# THE NERVOUS SYSTEM: THE BRAIN AND SPINAL CORD

The nervous system functions in *communication* between the various parts of an organism and between the organism and its external environment. It consists of the *central nervous system;* the brain and spinal cord, and the *peripheral nervous system*; the sense organs, cranial and spinal nerves, and their branches.

We shall begin our study of the nervous system with an examination of the brain and the cranial nerves.

## THE BRAIN

The advantages in studying the shark's brain include:

— The skull is composed of cartilage, not bone. This makes the brain accessible to the scalpel's blade.

— The brain of the shark is relatively large. Thus, the gross anatomy of smaller nerves and structures may be observed.

— It illustrates a lower level of development among vertebrates. Comparative studies of different vertebrates reveal ever-increasing complexity in the structure of the brain, especially in the cerebral region. The basic architectural plan of the vertebrate brain and cranial nerves is, however, already laid out.

### *The Dissection*

The larger mature dogfish sharks make the best specimens for dissecting the brain since their structures and nerve tracts can be more readily observed than those of smaller specimens.

We shall dissect the left side of the brain first. In the process, the structures within the *otic capsule,* the left semi-circular canals of the *inner ear,* will be destroyed and underlying parts of the brain and cranial nerves revealed. Then, the right side of the brain will be dissected. This time the delicate inner ear and associated structures will be preserved, carefully dissected, and studied.

The technique of dissection of the chondrocranium is unique to cartilaginous fish, for unlike bone, the cartilage permits the use of a scalpel in exposing the brain. First remove the skin from the dorsal surface of the head from the rostrum posteriorly to the first gill slit. Continue removing the skin ventrally to the level of the eye and the spiracle.

Make all of your cuts of the chondrocranium horizontal and shallow in a shaving motion. This is your best guarantee that you will not be injuring delicate brain tissue or cranial nerve fibers. The cartilage is transparent up to a depth of about one millimeter. Therefore, cut very thin horizontal chips of cranium no more than one millimeter thick. The thin chips may be broken loose and removed with fine-toothed forceps. It is also helpful, once the outer layers of cartilage have been removed and the fine work of separating cartilage from nerve tissue begins, to use a smaller, No. 15 scalpel. This can be inserted into small spaces without causing the damage which might result from the use of a larger average-sized blade. The important rules here are:

—Cut only very thin chips, and
—Look carefully before you cut.

Your scalpel blades are extremely sharp and the soft delicate nerve tissue, unlike the cartilage, offers virtually no resistance.

Begin the careful removal of the cranium on the left side antero-dorsally and work your way posteriorly. As was pointed out, the inner ear on this side will be destroyed in order to see the brain and cranial nerves lying beneath it.

Study the photographs and diagrams in this section to help you locate and identify the parts of the brain and cranial nerves.

At this point we should become familiar with some of the terms used to describe the major subdivisions of the vertebrate brain:

- **Prosencephalon (Forebrain)**
  - **Telencephalon**
  - **Diencephalon**
- **Mesencephalon (Midbrain)**
- **Rhombencephalon (Hindbrain)**
  - **Metencephalon**
  - **Myelencephalon**

**PRIMITIVE MENINX** — As you expose the brain and spinal cord, you will find them enclosed within a delicate vascular protective membrane called the *primitive meninx*. It sends blood vessels to the surface of the brain and is also connected to the inner membrane of the cranial walls by fine strands of tissue. Examine it by removing some from the surface of the brain. In life, cerebrospinal fluid fills the space between the brain and the wall of the cranial cavity.

## Prosencephalon (Forebrain)

**TELENCEPHALON** — This is the most anterior portion of the brain. Locate and identify each of the following:

**Olfactory Bulbs** — These are paired extensions of the anterior portion of the brain. They are rounded masses which make contact anteriorly with the spherical *olfactory sacs,* the organs of smell.

**Olfactory Tracts** — These are the long narrow nerve pathways extending posteriorly from the olfactory bulbs.

**Cerebral Hemispheres (Cerebrum)** — These two hemispheres are the rounded lobes of the anterior brain. Each lobe contains a cavity, the first and second ventricles of the brain, termed the *lateral ventricles*. These ventricles are continuous with the cavities in other parts of the brain, particularly the third and fourth ventricles. Trace the lateral ventricles to the central cavity in the olfactory tract and bulb. The anterior portions of the cerebrum are known as the *olfactory lobes*.

**Olfactory Lobes** — These are identified as the rounded masses at the anterior end of the cerebral hemispheres where the olfactory tracts terminate. They are separated from the rest of the cerebrum by externally visible indentations.

**DIENCEPHALON** — This is the second portion of the forebrain, directly posterior to the telencephalon. It is somewhat depressed with a dark-colored membrane covering a cavity, the *third ventricle*. The diencephalon is the part of the brain immediately surrounding the third ventricle.

**Third Ventricle** — This is an unpaired cavity in the diencephalon. It communicates anteriorly with the two lateral ventricles through an opening in the *foramen of Monro*. Posteriorly the third ventricle communicates with the fourth ventricle through a passageway, the *cerebral aqueduct (aqueduct of Sylvius)*.

The diencephalon consists of three parts:

**1. Epithalamus** — The area dorsal to the third ventricle. It includes:

**Tela Choroidea** — A thin roof consisting of a vascular membrane covers the diencephalon. It is rich in blood vessels and sends projections into the third ventricle to form the *anterior choroid plexus,* a delicate vascular membrane which secretes *cerebrospinal fluid* into the ventricles. Thus we see that the cerebrospinal fluid not only bathes the outside of the brain but is also the fluid of the ventricles and other cavities within the brain. The anterior portion of the roof forms a sac called the *paraphysis.*

**Epiphysis (Pineal Body)** — A slender stalk that projects anterodorsally from the rear of the diencephalon, an area known as the *habenula,* upwards through the roof of the chondrocranium by way of the *epiphysial foramen.* In most dissections it is destroyed when the roof of the chondrocranium is removed. Behind the pineal body is the *posterior commisure,* a tract of nerve fibers connecting the right and left sides of the brain.

**2. Thalamus** — An area of gray matter in the lateral walls of the third ventricle. These are best seen in a sagittal section of the brain.

**3. Hypothalamus** — It lies ventral to the third ventricle and is best seen in a ventral veiw of the brain. It forms the floor of the diencephalon and consists of the *infundibulum* and *hypophysis (pituitary body)* along the midventral line. Also seen in ventral view in this area is the optic chiasma, the point at which the optic nerves, one from each eye, cross medially and their fibers enter the opposite sides of the brain.

## Mesencephalon (Midbrain)

**OPTIC LOBES (OPTIC TECTUM)** — Directly posterior and slightly dorsal to the diencephalon find a pair of prominent bulged structures. These are the *optic lobes.* They form the dorsal and lateral walls of the *mesencephalon.* Each optic lobe contains an *optic ventricle* which communicates ventrally with the *cerebral aqueduct (Aqueduct of Sylvius),* the central cavity of the mesencephalon. The floor of the mesencephalon, the *tegmentum,* lies dorsal to the hypophysis.

## Rhombencephalon (Hindbrain)

**METENCEPHALON** — Immediately posterior and somewhat dorsal to the optic lobes is the *cerebellum.*

**Cerebellum** — The oval-shaped dorsal portion of the metencephalon. It partly overlaps the optic lobes. Its inner cavity is known as the *cerebellar ventricle,* which communicates anteriorly with the cerebral aqueduct and posteriorly with the fourth ventricle. Externally, one may see two grooves, one longitudinal and one transverse, in the form of a cross, dividing the cerebellum into four sections. At the posterior end find two lateral ear-like projections of convoluted tissue known as *auricles of the cerebellum.*

**MYELENCEPHALON** — It lies posterior to the metencephalon and forms a major part of the *medulla oblongata.*

**Medulla Oblongata** — The elongated posterior region of the brain that is continuous posteriorly with the spinal cord.

**Fourth Ventricle** – The cavity of the medulla is the *fourth ventricle,* which communicates posteriorly with the central canal of the spinal cord. As we saw at the third ventricle, the cavity of the fourth ventricle is covered dorsally by a roof-like membrane called *tela choroidea.* A *posterior choroid plexus* extends into the fourth ventricle. Remove the tela choroidea and examine the cavity of the fourth ventricle. Note that the fourth ventricle extends into the cerebellar auricles and that they are continuous with each other beneath the cerebellum.

