

nus, Salmo, and Cobitis. The bones called nasal bones and infra-orbital, are probably bones appertaining specially to the dermo-skeleton, and are, therefore, improperly so termed. The *inferior maxilla* invariably consists, upon either side, of at least two pieces, of which the anterior is usually blended with that of the opposite side to form a firm arch, and supports the teeth, whence it is called the *dental* piece; the posterior or *articular* piece articulates by ginglymus with the os quadratum. Usually, though not always, a third bone, the *angular* piece, is found lying behind and beneath the articular; and more rarely a fourth, or *complementary* piece, is super-added, which lies in the direction inward between the dental and articular piece. Six pieces are rarely met with as in the genus *Lepidosteus*, where the structure of the lower jaw reminds us of that in the *Reptilia*, as the *Crocodile*. Occasionally a very considerable gap remains between the dental and articular piece, *e. g.* in *Zeus*, *Pleuronectes maximus*. The asymmetrical condition of the bones of the cranium in the *Plaice* is extended also to those of the face, but slightly to the lower jaw.

Many Fishes exhibit greater varieties of cranium than those already mentioned, as is the case, for example, in *Uranoscopus*, *Lepidoleprus*, *Lophius*, *Chironectes*; yet the description already given is applicable in general to the Soft and Spiny-finned Fishes. The genera *Centrus*, *Polyodon*, *Lepidosteus*, *Polypterus*, &c., with the *Syngathi* and *Hippocampi*, exhibit greater anomalies, not only in the structure of their skull, but in the rest of the skeleton.

As concerns the *Vertebral Column* of the Osseous Fishes, it consists properly only of thoracic and caudal vertebræ, the first vertebræ supporting ribs as well as the others, so that the cervical series is wanting. The number of vertebræ is very various: in the elongated Fishes, as the *Eel*, and others of that kind, *e. g.* *Sphagebranchus*, it exceeds 100; in *Trichiurus lepturus* above 150; in *Gymnotus* and *Ophisurus* above 200; in others only 20—30, as in *Balistes*.

The bodies of the vertebræ in Fishes are well characterized by the deep grooves upon their sides, and which penetrate so far as to perforate the latter, so that they present a series of apertures, as in the *Shad*, *Silurus glanis*. Their anterior and posterior surfaces, where the bodies unite to each other, exhibit a conical depression. In this way a double infundibuliform cavity is formed, similar to that in the *Cartilaginous Fishes*, between two vertebræ, and is filled up with a gelatinous fluid which is found even in the centre of the vertebral body. This fluid is enclosed in a membrane forming a kind of sac

and being interposed in the above manner between two vertebræ, constitutes an elastic apparatus, performing functions similar to those of the intervertebral ligaments in *Man*; it is formed partly out of the remains of the *chorda dorsalis* and its sheath, as will be pointed out more closely further on in speaking of the *Cartilaginous Fishes*. The vertebræ frequently possess anterior oblique processes (often absent) and posterior, which are rarely wanting; both the one and the other, however, can be but improperly compared with the oblique processes of *Man* and the higher *Vertebrata*, seeing that they are not united by articulating surfaces. The parts that form the arch of the vertebræ are continued into very large *superior spinous processes*, which are well developed in *Sparus*, and still more in *Chætodon*, *Pleuronectes*, &c.; but they are, on the contrary, low and depressed in the *Anguilliform Fishes* and in *Lophius*. In *Syngnathus* the superior spinous processes of the vertebræ support the dorsal fins, and are divided into several widely radiating pieces. The thoracic vertebræ are frequently provided with transverse apophyses directed somewhat downward: although they may be called transverse processes, yet, judging from what we know of the developmental history of the vertebræ, they must be essentially different from those of the higher *Vertebrata*. They are frequently absent; when present they support ribs, but invariably project backward and downward, where, converging, they coalesce to form the inferior arches, which together constitute a canal, opposite to that of the superior arches enclosing the spinal cord, and through which the aorta passes. Upon the caudal vertebræ they support very large *inferior spinous processes*. Occasionally, as in the *Carp*, *Shad*, *Pike*, in *Clupea*, *Zeus*, *Trigla*, one or more ribless vertebræ, provided with peculiar processes, are situated in front of the costiferous set, and are regarded as cervical vertebræ. Situated above and upon the superior spinous processes, to which they are usually connected by membrane to a greater or less extent, are the *accessory* or *interspinous* bones, frequently of considerable size, and supporting superiorly the *rays of the fins*. It is rare for the interspinous bones to advance, as in *Plagusia*, far forward upon the skull, and form there a crest. The fin-rays are in some instances, as in the *Acanthopterygii*, simple, pointed, horny spines, but in others, as the *Mala-copterygii*, they are softer, divided several times at their extremity, and transversely articulated; they are united by ginglymus with the interspinous bones, and it is between them that the membrane of the dorsal fins is expanded. Perfectly similar interspinous and ray-



