Sense Organs

Olfactory receptors are paired **olfactory pits**, each of which opens to the external by means of two apertures but they do not communicate to the buccal cavity. Olfactory pits are lined by the olfactory cells. Their function is olfactory and has no role in respiration.

Taste buds (chemoreceptors) are found in many parts of the body. Taste buds are present over the lips, in the epithelial lining of the first three gill-slits and on the barbels.

Tactile receptors are abundant over the lips and barbels and are also found over the entire body.

Lateral line system is well developed in actinopterygians. Each sensory organ lies in a pit and communicates with surrounding water through a pore. These pits are linked by canals and innervated by the **lateral line** branch of the vagus. Lateral line system helps the fish to perceive low frequency vibrations in water and also apprises the fish of the approach of predator or prey.

Eye. A pair of eyes over the head are the photoreceptors. Each eye has three layers : (*i*) outer cartilaginous **sclerotic layer**, (*ii*) a median vascular **choroid layer** and an innermost photosensitive **retinal layer**. In between the sclerotic and choroid is a silvery layer or **argentea** which gives its colour. The **cornea** is flat with which the globular **lens** is almost in contact, so that the anterior chamber of the eye is extremely small. There are no choroid processes. In the posterior part of the eye, between the choroid and the argentea, is a thickened ring-shaped structure, the **choroid gland** which surrounds the optic nerve. It is not glandular, but it is a complex network of blood vessels or **rete mirabile**. Close to the entrance of the optic nerve a vascular fold of the choroid, the **falciform**

process, pierces the retina, and is continued to the back of the lens. Here it ends in a muscular knob, the **campanula Halleri** or **retractor lentis**. The falciform process and campanula Halleri takes an important part in the process of **accommodation** by which the eye becomes adapted to forming and receiving images of objects at various distances. Accommodation is also effected by shifting the position of lens and not by changing the shape of lens as occurs in higher vertebrates. The pupil size appears to alter very little or not at all. Vision is **monocular**, each eye has different visual field.

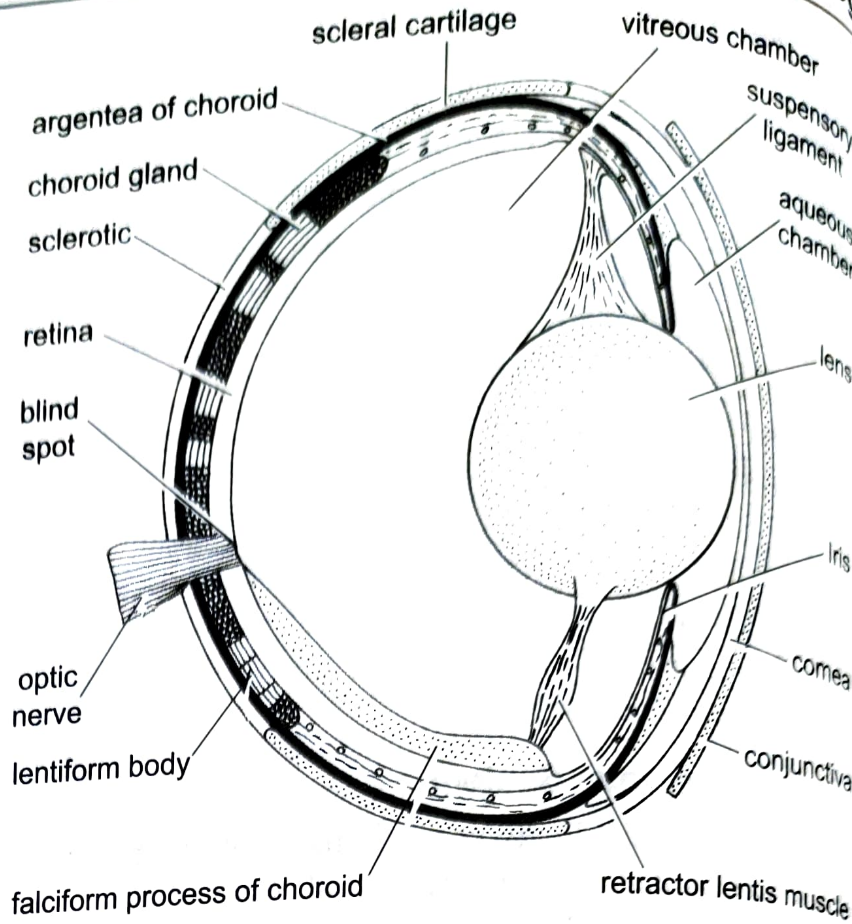

Fig. 15.12. V.S. eye of a bony fish.

