

may be proved to exist. The Rays, *e. g.* Torpedo, exhibit a peculiar disposition of the pupillary margin, for golden-colored processes, shaped like palm branches, depend from the iris, and are capable of closing the pupil like a curtain.

The *Optic nerve* in Fishes is generally formed of plicated laminae, which can be unfurled from each other like the vanes of a fan. It perforates the sclerotic obliquely, and at a distance from the central axis of the eye. The point of exit for the retina is a round opening, frequently, however, an elongated slit, from which the nervous tunic of that membrane expands. The latter exhibits the same component parts as in the remaining Vertebrata, such as a strongly developed racemose or papillary layer arranged in a peculiar manner.

The *Crystalline lens* is of large size, perfectly spherical, and enclosed within a thick capsule; it usually protrudes through the pupil, and approaches, like the iris, very close to the cornea, so that the posterior chamber of the aqueous humor is completely wanting, and the anterior very small, containing only a very slight quantity of that fluid. The lens consists, as in other animals, of peculiar fibres, which are united by toothed edges, like the sutures of the cranial bones. The *Vitreous body*, flat, and having the lens deeply imbedded in it, contains a small quantity of thin fluid.

The eye of a Fish, when most perfectly constructed, presents always a very flattened form of bulb and a short axis; owing to the watery medium in which they live being denser than that of air, the vitreous and aqueous humors appear to be present in smaller quantity, while the lens is more dense and spherical, so as to bring the rays of light to converge at a shorter focus. But besides these general, other special peculiarities occur in the structure of the eyeball in Fishes. Thus in *Pleuronectes* both eyes are placed asymmetrically upon one side. In *Anableps tetrophthalmos* the cornea of each eye is divided by a transverse band, and is thus rendered double along with the pupil, while the other parts remain single. The size to which the eyes are developed varies greatly; thus they are largest in many Osseous Fishes, and particularly so in the *Plagiostomi*, where, as in *Priacanthus*, they are of remarkable magnitude, and still more so in the rare *Pomatomus telescopium*, which lives in the greatest depths of the Mediterranean sea. The eyes are generally small in those Fish that bury themselves, as the Eels and *Cyclostomi*, in mud and sand. There are Fishes also with very small and rudimentary eyes, *e. g.* *Silurus caecutiens* and *Apterichthus*

cæcus. The eyes are in a still more rudimentary condition in the remarkable, and in many respects anomalous, family of *Myxines* among the *Cyclostomi*, which comprises some species that live as parasites upon the internal viscera of Fish, although others are also met with in a free state. The most imperfect state of development is that presented by the *Myxine*, where the eye is not even visible externally. It consists, in fact, of nothing else than a small bulb, covered by muscles, but which contains a nerve, and internally a transparent nucleus that may be compared to a vitreous body. The rudimentary eye is larger in *Bdellostoma*, in which it projects somewhat above the surface, and is covered by a thin prolongation of integument; it is enclosed in a spherical cushion of fat, through which passes the delicate optic nerve; several ocular tunics are distinguishable, which probably contain internally a transparent nucleus. The lowest stage of structure appears, however, to exist in the eye of *Amphioxus*; for here we find, as in many of the Invertebrate animals, only a couple of pigmentary spots, without, it seems, any organs for intercepting the light in its passage through the eye; they receive, however, a delicate nervous twig from the cerebral end of the spinal cord. The eyes are also but slightly developed in the Amphibious Fishes, and are devoid of eyelids and muscles; in the small bulb, however, we may distinguish a cornea and a small lens, while a delicate optic nerve may be also observed.

In many Fishes peculiar structures are superadded to the organs of vision. To these belong the *Choroidal glands* of the Osseous Fishes. Between the silver-colored and the internal plate of the choroid there is situated, as already alluded to, in many genera a red vascular mass, which, upon closer examination, is found to consist of a plexus or rete mirabile of vessels, formed by tufted ramifications of arteries as well as veins; these belong to what is called the amphicentric system of *retia mirabilia*, or that with double arterial and double venous vortices, and are connected with the vessels of the accessory branchiæ. Those genera which do not possess the latter organs, as *Silurus*, *Pimelodus*, *Cobitis*, and *Muræna*, have no choroid glands. The choroid, indeed, in all the Vertebrata is properly formed of *retia mirabilia*, but these are made up by the radiating distribution of arteries and veins from a single centre. In the *Carp* this vascular gland is much developed.