**Motor and Sensory Columns** — Columns of gray matter arising in the spinal cord may be seen in the ventral and lateral walls of the fourth ventricle. A pair of longitudinal ridges can readily be seen mid-ventrally on the floor of the ventricle. They are *somatic motor columns*. They contain the cell bodies of somatic motor neurons. Lateral to these are deep longitudinal grooves. The lateral wall of the grooves constitutes the *visceral motor columns,* containing the cell bodies of visceral motor neurons. More dorsolaterally along the walls of the fourth ventricle lie the *visceral sensory columns,* carrying impulses from visceral sensory neurons. The furthest dorsolateral wall of the cavity constitutes the *somatic sensory columns,* receiving impulses from somatic sensory neurons.

## CRANIAL NERVES

The cranial nerves originate in the brain and exit at the chondrocranium. These nerves may be *sensory,* carrying impulses to the brain; they may be *motor,* carrying impulses from the brain to muscles and glands; or they may be *mixed* nerves, carrying both sensory and motor fibers.

The cranial nerves of all vertebrates have similar names and similar functions. Fish are usually described as having ten pairs of cranial nerves, the higher vertebrates have twelve.

(0) **TERMINAL NERVE** — This nerve, although found in all verebrates except cyclostomes and birds, is not numbered amongst the ten cranial nerves. Some authors consider it a part of the olfactory nerve, with which it is clearly associated. It is a very slender nerve lying along the medial surface of the *olfactory tract* and extends between the olfactory sac and olfactory lobe of the cerebrum. Its function is uncertain, some authors indicating general somatic sensory function, others visceral motor functions associated with the autonomic nervous system.

(I) **OLFACTORY NERVE** — This is a *sensory* nerve originating in the olfactory epithelium of the *olfactory sac* and terminating in the *olfactory bulb of the cerebral hemisphere. It is concerned with the sense of smell.*

(II) **OPTIC NERVE** — This is also a *sensory* nerve. It originates in the *retina* of the eye, exits the back of the orbit, passes medially and posteriorly to the *optic chiasma* and enters the *optic lobes*.

(III) **OCULOMOTOR NERVE** — This is a *motor* nerve originating from the ventral surface of the *mesencephalon*. It innervates four of the six eye muscles: the *inferior oblique,* and the *superior, inferior,* and *medial recti* muscles. It enters the orbit just posterior to the optic nerve near the superior rectus muscle. A small branch, the ciliary nerve, conveys impulses to the smooth muscles of the *iris* and ciliary body of the eye, regulating accommodation and the size of the pupil.

(IV) **TROCHLEAR NERVE** — This is a thin *motor* nerve originating in the floor of the mesencephalon, but its fibers emerge from the roof of the mesencephalon, between the optic lobe and the cerebellum. It enters the orbit of the eye between the superior rectus and superior oblique muscles via the *trochlear foramen*. It supplies the *superior oblique muscle*. Thus, five of the six eye muscles have been innervated.

Cranial nerves number V, VII, and VIII originate together by a large common stem at the anterior end of the *medulla,* just ventral to the *cerebellar auricles*.

(V) **TRIGEMINAL NERVE** — This is a *mixed* (motor and sensory) nerve which has four branches:

**Superficial Ophthalmic Nerve** — This *sensory* nerve passes anteriorly, medial to the orbit. It runs to the rostrum where its trigeminal fibers have a general cutaneous sensory function. It also contains facial nerve fibers arising from the common *trigeminal facial root*. Their function will be described below.

**Deep Ophthalmic Nerve** — This nerve passes ventral to the superficial ophthalmic nerve while delivering several small branches to the ciliary muscles within the eye. It then turns medially, makes a connection with the superficial ophthalmic trunk, and extends anteriorly supplying *sensory* fibers to the *rostrum*.

**Infraorbital Nerve** — A thick *sensory* nerve that runs obliquely across the floor of the orbit. Near the anterior margin of the orbit it divides into the *buccal nerve* containing fibers of the facial nerve, and a *maxillary nerve*. The maxillary nerve carries impulses back from the snout.

**Mandibular Nerve** — This *mixed* nerve passes laterally between the *eye* and the *otic capsule*, then turns ventrally to supply the muscles of the jaw. It is *sensory* to the muscles of the lower jaw and *motor* to the muscles of the first gill arch.

(VI) **ABDUCENS NERVE** — This *motor* nerve originates at the ventral surface of the *medulla*. It passes anterolaterally to enter the orbit where it innervates the *lateral rectus muscle* of the eye. Thus, we have accounted for the innervation of all six eye muscles.

(VII) **FACIAL NERVE** — This *mixed* nerve arises from the *medulla* and is divided into three branches:

**Superficial Ophthalmic Nerve** — This nerve has already been described as a branch of the trigeminal nerve. Its facial nerve fibers supply both the *ampullae of Lorenzini* and the *lateral line system*.

**Buccal Nerve** — This is the branch of the infraorbital nerve containing fibers of the facial nerve. It carries *sensory* impulses from the lateral line system of the head.

**Hyomandibular Nerve** — Near its origin this nerve exhibits a swelling, the *geniculate ganglion*. From here a small *palatine nerve* arises passing to the roof of the mouth, where it supplies the *taste buds*. The main trunk innervates the *lateral line system*, the *skin*, the *muscles of the hyoid arch*, the *tongue*, and the *floor of the mouth*.

(VIII) **AUDITORY NERVE (STATOACOUSTIC NERVE)** — This nerve arises together with cranial nerves numbers V and VII from the anterior end of the medulla. It is a short *sensory* nerve which carries impulses of the sense of equilibrium from the *inner ear*. Its two branches are the *vestibular nerve* and the *saccular nerve*.

(IX) **GLOSSOPHARYNGEAL NERVE** — This *mixed* nerve arises from the *medulla* just posterior to cranial nerve number VIII. Near the first gill pouch it exhibits a swelling called the *petrosal ganglion*. Beyond the ganglion it divides into three branches, innervating the area of the first gill arch.

**Pretrematic Branch** — This innervates the *first demibranch* with *sensory fibers*.

**Post-trematic Branch** — This branch is *mixed;* sensory to the first gill pouch and motor to the muscles of the third gill arch.

**Pharyngeal Branch** — This branch is *sensory* to the pharynx.

(X) **VAGUS NERVE** — This is the longest of the cranial nerves innervating gills, pharynx, esophagus, heart, stomach, intestine, and body wall. The word vagus means "wanderer." It is a *mixed* nerve which originates at the posterior end of the *medulla*. It gives off several trunks or major branches as it passes posteriorly.

**Lateral Line Trunk** — This sensory nerve extends beneath the *lateral line canal* posteriorly to the caudal end of the body.

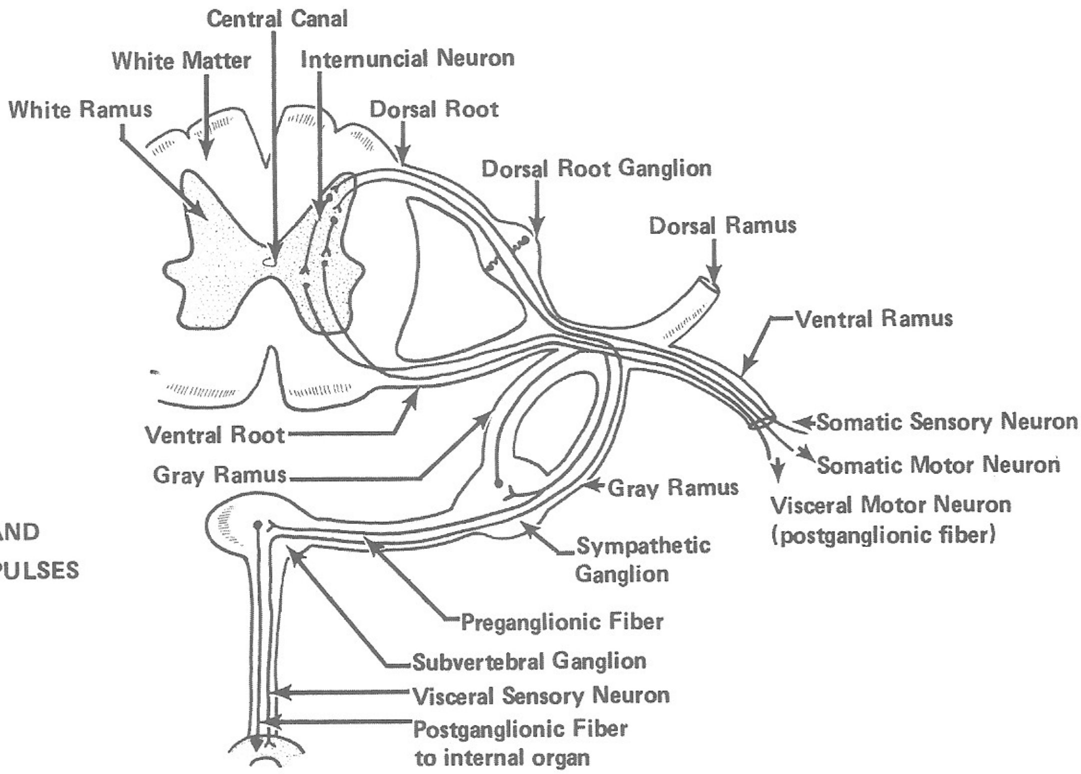
**Visceral Trunk** — This branch gives off four branchial nerves to the remaining *gill pouches*. Each of these four *branchial nerves* divides into *pretrematic, post-trematic,* and *pharyngeal* branches, as did the glossopharyngeal nerve. It then continues with branches to the heart and to the anterior part of the alimentary canal. Trace the many branches of the vagus nerve.