bones are met with in the anal fins, where the foremost of these *inferior interspines* are frequently of remarkable length and strength, as in *Pleuronectes*. The last vertebræ, or those which abut against the caudal fin, are usually formed in a peculiar manner, being very strongly compressed laterally, and their superior and inferior spines forming large flat bones. Frequently, as in the Anguilliform Fishes, the last vertebræ become smaller in size, but exhibit no peculiar conformation from the absence of the caudal fin.

Most of the Osseous Fishes are furnished with *Ribs*, which vary greatly in number, and are attached partly by their upper and strongest extremity to the transverse processes, and partly to the bodies of the vertebral series, inclining chiefly in the direction forward. The ribs are never, as in Man and the higher Vertebrata, laterally compressed, but from before backward, or they are rounded, and frequently present the appearance of slender spiculæ. In many fishes, *e. g.* *Balistes*, the ribs are small and few in number; in others they are rudimentary or entirely wanting, as in *Lophius*, in the *Pectognathi*, and others.

In many Fishes we meet with a series of bones that have been falsely termed *accessory ribs*; they consist of lateral spines, which are attached to the vertebræ above the true ribs, and are plunged among the muscular fasciculi to which they properly belong. They are greatly developed in the Herring, where they stand in two rows.

It is only in a few Fishes that parts are found which admit of being very remotely compared to a *Sternum*. To these belongs the chain of little bones, parts of the dermo-skeleton, that in *Zeus* and *Clupea* extend from the girdle of the thoracic fins to the anal fin. In other Fishes, *e. g.* *Balistes*, a single long bone occupies their place. No costal cartilages are, however, found connecting the ribs with the parts just described, so that the latter can only be viewed improperly as a sternum.

The *Thoracic* and *Ventral fins* of the Osseous Fishes correspond in position to the anterior and posterior extremities, and attempts have been made to reduce the osseous structures which serve for their support to corresponding bones in the arm and foot of the higher Vertebrata.

As regards the *Anterior Extremities*, they appear to be completely wanting in probably none of the Osseous Fishes. As in many Serpents and Apodal Lizards, even where they are not indicated externally by fins, they still exist, of which examples are met with in