A still greater peculiarity occurs in many Osseous Fishes, as the Pike, and in the Sturgeon among the Cartilaginous. In all these Fishes, at the point where the optic nerve enters the longitudinal

slit, we find what is called the *falciform process*; this is a fold of the choroid invested by black pigment, that passes through the above-mentioned slit and the substance of the vitreous body, and is inserted into the side of the capsule of the lens. A filament of the ciliary nerve frequently accompanies it, and dilates into a pear-shaped knot forming the *pyriform body* or *campanula Halleri*. Occasionally, as in *Muraena* Conger, two falciform processes have been observed, an anterior and a posterior one, which hold the lens between them like two poles. These structures, such as the falciform process, which reminds us of the pecten in the eye of Birds, are wanting in the Plagiostomi and many Malacopterygii, e. g. the Carp.

The bulb of the eye is but slightly moveable in Fishes. In the Osseous Fishes it is attached to the orbit by a short ligament near to the insertion of the optic nerve; in the Plagiostomi it stands upon a moveable cartilaginous stalk, which articulates with a short process of the sclerotic. Four straight and two oblique muscles move the eye, and between them we find some adipose and cellular tissue. In the Bdellostoma the rudimentary eyes are entirely destitute of muscles, which in Petromyzon among the Cyclostomi are present in their usual number and position.

Organs of Hearing.

In the structure of the organs of hearing in the class of Fishes we meet with an interesting series of gradations, ranging from the lowest and simplest stage, wherein their structure resembles that of the Invertebrate animals, to that which exhibits a combination of parts corresponding to some one or other of the more highly organized Vertebrata.

The general arrangement of the auditory organs in the Osseous Fishes is as follows: the whole membranous labyrinth lies for the most part free within the cranial cavity, and adjacent to the brain, or it is only imperfectly and partially enclosed in bones, which have been already (p. 189) regarded as belonging to the system of temporal and occipital bones. These cavities are, as it were, lateral continuations of the cranial cavity, and are, like the latter, often filled up by a lax cellular and adipose tissue containing freely floating drops of oil. In cases where the auditory ossicles (which we shall presently describe) of the membranous labyrinth are of very large size, the cavities for containing them are dilated into a bladder-like form, as in *Gadus*, *Sciaena*, and in a lesser degree in *Perca* and

others. The external coverings, namely, the skin and muscles, are continued over the organs of hearing as well as over the whole skull, so that the sonorous vibrations propagated in the water have no special or direct access to the auditory apparatus. Still, however, we may regard as external meatuses or conductors of sound certain membranous intervals in the skull resembling fontanelles, and situated upon the crown of the head, e. g., *Silurus*, *Cobitis*, *Clupea*, &c. It is very rare to find, as in *Lepidoleprus*, an infundibuliform canal, comparable to the external auditory meatus, and invariably situated above the external branchial fissure, where it opens upon the sides of the occipital bone and is there closed by integument.

The *Membranous Labyrinth* consists, 1st. Of the simple *vestibule*; this is a transparent sac, provided with nervous expansions, and of very varied form, which is loosely attached to the skull in the vicinity of the cerebellum, and receives the ampullæ of the semicircular canals. 2d. Of the *auditory sac* (*saccus vestibuli*), which, lying close upon the vestibule, is externally more or less detached, and internally always separated from the vestibule by a partition. Occasionally, however, it is united to the vestibule by a membranous commissure, lies further posteriorly, and is usually divided into a pair of chambers, which, like the vestibule, contain mostly auditory ossicles or calcareous parts, surrounded by the fluid of the labyrinth. 3d. Of the *arciform* or *semicircular canals*; of these an anterior and posterior canal are constantly found, both standing perpendicularly, and two of their crura usually opening together; lastly, an external horizontal canal. Toward the vestibule the canals are dilated into ampullæ, and their arched portions are not unfrequently received partly into the adjacent bones, to which they are fastened by cellular ligaments. The structure is similar in the true Cartilaginous Fishes (Plagiostomi); the labyrinth, however, is in them completely separated from the cranial cavity, and completely imbedded in a mass of cartilage, which is much harder where it is in contact with the membranous labyrinth. The sac and vestibule do not appear to be separate in these Fishes, though the labyrinth is elongated to form a flask-shaped duct leading upward and outward upon the middle of the occipital bone. In this situation are also placed either two or four openings, closed by membrane, and approximated to each other, which correspond to the two fenestræ, and have the external integument continued over them.