## OCCIPITAL AND SPINAL NERVES

Posteriorly, beyond the cranial nerves, two or three small occipital nerves originate. In order to observe these as well as the spinal nerves, carefully remove more muscle and cartilage from the vicinity of the spinal cord posterior to the medulla. Occipital nerves emerge from the ventral surface of the spinal cord; they have no dorsal roots. They emerge posterior to the vagus and anterior to the first spinal nerve. They join to form the *hypobranchial nerve*.

**HYPOBRANCHIAL NERVE** — This nerve appears to join the vagus, soon separates and is joined by the first two or three spinal nerves. The *hypobranchial nerve* carries *somatic motor* impulses to the hypobranchial muscles as well as *somatic sensory* impulses.

**SPINAL NERVES** — These emerge from the spinal cord between each pair of vertebra. They are formed from the union of *dorsal* and *ventral roots*. They are *mixed* nerves, innervating the skin, musculature, and viscera of the body.



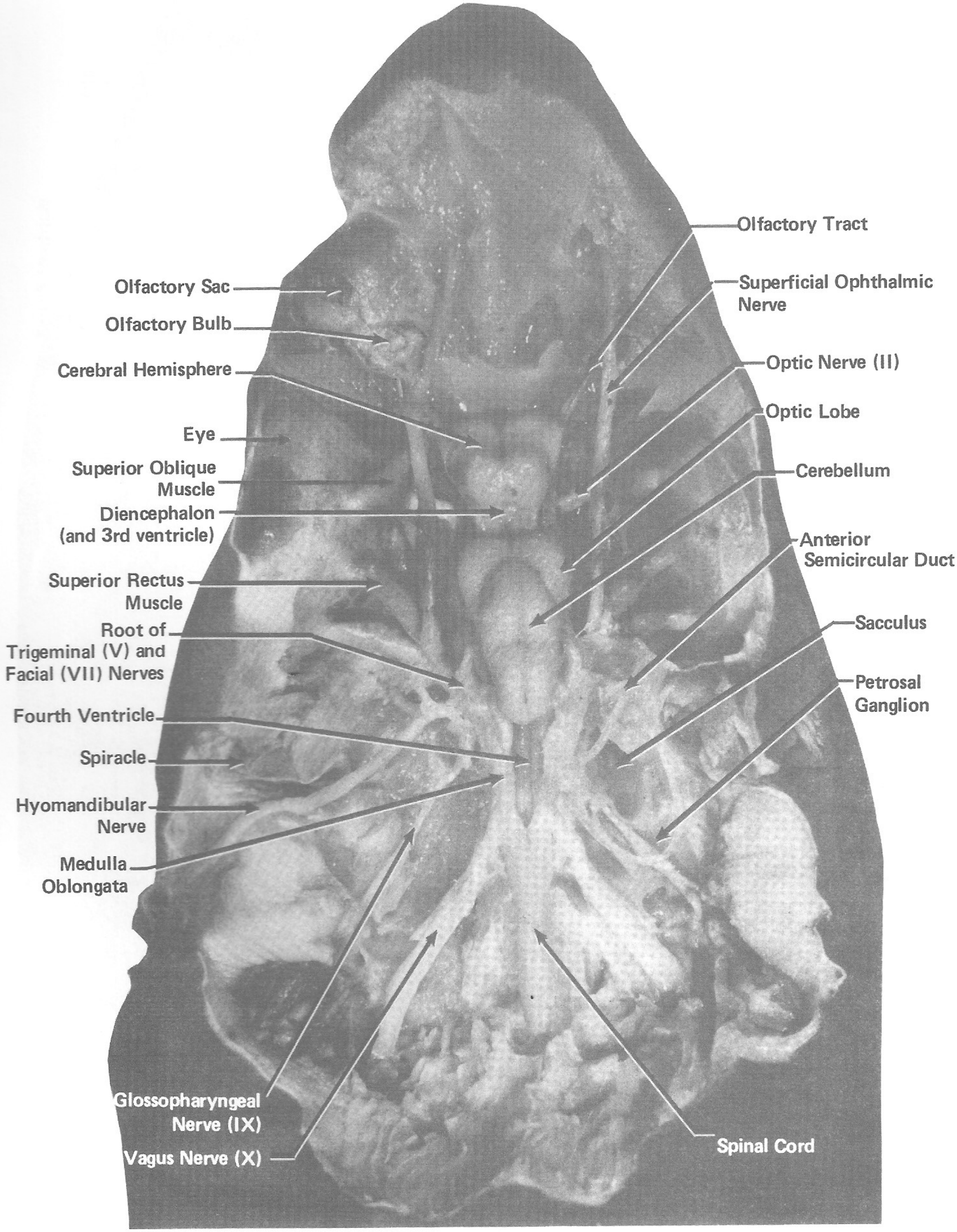

SENSORY AND MOTOR IMPULSES

As seen in the above diagram, *sensory* and *motor* impulses pass between the body and the spinal cord.

**Somatic Sensory (Afferent) Fibers** — These originate as *cutaneous receptors* of temperature, pain, pressure, and touch in the *skin,* and as *proprioceptors* feeding back information about the location of the various body parts in space, the degree of stretch of skeletal muscles and tendons, and the angles between bones. They enter the spinal cord by way of the dorsal root.

**Visceral Sensory (Afferent) Fibers** — These bring messages from the viscera, such as pain, hunger, thirst, fullness, and nausea. They also pass to the spinal cord by way of the dorsal root.

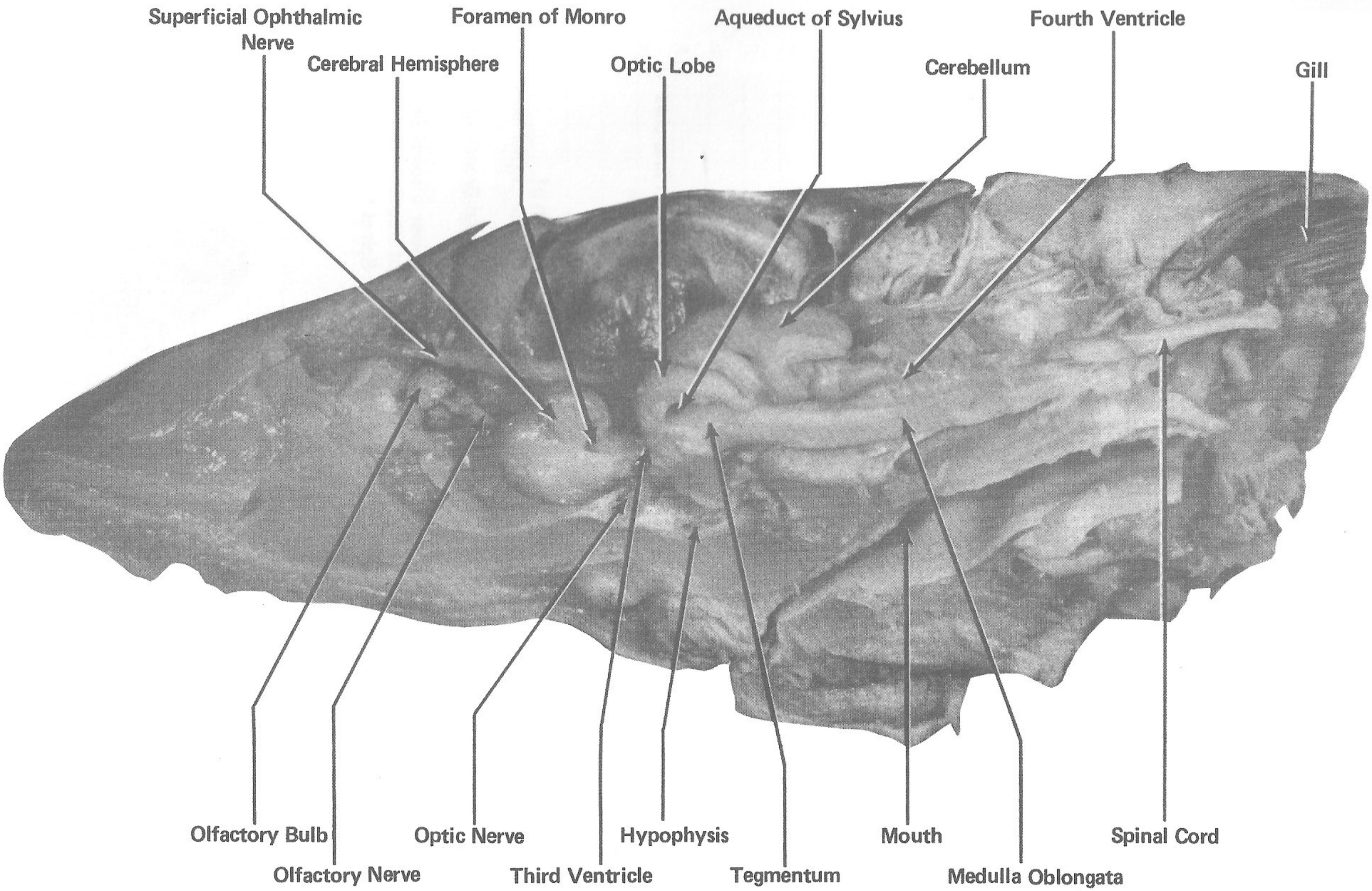
**Visceral Motor (Efferent) Fibers** — These are specialized fibers passing to the organs of the *autonomic nervous system*. They include the heart, intestines, glands, uterus, and other parts of the body that function involuntarily.