many Fishes of the Eel family; and it is here that their structure exhibits an interesting series of gradations. Their form appears to be of the simplest kind in *Muraenophis*, where, upon either side, there lies beneath the skin behind the gills a single bone, sloped out anteriorly and surrounded by muscles, which supports no fin. A similar pair of very delicate styliform bones, abutting together anteriorly, are situated behind the branchial apparatus in *Sphagebranchus*; these bones are more largely developed in *Synbranchus* (*Unibranchapertura*, Lacep.), where they form a girdle that corresponds somewhat to the clavicles. In *Murana* each of these bones is already divided into two, the uppermost of which may be viewed as a rudimentary scapula, while the remaining divisions enter into the composition of the fin—an arrangement approximating the usual structure which is as follows: There is generally situated most superiorly one bone, or occasionally several, that represent the *scapula*. The uppermost is usually bifurcated, and unites by means of its two processes with the occipital bone; it is rarely, however, firmly united to the skull by suture, but usually by ligament alone. To this, or to a second small bone, succeeds inferiorly one that is very much larger, presents a slight semilunar excavation in front, and comes in contact with that of the opposite side, so as to form a girdle for the anterior extremities, which gives off the main support of the fin. The bone, which corresponds to the single one in *Muraenophis* and *Synbranchus*, has been named, perhaps justly, the *anterior clavicular*. It is more difficult to admit the title of *posterior* or *coraco-clavicular* applied to the next bone, as the analogue of the coracoid process of the Mammalia, and the posterior clavicle of Birds. It is for the most part longer, more pointed, and rib-shaped, and, in the direction backward and inward, rests against the convex part of the anterior clavicle, and converges frequently to that of the other side; it consists usually of two pieces, of which the superior is broad and flat.

To the above follows the second or middle division of the bones of the thoracic fins, which is viewed as corresponding to the *humerus* and *antebrachial* bones. This division consists of three, or frequently only of two bones, perforated by openings, and often of very considerable size. A row of smaller, flatter, and rarely more elongated bones, follows the above division, and has, in conformity with nature, been viewed as corresponding to *carpal* and *metacarpal* bones. Four separate bones are mostly here present, but the number varies from two to five. A special division is in rare cases,



formed for the metacarpus. To these bones are appended the *digital* articulations or fin-rays (*radii pinnae pectoralis*), which form the supporting frame-work of the pectoral fins.

The varieties in the construction of the anterior extremities in the several genera are very great. The arrangement in the Eel is of a very simple kind, there being a single bone or scapula not bifurcated, and below that the clavicular bone. In addition to these are two bones for the second division, and several for the carpus and the fin-rays. The bones are somewhat more developed in Gymnotus, where the scapula is united to the skull. The genera *Exocætus*, *Lophius*, *Silurus*, *Tetrodon*, possess also but one bone for the scapula; most of the Osseous Fishes, *e. g.*, *Perca*, *Esox*, *Cyprinus*, *Cyclopterus*, *Trigla*, *Scomber*, *Chætodon*, *Gadus*, *Brama*, &c., are provided with two, an anterior and posterior, clavicular bones, two to three brachial, three to four carpal bones, and next in succession with fin-rays or phalanges; many, as several species of *Sciæna*, *Sparus*, *Labrus*, &c., have as many as three scapular bones; the posterior or coraco-clavicular bone is absent in *Anarrhicas*, *Silurus*, *Uranoscopus*, *Fistularia*, *Exocætus*, and consists invariably of only a single bony piece in *Cyprinus*, *Esox*, *Batrachus*, *Lophius*, and *Chironectes*; in *Chætodon* it abuts against the bones of the pelvis; in *Zeus* the two clavicles coalesce inferiorly; the carpus in *Lophius* and *Chironectes* is formed of two very long bones, that have been falsely compared with the ulna and radius; in *Batrachus* there are five similar bones, and in *Polypterus* two elongated bones, with one or several discoidal ossicles interposed between them; this Fish has also, as an occasional peculiarity, a row (amounting even to 18) of elongated bones, which correspond to the metacarpus. The carpal bones are very seldom wanting, as in *Exocætus* (where the fin-rays are remarkably long) and in *Uranoscopus*. For the second or ante-brachial division of the anterior extremity we find, in *Silurus* and *Heterobranchus*, only one bone; the first fin-ray is, on the contrary, strong and linked to the anterior clavicular bone; so that here, as in *Pimelodes*, *Platycephalus*, and others, it is very broad inferiorly, and united with that of the opposite side by a zigzag suture.

