adipose cells. A fluid oil is frequently found floating in large drops between the meshes of this tissue. The membranes situated between the dura and pia mater may be viewed as the arachnoid; the analogy being still more obvious where they cover the third ventricle. The dura mater is often of a silvery lustre, or partially coated by black pigment.

We shall do best to commence the consideration of the several parts of the brain with the *medulla oblongata*, which, though it differs slightly, is to be distinguished from the rest of the spinal marrow by being broader and flatter. Upon the medulla oblongata may be distinguished four thickened tracts, two superior and two inferior; the first are slightly enlarged, from the corpora restiformia, and recede from each other in the middle line, so that the floor of the fourth ventrical or rhomboidal sinus lies freely exposed to view; they give off processes that are prolonged, forming its crura, into the cerebellum. Some transverse fibres upon the inferior sur-

face of the medulla oblongata probably replace, as in other higher Vertebrata, the pons Varolii, that occurs only in the Mammalia. The *cerebellum* is a large spherical ganglion, for the most part slightly lobular in form, and curved upon itself posteriorly; it is destitute of transverse grooves, but frequently furnished with obtuse lateral projections. The fourth ventricle extends far into it. In front of the cerebellum are situated two large obovate hemispheres or ganglia, which in size, form, and situation, are similar to the hemispheres of the higher animals, and, from their forming the most considerable portion of the brain of the Osseous Fishes, have been regarded as such by some anatomists; others term them optic lobes, and they obviously correspond to the mesocerebrum, the corpora quadrigemina and optic thalami of the human subject taken conjointly; they may be called *median lobes*. Upon making a superficial section of one of them, we find beneath a thin roof of medullary matter, a large cavity extending through the whole ganglion. Upon the floor of this cavity or ventricle, in the posterior direction, are usually situated four small round ganglia (*e. g.*, in Perca, Esox, some Salmonidæ, Clupea, Trigla, Gadus Lota), more rarely two (as in Gadus, Lophius, Blennius, Muræna, Cyclopterus, some species of Pleuronectes), or six (*e. g.*, Scomber thynnus, Salmo trutta); these ganglia certainly appear to resemble the corpora quadrigemina of Man, and are even united with the cerebellum by some fasciculi of fibres, the *crura cerebelli ad corpora quadrigemina*. Further outwardly lies a larger ganglion, similar to the optic thalamus or corpus strtiatum, and on its external side we perceive a radiated expansion of fibres, called the staff-wreath, or *corona radiata*. Several transverse fibres or *commissures* are found, which partly correspond to the corpus callosum, partly to the commissura mollis; a rudiment also of the fornix probably exists. The hollow space included between the above-named ganglia is prolonged deeply into the infundibulum, and thence backward into the fourth ventricle, and corresponds itself to the third. Inferiorly and posteriorly, at the base of the brain, and behind the chiasma or decussation of the optic nerves, are situated a pair of mostly large ganglia, which agree in their position with the eminentiæ candicantes of the human subject, but can not certainly be compared with them. They are usually styled the *lobi inferiores*, are oval in form, and rest for the most part upon the pituitary body. In front of the pair of mesocerebral masses (*lobi optici*) are situated another pair of smaller yet tolerably distinct ganglia, which are united also posteriorly by a narrow me-

dullary band, or anterior commissure; the ganglia themselves correspond principally to the hemispheres of the higher Vertebrata; they are usually called the olfactory lobes, or *lobes of the hemispheres*. These ganglia are solid, and almost always smaller than the mesocerebral ganglia; for the most part they are composed of two kinds of substances, an anterior and a posterior; the first of these, the largest, presents a delicately tuberculated surface, or, as it were, traces of convolutions; this is distinctly to be seen in the Pike, and also in Gadus morrhua, the Salmonidæ, and others. From, or in front of, these ganglia of the hemispheres arise the nerves of smell; not, however, directly from them, but usually from small interposed round or oval ganglia, which are occasionally themselves of some considerable size, and have received the names of *olfactory ganglia* or *tubercles;* they are present in most, probably all, the Osseous Fishes, and are very distinct in all our indigenous Fishes, *e. g.*, Esox, Salmo, Clupea, Perca, Pleuronectes, Gobius, Gadus, Labrus, Uranoscopus, &c. They are, however, frequently so small and elongated as to be easily overlooked, *e. g.*, in the Carps. A small, vascular, and frequently all but membranous lobule, which is situated freely exposed, and directly in the middle line between the mesocerebrum and the ganglia of the hemispheres, may be regarded as the *pineal gland*. The *pituitary appendage* is of considerable size, and depends from its stem or the infundibulum; it is particularly large in Pleuronectes and Cyclopterus; indeed, generally speaking, Fishes have the largest pituitary body of all the Vertebrata.

The above-described is the usual arrangement of the structure of the brain in the Osseous Fishes, but it is subject to many varieties in the several families and genera, these consisting chiefly in the number of the several hemispheres or superficial ganglia being increased, or in their being severally enlarged and subdivided to a striking degree.