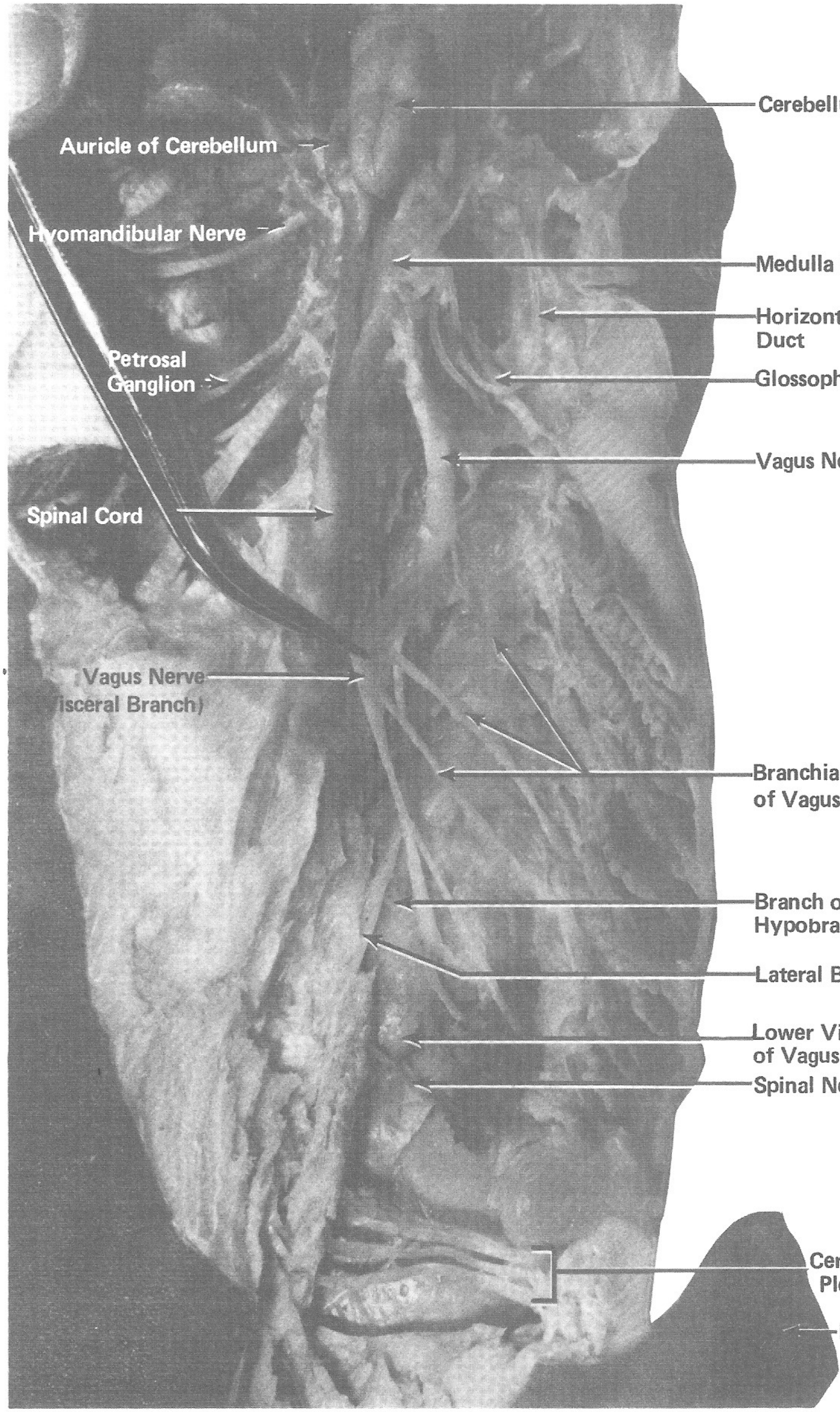

THE BRAIN AND CRANIAL NERVES – DORSAL VIEW




THE BRAIN AND CRANIAL NERVES (CLOSE-UP) – DORSAL VIEW




THE BRAIN — SAGITTAL SECTION




THE VAGUS AND HYPOBRANCHIAL NERVES – DORSAL VIEW

# THE NERVOUS SYSTEM: THE SENSE ORGANS

A number of the shark's sense organs can be identified. Some are similar to those of higher vertebrates, others are unique to the fish. They include the *ear,* the *eye,* the *olfactory organ,* the *ampullae of Lorenzini,* the *organs of the lateral line system,* and the *pit organs*.

## THE EAR

The *ear* of the shark is entirely internal. It is embedded within the *otic capsule* of the chondrocranium. Like the inner ear of higher vertebrates, its primary function is the maintaining of balance and equilibrium. There is also significant evidence that sharks detect sound waves, but its relationship to the inner ear is unclear.

The inner ear is known as the *membranous labyrinth,* and consists of a series of ducts and sacs. These canals are filled with a fluid called the *endolymph*. In sharks this is primarily sea water entering through the endolymphatic ducts. Surrounding the membranous labyrinth and following its shape is a similar series of canals in the chondrocranium, known as the *cartilaginous labyrinth,* also filled with a fluid, that protects the more delicate membranous labyrinth, the *perilymph,* which enters through the *perilymphatic ducts*. Fine connective fibers run between the cartilaginous and membranous labyrinths.

### *The Dissection*

Locate the mid-dorsal line between the two spiracles. Look for two pores in this area. These are the openings of the *endolymphatic ducts* which lead into the *membranous labyrinth*. On the right side of the head remove the skin from the dorsal and lateral surfaces of the chondrocranium. Now, using horizontal shaving motions, remove very thin chips of chondrocranial cartilage about one millimeter thick. Look carefully if any structures can be detected below. Soon you will expose three *semicircular canals* and the sac-like structures to which they are attached.

This dissection is done on the right side of the head, since the contents of the ear have already been destroyed on the left side in exposing the brain.

**SEMICIRCULAR CANALS** — These are three narrow tubes about a millimeter in thickness. They are oriented in the three planes of space. One is *anterior,* the other *posterior,* and the third is *horizontal*. They are filled with *endolymph*. A disturbance of the fluid, by sudden turning or shifting of the position of the head, disturbs the endolymph.

**Ampullae** — Nerve endings of the cranial nerve number VIII, the *auditory nerve,* are located in a swollen area of each semicircular canal, the *ampulla*. Within the ampullae one may locate white patches of sensory epithelium called *cristae*.

**Utriculi** — The anterior utriculus is an enlarged area of the labyrinth that receives the anterior and horizontal semicircular canals, while the *posterior utriculus* receives the posterior semicircular canal. The utriculi also contain sensory epithelium known as the *maculae*.

**SACCULUS** — This is the large central chamber of the inner ear into which the endolymphatic ducts lead. The small enlargement at the posterior end of the sacculus is the *lagena*. In some fish this area has been shown to receive sound waves. White patches of sensory epithelium known as *maculae* line the inner sacculus and lagena. These patches are covered by calcareous concentrations and sand grains known as *otoliths*. Smaller otoliths are contained in the utriculi. Sudden disturbances of the endolymph and the otoliths result in sensations of imbalance. The organism responds to these by mechanisms which restore its equilibrium.