Ear or organ of audio-equilibrium. In fishes, the external and middle ears are absent, only internal ear or **membranous labyrinth** is found. The membranous labyrinth is formed of an upper **utriculus** and a lower **sacculus**. Three semicircular canals open into the utriculus. The sacculus is sac-like and its floor gives rise to a **lagena**. The endolymph present in the membranous labyrinth contains **otoliths** or ear-stones, which are of three types: **sagitta** is relatively large and it almost fills the sacculus, **asteriscus** is a small granule lying in the lagena, and the **lapillus** is found in utriculus close to the ampullae of the anterior and horizontal canals. Bony fishes hear with great discrimination, despite the absence of organ of Corti. The utriculus and the semicircular canals help the fish to maintain equilibrium. The sacculus and lagena perceive the sound waves. The body surface transmits the vibrations to the membranous labyrinth.

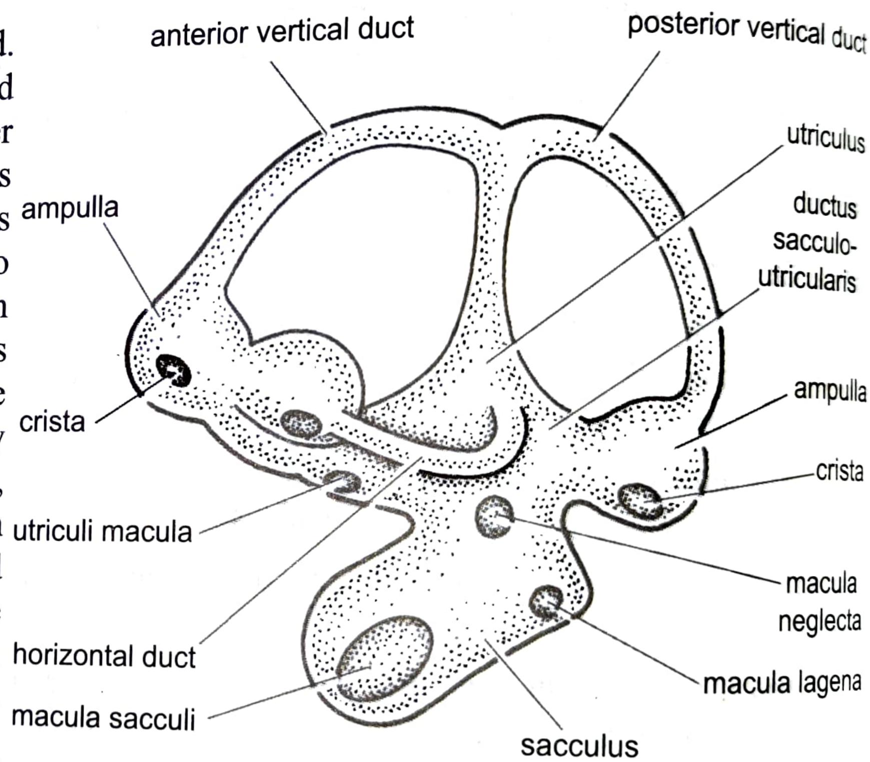

Fig. 15.13. *Labeo*. Internal ear.

RECEPTORS

In frog various types of **receptors** or **organs of special sense** are found which are supplied with nerve fibre and, thus, convey the stimulus to the central nervous system. These receptors can be grouped under two heads :

1. External or Exteroceptors. External receptors are those which receive impulses from the external environment. External receptors can be grouped under following heads :

(*i*) **Tangoreceptors** or organs of touch;
(*ii*) **Olfactoreceptors** or organs of smell;
(*iii*) **Gustatoreceptors** or organs of taste;
(*iv*) **Photoreceptors** or organs of sight;
(*v*) **Statoacoustic receptors** or organs of hearing and balance.