In Fishes of the Eel kind we find two pairs of olfactory lobes or ganglia introduced between the small olfactory tubercles and optic lobes. The posterior pair is largest, and manifestly identical in its whole structure with the olfactory lobes of the remaining Osseous Fishes; for, as in them, they exhibit two divisions of structure, their anterior portion being rendered uneven by rudimentary convolutions, the posterior presenting a smoother surface. This structure is particularly distinct in the common Eel, but occurs also with modifications in the Conger and Murænophis. In the Electrical Eel

(Gymnotus) the mesocerebrum is very strikingly developed. A larger lobe, divided by a median groove, arises from the optic lobes by sloping semilunar-shaped roots, and forms a conical eminence that extends far forward. The whole brain from this derives a peculiar appearance; it is in this ganglion that the roots of the nerves destined to supply the electric organ arise, so that it may be termed *lobus electricus*.

A median lobe is developed in a similar manner in Echeneis remora, and probably contains the nervous elements for the supply of those remarkable organs situated upon the skull, by means of which this fish adheres to ships, stones, and other bodies.

Behind the cerebellum, and to the side of the fourth ventricle, are situated frequently a pair of *posterior lobes*, which are occasionally further subdivided into a special pair of lobes for the roots of the nervi vagi. They are very small and rudimentary in many Fishes, and are therefore easily overlooked; but are most developed in the Carps, being as large, or even larger than the optic lobes. Other Cyprinidæ likewise possess these lobes of the nervi vagi, and they appear also to contain the special nervous elements for a very irritable and contractile organ situated at the base of the cranium above the pharyngeal bones, and which will be described more minutely in speaking of the organs of taste. The lobes of either side are connected by transverse white fibres, forming a kind of commissure upon the under surface of the medulla oblongata. There frequently occurs, as in many also of the Carp tribe, a single median ganglion, which rests upon the floor of the fourth ventricle. This ganglion is of largest size in the common Carp, and appears to exist also in the Sheat-fish (Silurus).

In many Fishes, *e. g.*, in Trigla, from three to five ganglia are constantly interposed behind the already-mentioned lobi posteriores, near to the medulla oblongata, resting upon its upper tracts or corpora restiformia; they are also in connexion with peculiar structures, namely, with the large digitiform rays that are given off from the pectoral fins in the Triglæ, and which receive nerves of proportionate size. Besides this, great diversities occur in the relative proportions of the several parts of the brain; thus the cerebellum is in some cases greatly developed, in others very small. It is largest indeed in the Tunny-fish (Scomber thynnus), and perhaps generally in the Scomberidæ, at least in S. scomber, where it forms a lobe covering the mesocerebrum in the direction forward and upward.

In Silurus glanis it is very large; very small, on the contrary, in Gobius, but rarely provided, *e. g.* Echeneis remora, or Sucking-fish, with transverse grooves, as in the higher Vertebrata.

A want of symmetry between the two sides of the brain occurs in different Osseous Fishes; it is present in the least degree in Gadus, where the cerebellum is mostly placed more toward the right side. In Pleuronectes this asymmetrical condition is carried to a greater degree, being extended to the cerebral ganglia, the optic lobes (the left of which is usually placed above the other), and still more to the olfactory lobes and olfactory turbercles, which are much larger upon the left or uppermost side than upon the right.

In the structure of the brain, as in many other points of its organization, the *Sturgeon* makes the transition from the Osseous to the true Cartilaginous Fishes. The medulla oblongata is broader; the spinal canal opens into a very long and patulous rhomboidal sinus, which is bounded upon either side by the ridges formed by the posterior columns of the chord or corpora restiformia, that enter, as its crura, the broad but small cerebellum. In front of the cerebellum are placed the two moderately large optic lobes, which form the mesocerebrum, together with the narrow mass that inferiorly and laterally includes the freely exposed third ventricle. The olfactory lobes are considerably larger in proportion than in the Osseous Fishes, already presenting more the form of hemispheres, are further subdivided and continued into small olfactory tubercles. The very large pituitary body rests, without any stem or infundibulum, upon the base of the brain. Upon the sides of the medulla oblongata are a pair of posterior lobes, which appear to be chiefly in connexion with the root of the fifth pair of nerves.

The brain varies also in form in the *Plagiostomi* (Rays and Sharks), but not nearly so much in proportion as that of the Osseous Fishes; and from its agreeing more, even when very different in external appearance, with the brain of Amphibia, it is easier to determine the signification of its component parts. The brain is chiefly characterized by the more considerable development of its hemispheres, from which arise either thick or slender nerves of smell; the lobes of the hemispheres are actually blended into a common mass, divided only above in the longitudinal direction; they are either solid, as in most of the Rays when they have grown old, or they are provided with a ventricle, which is continued then into the olfactory nerves, as is seen chiefly in the Sharks, as Scymnus, Acanthias. This mass is prolonged by means of a narrow part of the