## THE EYE

The eye of the shark is very similar to the eye of higher vertebrates. The one major difference is its method of accommodation in focusing for near and distant objects. While in the higher forms this is accomplished by changing the shape of the lens, in the shark it is done as in most cameras by moving the lens further or closer to the retina.

### *The Dissection*

The dissection will be done in two stages. First, the eyeball will be removed from its socket (the orbit) in order to view some of the muscles, nerves, and supporting structures of the orbit and the external parts of the eyeball. Then we shall cut into the eye to view its internal structure.

**EYELIDS** — Although most fish have no *eyelids,* the shark does possess eyelid folds. However, unlike the eyelids of the higher vertebrates, those of the shark are immovable.

**CONJUNCTIVA** — A thin transparent membrane which covers the outer surface of the eye. It folds at its outer edge and passes under the lid.

### *The Dissection*

Make a circular cut around the edge of the eye at the junction of the conjunctiva and eyelid to separate the eyeball from its orbit. Remove some of the dorsal chondrocranium over the eye. You will expose the six extrinsic eye muscles and other structures to be described below. Cut the eye muscles and nerves near their insertions on the eyeball. Lift out and remove the eyeball from its orbit.

**EYE MUSCLES** — Of the six extrinsic eye muscles, two originate in the anteromedial orbital wall; these are the *oblique muscles* which pull the eye diagonally. The other four originate in the posteromedial wall of the orbital wall; these are the *rectus* muscles which pull straight back on the eyeball. The nerves which innervate these muscles were described in the last chapter, see page 94.

**Oblique Muscles (Superior and Inferior)** — As the names indicate, one of the oblique muscles is inserted superiorly, or on the dorsal portion of the orbit; the second inferiorly, or on the ventral surface.

**Rectus Muscles (Superior, Inferior, Medial, and Lateral)** — The names of these muscles indicate the directions in which the eye is moved. The *superior rectus* which moves the eye upwards is inserted on the dorsal surface. The *inferior rectus* which moves the eye downwards is inserted on the ventral surface. The *medial rectus* which moves the eye anteriorly is inserted on the anterior surface of the eye. The *lateral rectus* which moves the eye posteriorly is inserted on the posterior surface of the eye.

**OPTIC PEDICEL** — This cartilaginous structure, shaped like a golf tee, projects from near the origin of the rectus muscles. Its flattened disc-like distal end rests against and supports the eyeball medially and aids in its rotation.

**OPTIC NERVE** — A thick white stump, the *optic nerve* may be seen exiting the back of the eyeball. It emerges just ventral to the site of the insertion of the medial rectus muscle.

**OTHER NERVES OF THE EYE** — Nerves previously described in the discussion of cranial nerves may also be found in the orbit. These include the *deep opthalmic nerve, oculomotor nerve, trachlear nerve, infraorbital nerve, abducens nerve,* and the *superficial ophthalmic nerve*.

***The Dissection***

The eyeball has already been removed from its orbit. We are now ready to observe the eyeball itself, both externally and internally. First observe the external features, then cut through the eyeball about halfway between dorsal and ventral surfaces. This will expose the inner structures. See photos on pages 110 and 112.

**SCLERA** — This is the tough white fibrous outer coat of the eye. At places it is made even more firm by cartilage embedded in the sclera.

**CORNEA** — At the front of the eye this tough coat becomes transparent as the cornea of the eye. The *conjunctiva* lies over the cornea.

**CHOROID** — This is the vascular black pigmented middle layer of the eye. Laterally, it is fused to the *retina*. The darkly pigmented layers help in absorbing light within the eye.

**SUPRACHOROIDEA** — A thick non-pigmented layer between the *sclera* and *choroid*. It is composed of connective tissue, lymph spaces and vascular tissue. It is only found in species which possess an *optic pedicel*.

**RETINA** — This is the multi-layered sensory gray-white colored membrane. The *rods* and *cones* which receive light stimuli are located here. The optic nerve leaving the eye is a continuation of the light receptor cells in this membrane.

**PUPIL** — This round hole behind the cornea is an opening in the *iris* of the eye. It can dilate or constrict to allow more or less light to enter.

**IRIS** — A pigmented anterior extension of the *choroid* layer. In its center is the *pupil*. The iris regulates the size of the pupil.

**CILIARY BODY** — This is another extension of the black pigmented *choroid*. It is a thin black band indented with faint radial lines. It lies between the iris and the choroid.

**LENS** — While in preserved specimens the spherical *lens* is opaque and hard, in living organisms it is clear and flexible. It lies behind the *pupil*. It helps to focus the light upon the light sensitive retina. It is suspended in the eyeball by a *suspensory ligament* which originates from the *ciliary body* and is attached to the equator of the lens.

**VITREOUS CHAMBER** — The main cavity of the eyeball contains a gelatinous, transparent semi-solid called the *vitreous humor*. It gives shape to the eyeball and prevents it from collapsing.

**ANTERIOR CHAMBER** — This chamber, much smaller than the vitreous chamber, lies anteriorly between the cornea and the iris. It contains a clear watery fluid, the *aqueous humor*.

## OLFACTORY ORGAN

This is the shark's organ of smell. Note the location of the external *nares* (nostrils). Each is divided into two openings: the lateral one, an *incurrent aperture,* and the medial one, an *excurrent aperture*. These are partially separated by a flap of skin that regulates the flow of water into and out of the nares ,as in the photo on page 113. There is no connection between the nasal area and the mouth or oral cavity.

*The Dissection*

Make a transverse cut across the snout through the center of one of the nares. Observe the following:

**OLFACTORY SACS** — These bulb-like structures, spherical in shape, contain a series of radial folds which increase the surface area called *olfactory lamellae*. Their surfaces are covered with *olfactory epithelium*. Sea water taken into the nares is passed over these sensory areas. Here the odors stimulate the cilia-like endings of neuro-sensory cells.

**OLFACTORY BULBS** — These are a paired anterior extension of the brain leading into the posterior end of the olfactory sacs. Their fibers continue into the *olfactory tract* and the *olfactory lobe* of the *cerebral hemisphere*.

## LATERAL LINE SYSTEM

This sensory system is only found in fish and amphibian larvae.

**LATERAL LINE CANALS** — It is a system of sensory cells and canals under the skin which responds to mechanical movement of the water, to changes in water pressure and other disturbances in the water. It consists of a series of interconnected *lateral line canals*. One long lateral line canal runs the length of the body on either side along the lateral surface. This can be readily observed as a thin light-colored line upon the skin. Other canals are found in the head region, near the eyes and jaws. The canals open to the outside of the skin by tiny *pores* which admit water.

The interconnected lateral line canal system in the region of the head includes the *infraorbital canal,* which passes ventrally posterior to the eye, then extends to the tip of the snout. The *supraorbital canal* passes forward above the eye to the snout, then turns to extend posteriorly to connect with the infraorbital canal. A *supratemporal canal* passes over the top of the head at the level of the spiracles. Several smaller canals may also be detected in the areas of the jaws. These are all a part of the *lateral line system*.

**Neuromasts** — These are the ciliated sensory cells lining the canals that can detect water currents.

*The Dissection*

Remove a section of skin, about two inches by two, along the lateral surface of the body. Examine the muscular body wall to detect the *lateral line canal*. Use a hand lens to find some of the pores along the lateral line on the surface of the skin.

## AMPULLAE OF LORENZINI

These sense organs are modifications of the lateral line system, and are similarly innervated. They detect changes in water temperature, electric current, and salinity.