In the Rays, and some species of Sharks, we find four openings upon the skull, two for each ear; the posterior conduct only into the

cartilaginous vestibule, and correspond to the round fenestræ; the anterior are comparable to the oval fenestræ; between each of these openings and the external skin a membranous sac is placed, which is filled with a calcareous mass, and extends into the membranous vestibule. At their commencement we find a muscle arising from the integument, and serving to compress the two sacs.

The Plagiostomi have a pair of soft calcareous concretions (otoliths), composed of carbonate of chalk, appended to the walls of the sacs; the Osseous Fishes are generally furnished with three stones (lapilli), hard and dense as porcelain, and of very varied form; one of these is situated in the vestibule, two in the two chambers of the sac.

Manifold diversities occur in the form, number, and structure of these otoliths. Thus the porcelainic otoliths are frequently, as in Cyprinus, Gadus, Scomber, toothed at the edges, and are occasionally, as in Sciaena, Lepidoleprus, and others, of remarkable size.

The form, size, width, and mode of union of the semicircular canals, with their position also in the cranium, exhibit likewise remarkable diversities; while, *e. g.*, in Cobitis, they are situated quite free in the cranial cavity, the external and posterior canal, or only one of the two, are partly enclosed in the bones, or, as in the Pike, Orthogoriscus, the Sturgeons, and Chimæras, they are more or less surrounded by cartilaginous coverings; this, as has already been mentioned, is their condition generally in the Plagiostomi. The ampullæ are retained in their expanded condition by peculiar double-coned septa, upon which the auditory nerve expands; the expansions and terminal looped plexuses of this nerve may be very easily and distinctly observed under the microscope.

In many Osseous Fishes, but particularly the Ventrals, a most remarkable communication subsists between the swimming-bladder and the internal ear. The vestibule always gives off in the direction backward a canal which coalesces with that of the opposite side into a single reservoir (*sinus impar*); this latter is a pouch of more membranous texture than the vestibule: it is situated in the basilar portion of the occipital bone, bifurcates again in the direction backward, and forms constantly a round sacculus placed between the first cervical vertebra and occipital bone, and filled with the fluid of the labyrinth; it is called the *sinus sphericus s. atria sinus imparis*. Three ossicles are placed near to the three most anterior vertebrae, and are connected to their transverse processes by joints and ligaments; they are of varied form; the most posterior, which is the

largest, corresponds to the *malleus*, and is appended by an unciform process to the swimming-bladder, the middle to the *incus*, the anterior to the *stapes*. The last-named ossicle may close the prevestibulum (*atrium sinus imparis*), and by pressure upon the swimming-bladder may be drawn apart from or pressed against it. Each prevestibulum is provided with a peculiar ossicle encircling it like a staple (*claustrum*). The auditory ossicles are found distinct in all the species of Cyprinus, in Cobitis, and Silurus, while in other Osseous Fishes they are wanting. The swimming-bladder is slit in front to form two ducts, which enter the vestibule.

As Fishes, at least the Osseous, are destitute of external auditory passages, sound in these animals must penetrate or be transmitted through the bones of the head to the labyrinth. The different membranous regions of the skull may indeed serve the function of tympanic membranes, and the swimming-bladder exert some similar office by exercising compression upon the fluid contained in the labyrinth.

The organ of hearing becomes remarkably simplified in the lower organized Fishes, and in this respect the Cyclostomi exhibit very interesting stages of development, which partly correspond to the fetal structure of the auditory organs in the higher Vertebrata.

The organ of hearing in Petromyzon and Ammocetes consists of a bony or cartilaginous part, and of a pair of hard, yellow, oval capsules connected with the skull, and enclosing, like a bony labyrinth, the membrane lining the same; between the two is placed a fibromembranous layer. The membrane of the labyrinth consists of a small sac, which is divided into two symmetrical cells by an external groove that forms a fold projecting into its interior. Two wide, depressed, semicircular canals arise with ampulliform enlargements, and unite into a common opening which enters the vestibule. A single smaller, more rounded appendage to the vestibule corresponds to the auditory sac (*sacculus*) of other Fishes. Two branches of the auditory nerve pass to the supply of the ampullæ.