The *Pelvis* and *Posterior Extremities* are but very rudimentary in the Osseous Fishes, and not connected to the vertebral column, but are imbedded simply in the flesh, as in the *Amdominales*, or abut against the anterior clavicular bones, as in the *Thoracici* and *Jugulares*; occasionally they are completely wanting, or we find in their place two usually long flat bones, which support on their posterior

edge the digital portion or abdominal fin; it is rare for a third set of bones to be interposed between these.

More diversities appear in the posterior than in the anterior extremities; thus they are often completely absent, as in *Xiphias* and Fishes of the Eel kind, *e. g.*, *Muræna*, *Murænophis*, *Sphagebranchus*, *Gymnotus*, &c., and are placed in some instances far forward, in others far backward; upon these varieties of position of the ventral fins the old Linnæan division of Fishes into *Apodal*, *Abdominal*, *Pectoral*, and *Jugular*, was based.

Both pelvic or iliac bones are usually more or less united to each other; in some Fishes they are completely anchylosed, in others prolonged backward in the form of a spine, as in *Cyprinus*, *Scomber*, *Zeus*, &c.; they are occasionally separate, as in *Lophius*, *Batrachus*. *Polypterus* possesses four elongated bones, that correspond as the third division of the extremities to the tarsus and metatarsus.

The Skeleton in the Cartilaginous differs altogether in structure from that already described as belonging to the Osseous Fishes, and it is only its fundamental types which are common to the two as Vertebrate animals. It is scarcely possible to offer any general remarks relative to the skeleton of the Cartilaginous Fishes, and we must therefore characterize its peculiarities in the several orders and families.

In the Cartilaginous Fishes the skeleton remains throughout life in a cartilaginous condition, and true ossification occurs only in the tegumentary bones, *e. g.*, in the Sturgeon, or in particular parts of the skeleton. In some Cartilaginous Fishes, such as those with free branchiæ (*Acipenser*, *Chimæra*), the permanent cartilage resembles the cartilage that precedes the formation of bone in the Osseous Fishes: the cyclostomi, however, are distinguished by possessing a very peculiar kind of cartilaginous tissue with coarse cells, while the Plagiostomi possess the cartilaginous tissue of the Sturgeon and *Chimæra*; and in addition thereto, other kinds of cartilaginous tissue, namely, 1st. The hyaline or transparent tissue, with more or less membranous cartilaginous corpuscles; this occurs in the Sturgeon, and also in the Osseous Fishes, and forms mostly the internal part of the cartilage, with the exception, however, of the vertebral bodies. 2d. The tessellated calciferous cartilaginous tissue, which occurs only in the Sharks and Rays, and invests the hyaline cartilage like a hard crust, with the exception of the vertebral bodies. This cartilage consists of prismatic pieces which resemble brick-work, and are separable from each other. 3d. The cellular cartilaginous tissue



occurs in the Cyclostomi. The cartilaginous corpuscles disappear by degrees, and the cartilage appears devoid of cells, like the hairs of one of the Goat tribe. 4th. The completely-ossified cartilaginous tissue, as exemplified in the solid vertebral bodies of the Rays and Sharks.

The Sturgeon, although a true Cartilaginous Fish, effects the transition from that type to the Osseous, of which we are reminded by the disposition of the parts of its skeleton. Already do we find in many of the Osseous Fishes, as the Pike and Trout, that the cranium consists internally, where it encloses the brain, of cartilage, upon the external surface of which the bones of the cranium, as already described, are deposited. In the Sturgeon the cartilaginous cranium becomes ossified at its base; this bony portion corresponding to the basilar element or body of the occipital and sphenoid. But even here the ossific process has taken place only externally, and that surface which forms the cavity of the cranium still continues cartilaginous; the ossification is most apparent in the fibrous tunic, which, continued from the fibrous sheath of the medulla spinalis, lines the skull. In other parts the cranium is perfectly cartilaginous, and covered in with firmly adherent bony scutes, which belong properly to the dermo-skeleton, and admit only of an inaccurate or very remote comparison with the cranial bones of the Osseous Fishes. In front and on the sides the cartilage of the head presents depressions for the eyes and nasal cavities, and then projects into a long process. The palatal bones are separate from the skull, united with the superior maxilla, and consists posteriorly of an azygos bony plate, and two anterior osseous pieces in pairs. The quadratal bone consists of a superior bony piece united to the cranium and two inferior cartilaginous pieces; the last of these is united to the lower jaw, which, with the small and double superior maxillary bone, closes the edentulous mouth.