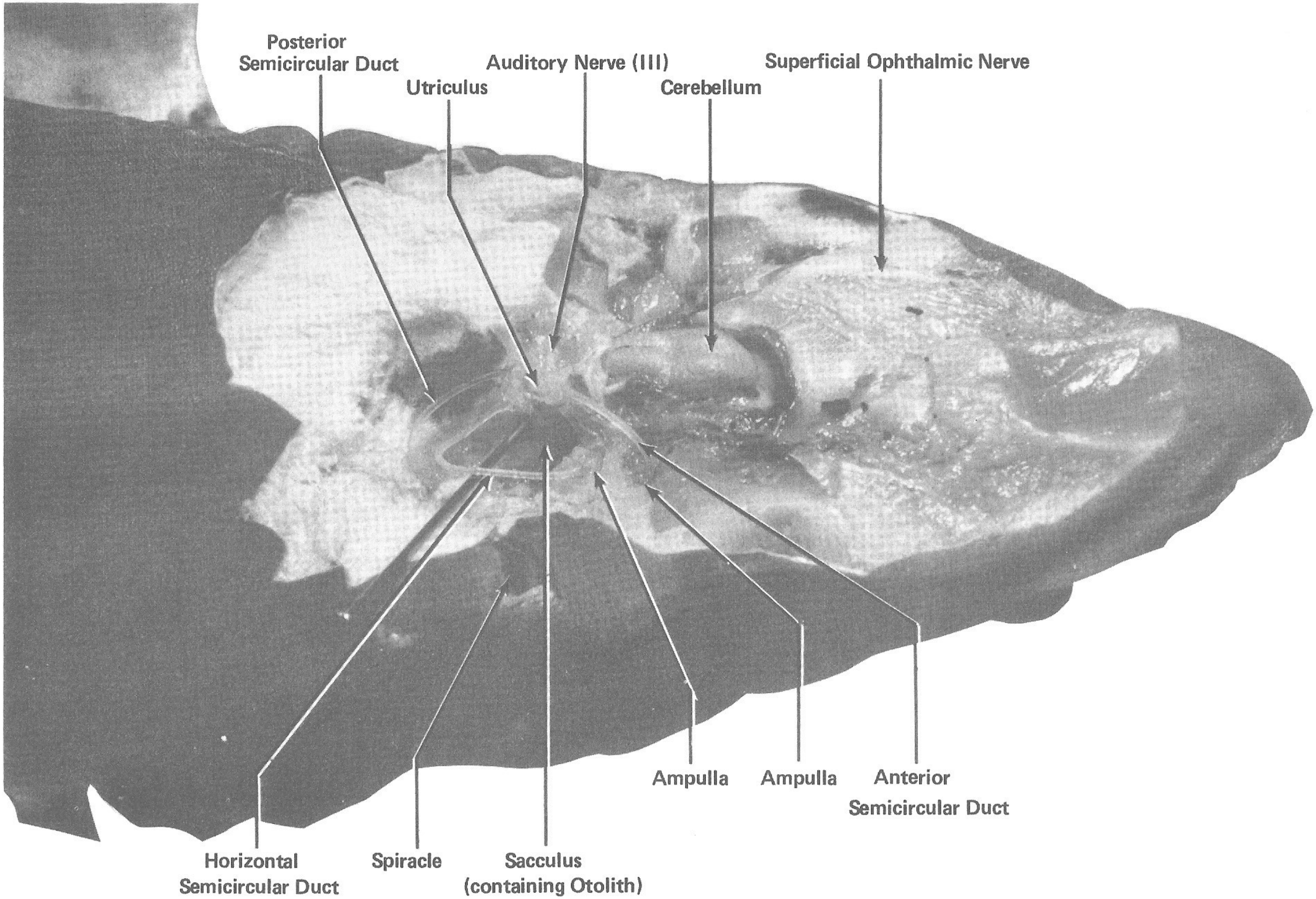
Examine the underside of the snout. Note many large *pores*. Press down upon these areas and observe the gelatinous secretion exuded. The pores connect to elongated, cylindrical, tube-like canals which store the jelly-like secretion. At their bases they form the main bulb-like *ampullae of Lorenzini*. Several secondary ampullae may also be seen. At the base of the ampullae find the sensory nerve by which it is innervated.

*The Dissection*

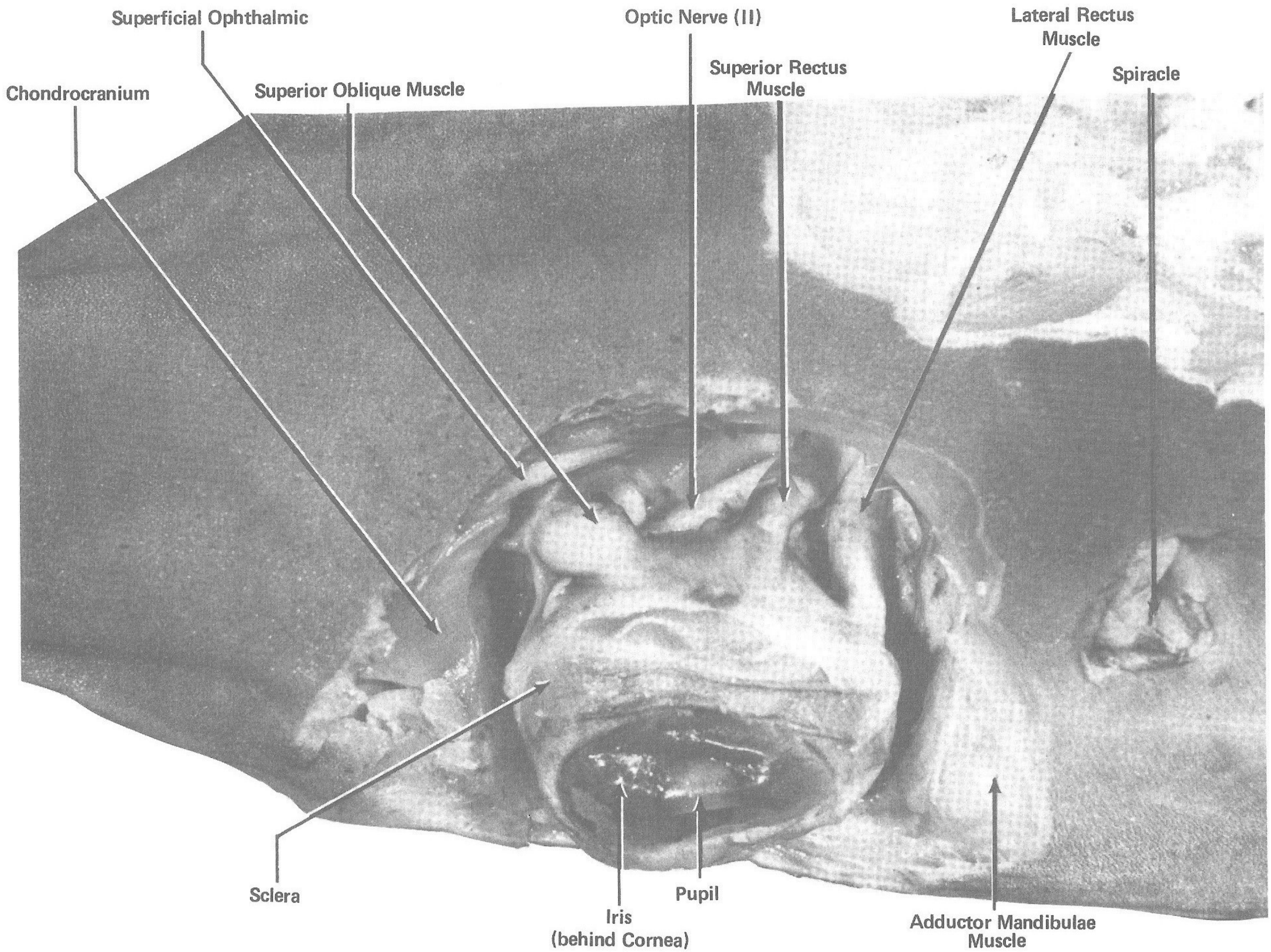
Remove the skin from the underside of the snout and observe the structures just described.