The structure of the auditory apparatus is still more simple in Myxine and Bdellostoma. It is situated, as in Petromyzon and Ammocetes, in a hard ellipsoid capsule, the cavity of which resembles a ring, filled up by a similarly formed membranous labyrinth, within which the single semicircular canal is blended with the vestibule.

Otoliths are completely absent in the hearing organs of the Cyclostomi. Not a trace even of calcareous crystals can be detected

by the microscope; and this is the more remarkable, as these structures appear to occur generally in the auditory organs of the Invertebrate animals.

No vestige of an organ of hearing has hitherto been found in *Amphioxus*, so that we have an example among the Vertebrata of a creature completely destitute of the auditory function.

The Amphibious Fishes have a more complete organ of hearing. At least in *Lepidosiren annectens* a large labyrinth has been found with three small semicircular canals, and two great sacs containing otoliths, but without a trace of tympanic cavity.

Organs of Smell.

In all Fishes we find distinctly developed organs of smell. They consist of cavities situated at the anterior extremity of the snout, in front of the eyes, and beneath the nasal bones; they are bounded by the maxillary bones and vomer, present an elongated, oval, or round form, and open by two nasal apertures lying one behind the other; the anterior opening is occasionally, as in *Muraena*, lengthened out to form a short contractile tube; the posterior is in some instances removed to a distance from the first, and patulous. This is the general arrangement of these parts in the Osseous Fishes; the nasal passages are scarcely ever perforate throughout, as in the air-breathing animals, though in several species of Conger (as in the Amphibia that breathe by branchiæ) they are found to open internally beneath the upper lip. Minor peculiarities frequently occur in the structure of these organs, as in *Lophius piscatorius*, where the nasal cavities exhibit the form of two small bell-shaped sacs situated beneath the upper lip, and lined by folded mucous membrane. In the Plagiostomi the nasal depressions are very large, and can be closed by means of a membranous or cartilaginous operculum; they are placed inferiorly near to the angles of the mouth, and the operculum can be raised by muscles. The mucous membrane lining them is very vascular, provided with crypts that secrete a copious mucus, and disposed in exceedingly delicate and frequently very vascular folds. In some instances these folds radiate from a projecting middle elevation of the mucous membrane; more frequently, however, they arise like the teeth of a comb, in the form of ridges transversely directed, from the sides of a middle longitudinal fold; the transverse plications in the Plagiostomi are further provided with stellated folds upon their walls, in order to increase the extent of surface of the

mucous membrane; in other Fishes we even meet with tufted ramifications of the folds. The olfactory nerve usually dilates close against the nasal cavity of its side into a considerable bulb, or it forms, as in the Plagiostomi, an elongated knot corresponding to the chief mucous fold, and from this its branches proceed along the plaits of the mucous membrane and their subdivisions; frequently the olfactory nerve divides previously to this into several branches; a branch of the fifth pair passes also as an accessory nerve to the organs of smell.

Peculiar arrangements of the organs of smell are exhibited by the Cyclostomi, for in them the nasal cavity is single, but the two families composing this order differ in some respects from each other. In that family to which *Petromyzon* and *Ammocætes* belong, we find a single nasal aperture or spiracle upon the head, which leads into a rather narrower nasal canal, that finally expands into the single nasal cavity lined by plicated mucous membrane; upon the bottom of this cavity is found a more membranous, contractile flask-shaped cæcal pouch, an appendage that does not communicate with the pharynx, but with the nasal cavity by a small opening.

In the second family, the Myxinoidæ, the palate is perforated in a remarkable manner, and in *Myxine* there is a broad naso-palatal opening. In *Bdellostoma* the lesser naso-palatal opening lies above a fold of the mucous membrane at the extremity of the palate, and leads freely into the naso-palatal duct. The external nasal aperture communicates by means of the nasal tube formerly described as composed of cartilaginous rings, with the naso-palatal opening.

As regards the Amphibious Fishes, typified by the *Lepidosiren*, the two species of this genus at present known appear to comport themselves differently as regards the structure of the olfactory organs. In *L. annectens* the nasal depressions are imperforate; the olfactory nerve passes through a cartilaginous ethmoidal plate to the organ of smell, which always consists of a sac lined by transversely-plicated mucous membrane; an external opening is merely found beneath the upper lip. *L. paradoxa* seems to agree completely with *Siren* and *Proteus* among the Amphibia, for in it we find a posterior opening upon the internal side of the upper lip, and the mucous membrane disposed in folds.