In the Chimæra, the Sharks, and the Rays, the skull is a large cartilaginous capsule, enclosing the brain and auditory apparatus; it is free of the vertebral column, and exhibits no traces of ossification. In the Plagiostomi there usually remains upon its upper surface an open space or fontanelle, closed only by a fibrous membrane. This cartilaginous capsule is particularly flattened upon its upper surface in the Rays, and has posteriorly an opening, the occipital or foramen magnum, and lesser apertures also for the exit of nerves. A portion of this capsule, convoluted upon itself laterally, forms the orbital cavities, and frequently presents superiorly, as in Scymnus

an orbital process. United to the anterior extremity of the cranium we meet with a deep hollow leaflet of cartilage, forming the nasal fossa. The upper jaw is constituted by a narrow arch of cartilage, occasionally, however, deep, as in the Sharks, and of a semilunar form; it is beset completely, both upon its edge and posterior wall, with teeth. A quadratal cartilage, more simple and elongated, is lodged in a posterior lateral depression in the skull, and articulates with the lower jaw, an arch provided with teeth, and composed of two lateral halves like the upper. There occur, moreover, in the Rays small palatal cartilages, as also peculiar cartilages belonging to the spiracles, and which correspond somewhat to the pterygoid bones or processes in the Osseous Fishes. The intermaxillary bone must be regarded as absent, if we do not consider it united with the superior maxilla in the arch of cartilage just described. In the Chimæra the skull is very peculiarly formed, being provided with distinct convoluted nasal cartilages, while upon the fore part of the head stands a style-shaped piece of cartilage.

Furthermore, there exists in many of the Sharks and Chimæras a peculiar system of labial cartilages, which is wanting in the Rays and Sturgeons; the question of its homology has given rise to various incorrect speculations; a portion of it was regarded formerly by some anatomists as belonging to the maxillary apparatus. It consists of several more or less elongated muzzles of cartilage varying in form and particularly remarkable in the Chimæra, which rest externally and laterally against the upper and lower jaw. In Acanthias and other genera, for example, a lower labial cartilage is to be distinguished lying upon the inferior, and a superior upon the upper maxilla, and occasionally, as in Scymnus, Chimæra, a third cartilage situated above the latter one. Among the Rays, it is only in Narcina that small labial cartilages are met with. In them and in the true Electric Rays (Torpedo) there is situated in front of the body a cartilaginous production of the muzzle which unites the pectoral fins to the skull.

Still more abnormal is the structure of the cranium in the Cyclostomi, and in them we are again met by numerous varieties in the structure of the buccal cartilages. With this group, indeed, all attempts to draw any analogy or comparison with the typical Fishes must be laid aside.

The cranium of *Petromyzon marinus* and *fluviatilis* consists of a hard, nearly osseous brain-capsule, having a detached flattened basilar portion, that gives off in the direction backward a pair of pro-



cesses. Upon its sides are found the hard, oval auditory capsules, united continuously with the skull, and enclosing the membranous labyrinth; upon the upper part of the skull itself we remark, as in the Rays, a fontanelle closed by fibrous membrane. In front also and inferiorly, the arch of the cranium is to a great extent membranous. Superiorly, and in front of the skull, is the opening of the nasal tube, which perforates the palate, and on its posterior wall the olfactory nerve is distributed as it issues from the cranium. A number of cartilaginous plates lying behind each other belong to the parts of the mouth: thus there is found an anterior and posterior operculum of the oral aperture, to which are superadded inferiorly a pair of lateral plates; a ring-shaped piece of cartilage, the labial ring, corresponds to the maxilla, and to this is fastened laterally a styloid cartilage, which is directed horizontally backward.