## PIT ORGANS

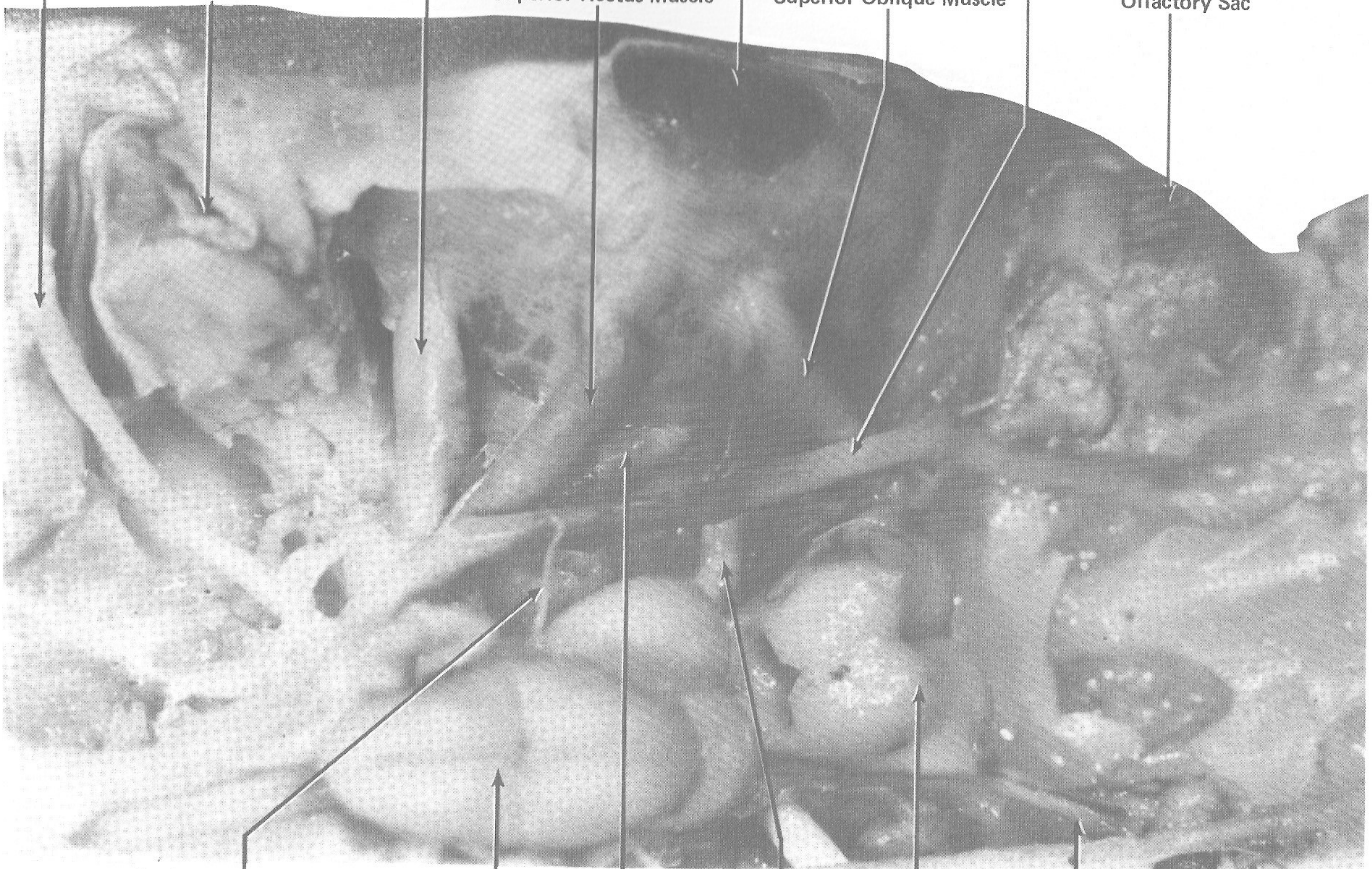
These sensory areas are also innervated by *neuromast-like cells*. Their pores may be found in a row near the bases of the pectoral fins and anterior to the first gill slit. They are believed to aid the shark in the detection of temperature changes.