(*i*) Tangoreceptors or organs of touch. The entire skin serves as organs of touch as it is abundantly supplied with sensory nerve endings situated in the spaces between the cells. At places compact groups of cells form **corpuscles** which project into papillae of epidermis. These are supplied with sensory nerve endings. Such groups of cells are called **tactile organs** or **patches**. These are very much sensitive to touch and also to temperature. The nerve endings never reach the cells of the outermost layer of epidermis. Consequently the stimuli which produce the sensation of touch are not directly received by the tactile organs. The tactile organs make the skin of the frog sensitive to touch, heat, cold and the effects of the chemicals. In tadpole larva a lateral line system is found which is absent in adult frog.

(*ii*) Olfactoreceptors or organs of smell. These are the organs which are simply concerned with distinguishing the various kinds of smell given off from different substances or things. They include a pair of **olfactory** or **nasal sacs** located in the olfactory capsules of the skull. Each nasal sac communicates with the outside by the external nares and with the buccal cavity through the internal nares. These are internally lined with columnar epithelial cells out of which certain are special modified cells called **neurosensory** or **olfactory cells** which are bipolar in shape. Their deeper ends are connected to the fibres of the **olfactory nerves** which are directly connected with the brain (olfactory lobes), while their other ends are produced into **sensory hairs** projecting into the lumen of the nasal sac. The mucous lining of the sac also has supporting and mucus secreting cells whose secretion keeps the nasal epithelium moist in order to make it more effective. The odours of a substance are brought to these organs either through the medium of air or water. From these organs the stimuli travel along the olfactory nerves to the brain.

(*iii*) Gustatoreceptors or organs of taste. Gustatoreceptors or organs of taste are found in the form of **taste buds** which are confined chiefly over the tongue and the floor and roof of the buccal cavity. Each **taste bud** is more or less spherical body consisting of a group of barrel-shaped columnar cells, some of which are **neurosensory** and others are supporting cells. The neurosecretory cells are slender and elongated and found in the middle and are covered all around by supporting cells. The free ends of neurosensory cells are produced into delicate fine **taste hairs** projecting above the surface, while other ends are innervated with sensory nerve fibres. The supporting cells are larger in size but lack sensory hairs. Taste buds of frog are supplied by the branches of the VII and IX cranial nerves.

The mucous membrane of the tongue is produced into two kinds of papillae : the conical **filiform papillae** and rounded knob-like **fungiform papillae**. The taste buds are confined only in fungiform papillae and stimulates whenever their taste hairs come in contact with a substance in solution.

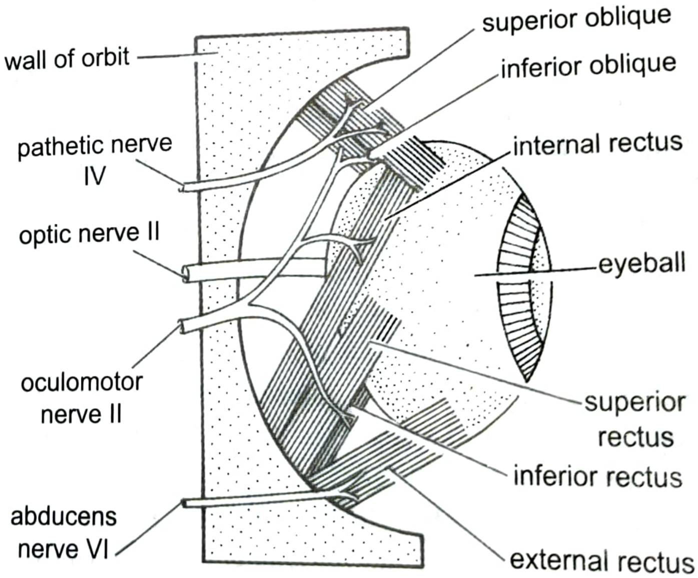

Fig. 18.55. Frog. Dissection of right eyeball in dorsal view showing eye muscles and their nerve supply.