The organ of smell, recently discovered in *Amphioxus*, is of a still more simple kind. It consists of a single depression, situated to the left side, which terminates freely in a small cup, and rests directly upon the central axis of the nervous system. It presents upon its

mucous membrane a glistening epithelium; it does not perforate the mouth, but terminates in a small blind pouch, having its mucous surface increased by folds.

Organs of Taste.

THE tongue is absent in Fishes, and the anterior part of the lingual bone, which frequently supports teeth, exhibits neither in its external condition, nor in the distribution of its nerves, any analogy with the tongue of the other Vertebrata. In cases where the glosso-pharyngeal nerve is developed, as in the Sturgeon, it only gives twigs to the branchial arches and palate, which last is in Fishes probably the seat of the sense of taste. No branch arises from the fifth pair that can be compared to the lingual nerve.

That the gustatory function is probably seated in the palate, appears to be confirmed by the fact that in many Fishes, *e. g.* the Cyprini and in *C. carpio*, peculiar organs, richly supplied by nerves, are developed in that situation. In the Carp there is found at the base of the skull, in front of the excavated plate, which is met with on the body of the sphenoid, and supports what has been called the Carp's stone, and also in front of the pharyngeal jaws, a single white spongy mass, which receives numerous large branches from the glosso-pharyngeal nerve, and is possessed of such a high degree of irritability, that it becomes erect and turgid upon mechanical and chemical stimulants being applied. This organ forms a very broad cushion immediately above the inner edges of the branchial arches.

Organs of Touch.

As organs of touch in Fishes, we must unquestionably regard the beard-like filaments that occur in many, as in sundry species of Cobitis, upon the chin and at the commencement of the mouth; they receive large branches from the fifth pair of nerves.

DIGESTIVE SYSTEM.

If throughout the class of Fishes we have seen the hard parts of the body assuming the greatest variety of structure as compared with those of other Vertebrata, so also in the *Teeth* that form the armature of the jaws, and other facial bones, shall we find the same

character to hold good in a pre-eminent degree. For not only do the dental organs vary in their more minute structure, but in number, form, situation, mode of attachment, and development, so that it is by no means easy to give a general survey of these peculiarities without describing them in the several families and genera.

All Fishes, with but few exceptions, are provided with teeth. In some, however, they are completely wanting, as in the Sturgeon, the genera Aodon, Syngnathus, Amphioxus, while others, as the Salmon, exhibit them upon all, or nearly all, the bones that generally support teeth. These bones are chiefly the intermaxillary and inferior maxillary, the palatal bones, the vomer, lingual bone, and branchial arches; also, though rarely, the superior maxilla, instances of this bone supporting teeth occurring, at least in the Osseous Fishes, only in *Salmo*, *Clupea*, and *Muraenopsis*; it is rare too for the pterygoid bones or the sphenoid to be, as in *Sudis*, armed with teeth. It is very uncommon for a broad dental plate to be present upon the occipital bone, the base of which in the Carp exhibits for this purpose a broad process with a concave surface. Teeth are in some instances met with only upon the pharyngeal bones, which are peculiar bones situated behind the branchial arches, and found both above and below the entrance to the pharynx, their number varying from one to six. The jaws in the Cyprini are edentulous, but there are teeth upon the pharyngeal maxillæ, which in the Carp exhibit broad molar-like crowns; other forms occur in other Cyprini, so that the several species may be partly distinguished by the varieties of the pharyngeal teeth. In other genera, such as *Labrus* and *Scarus*, the true as well as the pharyngeal jaws are furnished with teeth. Occasionally, as in the Lampreys, and in the genus *Helostomus* among the Osseous Fishes, the teeth are chiefly fastened to the lips. As regards, however, the situation of the teeth, the Rays and Sharks, and then the *Chimæra*, agree most with Man and Mammalia, for in all three the teeth are limited to the two arch-shaped maxillæ. A singular position for the teeth occurs in the Saw-fish (*Pristis*), where, besides the jaws, the bill-shaped process prolonged from the cranium is armed upon either edge with a row of pointed teeth, giving it the appearance of a double saw.

Diversities occur, moreover, in reference to the mode of attachment of the teeth in Fishes, such as are met with in no other class of Vertebrata. In some instances the teeth are inserted in cavities or distinct sockets, as in the weapon of the Saw-fish. Some teeth have their basis hollow, and implanted like the claws of a cat upon