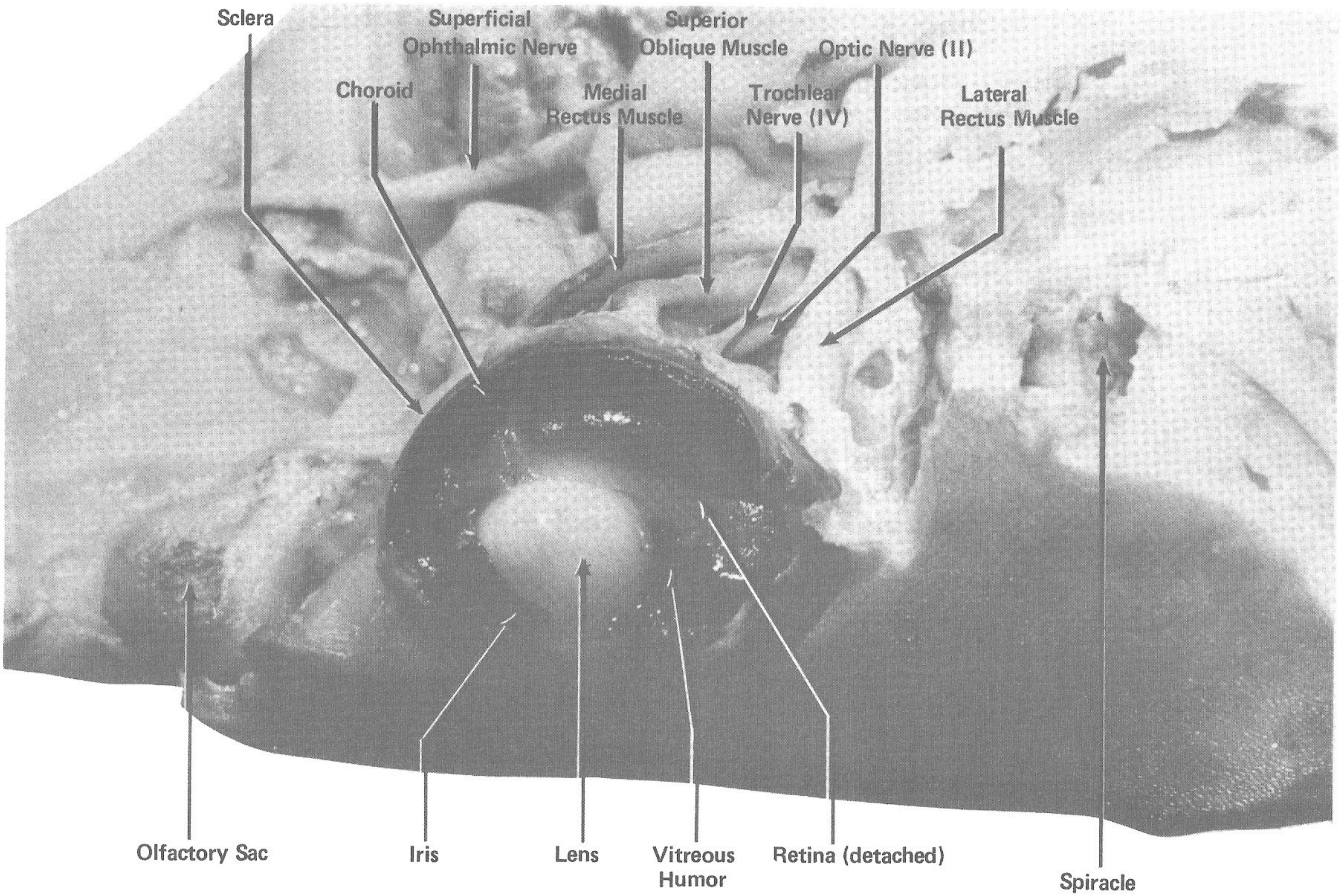

THE MEMBRANOUS LABYRINTH – DORSO-LATERAL VIEW



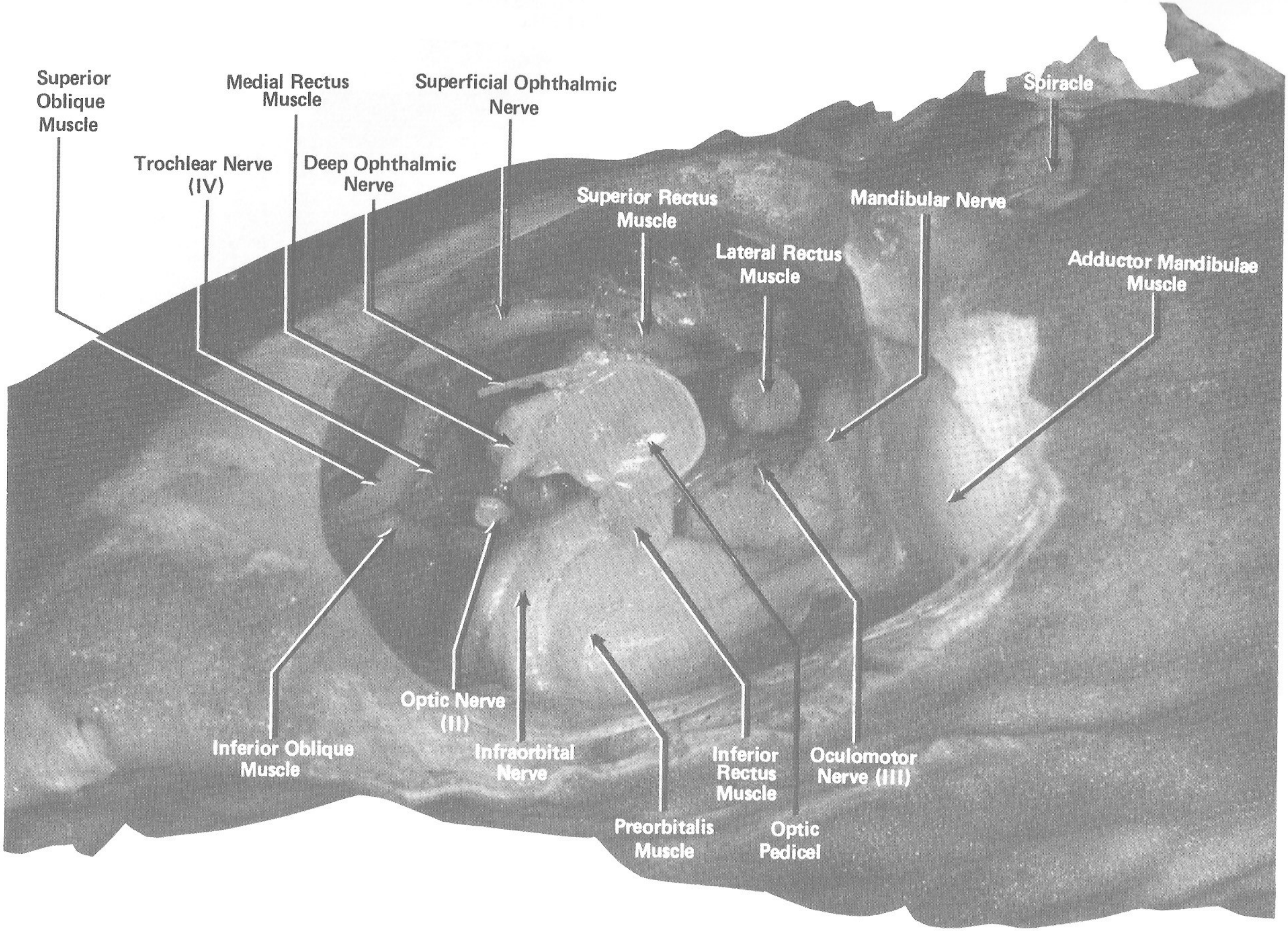

THE EYE — DORSO-LATERAL VIEW

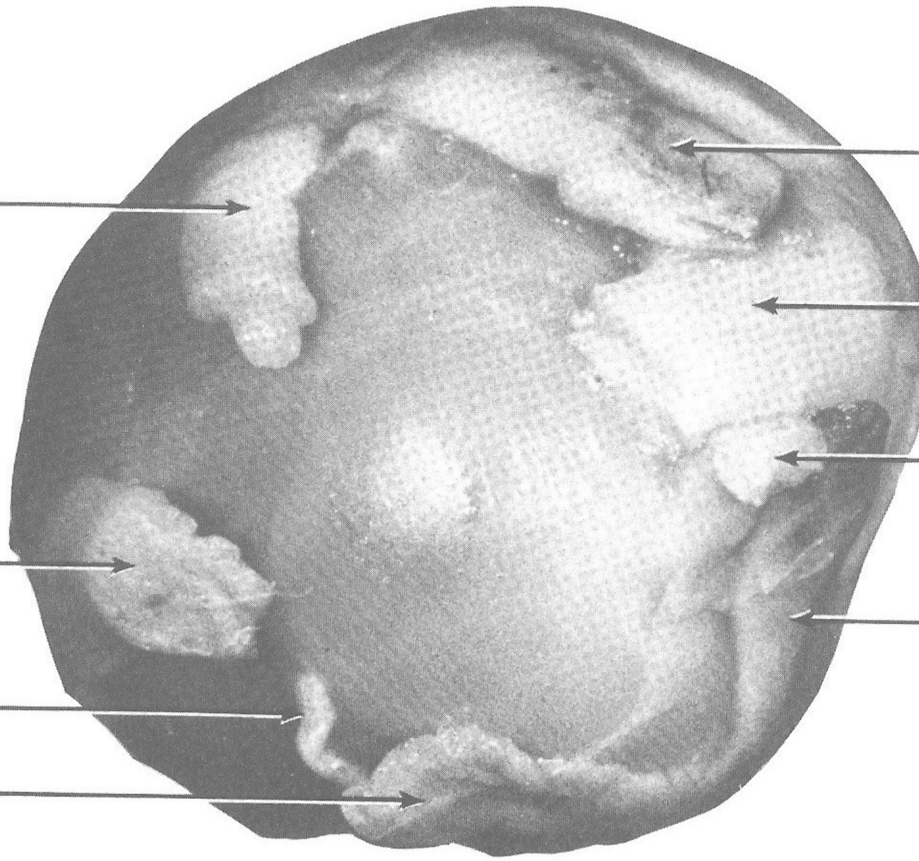



THE EYE – DORSAL VIEW

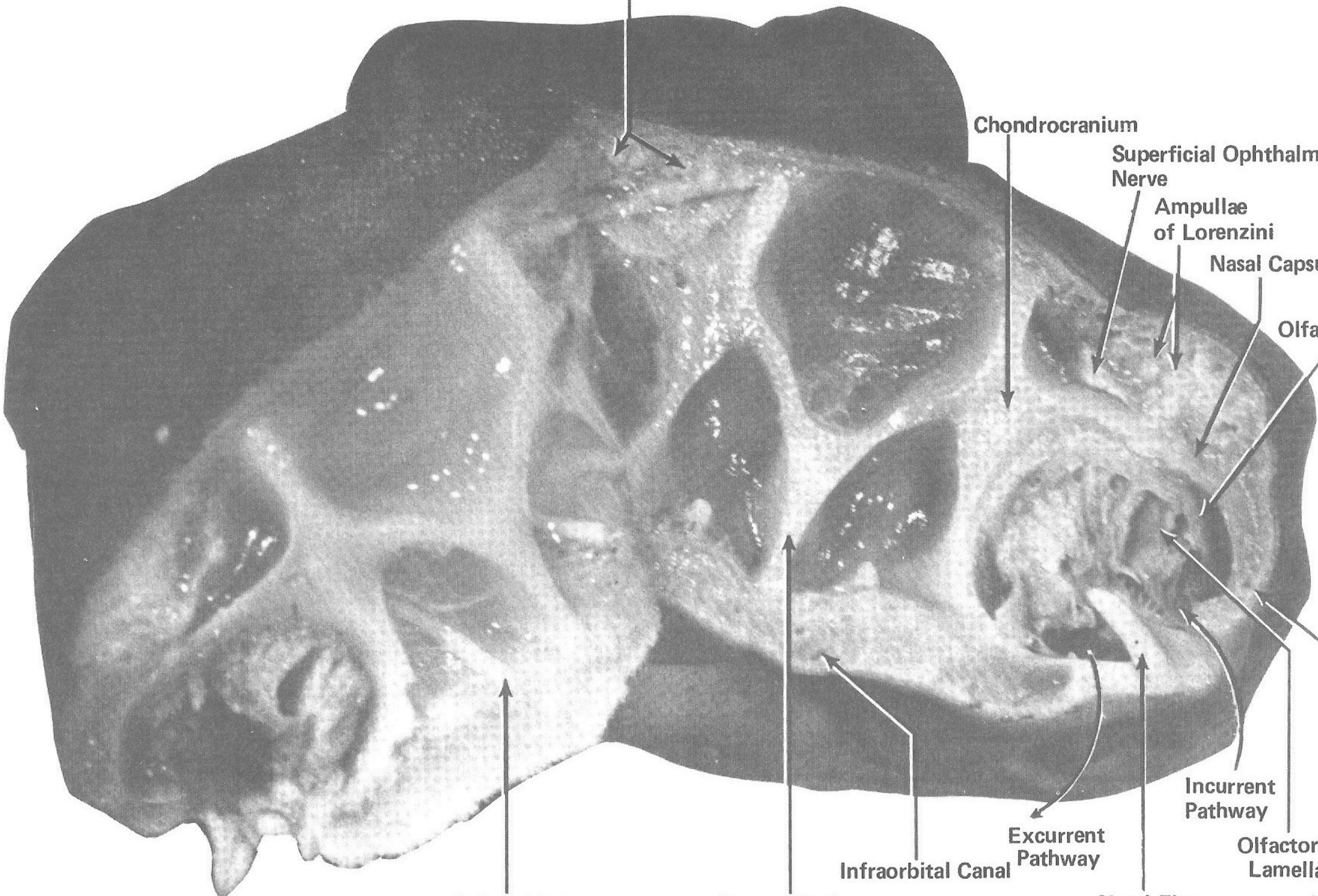



THE EYE – SAGITTAL SECTION


Superior Oblique Muscle
Medial Rectus Muscle
Superficial Ophthalmic Nerve
Spiracle
Trochlear Nerve (IV)
Deep Ophthalmic Nerve
Superior Rectus Muscle
Mandibular Nerve
Lateral Rectus Muscle
Adductor Mandibulae Muscle
Optic Nerve (II)
Inferior Oblique Muscle
Infraorbital Nerve
Inferior Rectus Muscle
Oculomotor Nerve (III)
Preorbitalis Muscle
Optic Pedicel




THE LEFT EYE – MEDIAL VIEW




THE OLFACTORY SAC – CROSS SECTION