***(iv)* Photoreceptors or organs of sight.** The organs of sight are two spherical eyes which are situated in the orbital fossae on either side of the head. Their structure and function is like that of other vertebrates. Their one-third part is visible externally but remaining part lies hidden in the orbit. The orbit has no bone at its bottom, therefore, the eyeballs can be seen projecting on the roof of the buccal cavity as spherical prominences. The eyes are protected with two eyelids, the upper is immovable and lower one is movable. There is a transparent **nictitating membrane** which covers the eyes when the frog goes inside the water or underground. The nictitating membrane is simply a transparent part of the upper border of the lower eyelid which lies folded beneath the opaque part of the lower eyelid. Its movement is controlled by means of two types of muscles, the **retrator bulbi** and the **levator bulbi**. On the contraction of the **retrator bulbi** muscles the eyeball is drawn deep into the orbit due to which the eyelids come nearer and the nictitating membrane is unfolded over the eye. On the contraction of the **levator bulbi** muscles the eyelids are separated that results in the folding back of the nictitating membrane to its original position.

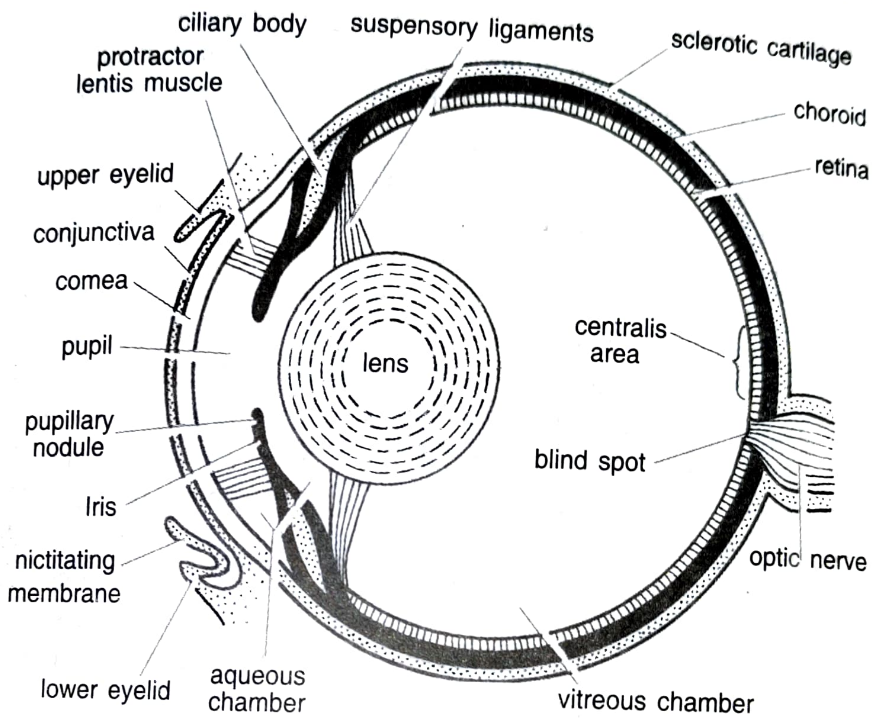

Fig. 18.56. Frog. V.S. of eye.

Movement of eyeball. The eyeball is moved by a set of six extrinsic muscles : (*i*) Four **rectus mucles** (anterior rectus, posterior rectus, superior rectus and inferior rectus). These muscles rotate the eyeball forwards, backwards, upwards and downwards respectively. (*ii*) Two muscles are **superior** and **inferior oblique muscles**. The superior oblique muscles bring about the rotation of the eyeball along the axis between the optic nerve and cornea, while inferior oblique muscles bring just the opposite movement. The muscles arise from the front part of the orbit.

Harderian glands. The surface of the eyes remains moist due to the presence of **Harderian glands** situated at the lower inner angle of the eye. These glands secrete a liquid which lubricates the eyeball. Excess secretion is drained into the nasal sac through a fine **naso-lachrymal duct**.

Structure of eyeball. The eyeball is made of three concentric layers or coats, an outermost **sclerotic**, a middle **choroid** and an inner **retina**.

1. Sclerotic. It is the outermost thick protective layer which is made of fibrous connective tissue and cartilage. It is actually the optic capsule which has not fused with the skull but fits closely to the eye. It occupies about two-thirds of the entire circumference of the eyeball and is mostly out of sight being within the orbits. The remaining one-third of it is continued in front as an arched transparent **cornea**. It simply maintains the shape of the eyeball and also protects the eyeball and also provides surface for attachment of extrinsic eye muscles. Cornea is covered externally by a thin transparent membrane called **conjunctiva** which is the continuation of skin. It is also continued with the inner lining of the eyelids. Nictitating membrane which is the continuation of the inner membrane of lower eyelid protects the outer exposed surface of the eye. It has thin blood capillaries.