The skull is still more simple in *Ammocetes*, where the parts of the mouth just described are in a great measure wanting, while the cranial capsule is essentially similar in structure to that of *Petromyzon*.

In the family *Myxinoidea* very varied and peculiar forms of oral cartilages are developed, while the cranium of the genera *Myxine* and *Bdellostoma* admits of a comparison with that of *Petromyzon*. All the essential parts described above, namely, in reference to the capsule of the brain, are here repeated, and we meet with similar hard auditory capsules; but there is also a singular frame-work to the pharynx formed of cartilaginous hoops, a long nasal tube consisting, like a trachea, of cartilaginous rings, the nasal capsule, and the palatal plate with its raised borders. In the *Myxinoidea* the nasal canal is open inferiorly toward the palate, while in *Petromyzon* and *Ammocetes* it there terminates in a caecal manner.

In the remarkable genus *Amphioxus* s. *Branchiostoma*, a case or shell is completely wanting for the rudimentary brain, which is merely included in a membranous capsule; in the mouth, however, is found a cartilaginous ring with cartilaginous filaments; there is also present a system of oral cartilages, as in the *Sharks*, *Chimæra*, and *Petromyzon*.

The structure of the head in the *Amphibious Fishes*, including the genus *Lepidosiren*, of which it is doubtful whether it should be arranged among the members of the present class or among *Reptiles*, offers very great peculiarities. The skull, as in all *Fishes*, is immovably united to the occiput, presents a cartilaginous substratum upon which the peculiarly-formed bones of the head repose, and

remain themselves partly cartilaginous. The number of the cranial bones is small, and their homologies difficult to determine by comparison with those of other *Osseous Fishes*; yet we find lateral occipital elements, and a single bone forming the upper covering of the skull; to this last there corresponds a similar bone at the base of the cranium, which may be viewed as the body of the sphenoid. The bones of the face also attract our attention from their peculiarities; the superior maxilla appears to be wanting, while the intermaxillary is present; and there exists moreover a system of labial cartilages, which, with the tooth-bearing lower jaw, exhibits a relationship of structure with that of *Chimæra*. A more simple quadratal cartilage unites the inferior maxilla to the skull.

In the structure of the *Vertebral Column of the Cartilaginous Fishes* we encounter peculiarities and differences in the several orders and families, which are the more interesting when the development of vertebræ comes to be studied, and the plan of their formation followed out through the series of *Vertebrate animals*; an extensive subject belonging to the departments of philosophical anatomy, and not to be entered upon here.

In the *Sturgeon* and *Chimæra* the vertebral column is constituted by a fibro-cartilaginous tube, which is filled with a gelatinous substance, and surrounded by a fibrous tunic, that is closed above to form a tube for the spinal marrow. Upon the inferior surface of this fibro-cartilaginous tube are situated the rudimentary basilar parts of the vertebræ; they are united beneath by a membrane, along which the aorta passes. Between the upper triangular pieces of the arch other triangular pieces of cartilage (*cart. intercrurales*) are found, and the roof of the spinal canal is closed in by a series of more elongated cartilages, above which there are placed in the *Sturgeon* large spinous processes. The fibro-cartilaginous tube of the *Chimæra*, very beautifully annulated by thin transverse rings that were formerly falsely compared to vertebræ, remains in a great measure exposed to view, and corresponds to that part in the rest of the *vertebrata*, present only in their foetal condition, but in *Fishes* more or less persistent, namely the *chorda dorsalis*, or central cylindrical axis, around which the formation of vertebræ takes place. The persistent structure of the vertebral bodies in the *Sturgeon* and *Chimæra* corresponds to that which exists only in the foetal state of the *Osseous Fishes*. In these latter *Fish*, when fully formed, the gelatinous tube is reduced to constricted masses of gelatine, surrounded by the conical facets forming the bodies of the