2. Choroid. It is the middle vascular and pigmented layer made of loose connective tissue fibres. Towards the anterior side it thickens as a ring-like **ciliary body** having ciliary muscles and then separates from the sclerotic forming a circular pigmented **iris** with a central aperture, the **pupil**, which looks like a black spot. Within the iris are two sets of involuntary muscles, circular and radials, which regulate the opening of pupil.

Immediately behind the pupile iris is a large, circular and transparent crystalline lens which is enclosed in a delicate **lens capsule**. It is suspended behind the pupil by a membranous **suspensory ligament** from ciliary body. The iris divides the hollow of the eyeball into a small anterior **aqueous chamber** and a large posterior **vitreous chamber**. The aqueous chamber is filled with a watery **aqueous humour**, whereas the vitreous chamber is filled with **gelatinous vitreous humour**.

3. Retina. It is the innermost sensitive layer present only in the posterior part of eyeball behind ciliary body. It is made of several layers. The outermost layer is formed of pigment cells lining the choroid and beneath it is the sensory layer of rods and cones, which is followed by several layers of sensory cells. The innermost layer is of nerve fibres which are connected to the **optic nerve**. Towards the posterior side the optic nerve leaves the eyeball through the three coats. This site is called the **blind spot** which has no rods and cones. Close to it is the **yellow spot** where a distinct image is formed but at blind spot no image is formed.

Microscopic structure of retina. Microscopically the retina is a complicated coat consisting of several layers of different kinds of sensory cells. Next to the outer pigmented layer of the retina, there is a layer of visual cells consisting of **rods** and **cones** followed by a layer of **bipolar nerve cells** and an outer layer of **ganglionic cells**. The rods and cones are modified sensory cells which have been so named due to their shape. These cells are placed at right angle to the surface of the retina and their thin ends are embedded in a layer of pigment cells. The rods are cylindrical cells containing a purple pigment and the cones are conical tapering cells. The rods are meant simply to perceive the amount of light, while the cones for distinguishing colours.

The bipolar nerve cells on one side form synapses with the rods and cones, while on the other side with the ganglionic cells. The axons of ganglionic cells spread over the inner surface of the retina, and converge at the back of the eyeball where they pierce the retina and come together to form the **optic nerve** going to the brain.

The posterior part of the retina just opposite to the lens is called **area centralis** or **yellow spot** which contains only cones and has yellow pigment, the images are normally focussed on this area.

Working of the eye. Frog has a **monocular vision** as the two eyes are situated far away from each other over the head and their images also do not coincide. The eyes function like photographic camera. The eyelids function like the shutter of camera, the iris like diaphragm which regulates the amount of light entering the eye through the pupil, the **lens** like camera's lens and the sensitive **retina** like the film or the plates of the camera.

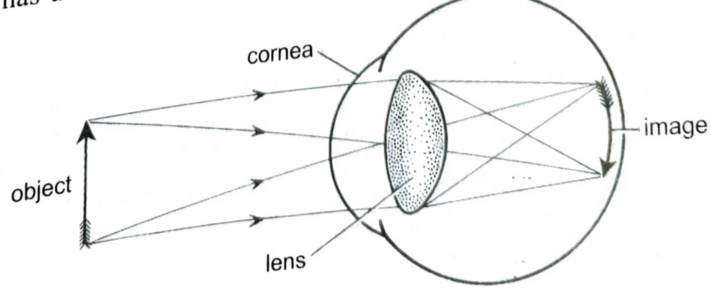

Fig. 18.57. Frog. Image formation in the eye.

When light from any object in front of the eye falls upon it, the rays pass through the cornea and aqueous humour and reach the spherical lens through the pupil. The cornea and lens both in combination focus the rays on the retina to stimulate the rods and cones. The impulses then pass along the bipolar and ganglionic cells to reach the brain through the optic nerve. Light rays falling on the retina produce an **inverted** and **reduced image** of the object which is rightly corrected by the brain but never reinverted in the brain as it is often supposed. The rays passing through the pupil converge due to their passage through the cornea and aqueous humour which together act as a convex lens but the rays as pass through the **crystalline lens** are further refracted in order to form an inverted and diminished image of the object on the retina which is rightly corrected by the brain.

During the image formation the iris acts as a diaphragm. If the object is well illuminated the pupil closes down to a pin point in order to check the excess of light intensity inside the eyeball and also to prevent the disintegration of the retinal cells, but when the object is poorly illuminated the pupil is widely open in order to allow as much light as possible to enter the eyeball to form the clear image of the object. In this way the iris helps in the formation of a well defined image after regulating the amount of light entering the eye.

(*v*) Statoacoustic receptors or Organs of hearing (Ear). The statoacoustic organ is for hearing and equilibrium. It includes a pair of ears present on the postero-lateral sides of skull enclosed in auditory capsules. The ear of frog includes a **middle ear** and an **internal ear**. The external ears are absent.

1. Middle ear. The middle ear consists of all those structures which are related simply in transmitting the sound waves to the internal ear which acts as suspensory apparatus. The cavity of middle ear is called the tympanic cavity lined by a membrane. It is an air-filled chamber communicating with the pharynx by a slender **eustachian tube**, the opening is normally kept closed by a valve. Externally the cavity of middle ear is bounded by a circular patch of dark skin, the **tympanic membrane** or **eardrum** which is tightly stretched over a ring of cartilage, the **annulus tympanicus**, it is simply a modified skin. It is vibratile in nature and from the centre of which a club-shaped rod, the **columella auris**, is extended across the tympanic cavity and attached internally to a membrane and a cartilaginous small nodule, the **stapedial plate** fused over a small window-like oval aperture, **fenestra ovalis** (a hole in the auditory capsule). The columella auris is partly made of bone and partly of cartilage. The columella auris is equivalent to hymandibula of dogfish.

2. Internal ear. The internal ear consists of a bony **auditory capsule** which is cartilaginous in the beginning but later in the adult is bony. It is formed by the **pro-otic** and **exoccipital** bones. The auditory capsule is filled with a watery fluid called **perilymph** in which the **membranous labyrinth** floats which is partially supported by connective tissue. It is comparable with inner ear of dogfish in structure and function.

The **membranous labyrinth** is a sac-like complicated structure consisting of a larger oblong **utriculus** on the dorsal side and the smaller oval **sacculus** on the ventral side.

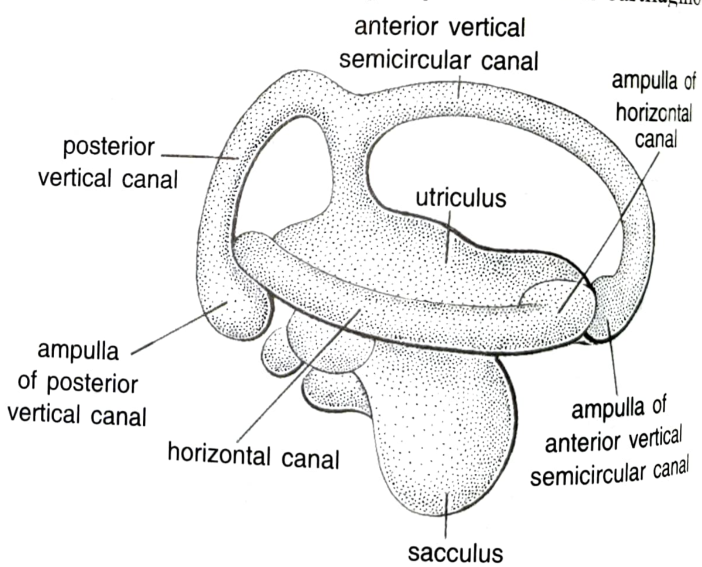

Fig. 18.58. Frog. Internal ear.

From the posterior side of the sacculus arise two small dilations, the **lagena** or **cochlea** and the **pars basilaris** which is now regarded as a part of lagena. Lagena is the forerunner of cochlea of higher vertebrates.

Dorsal to these is the protuberance of utriculus, called the **pars neglecta**. From the inner dorsal side of the sacculus arises a narrow tube, the **ductus endolymphaticus** and terminates in a dilated thin-walled endolymphatic sac present over the hindbrain within skull.

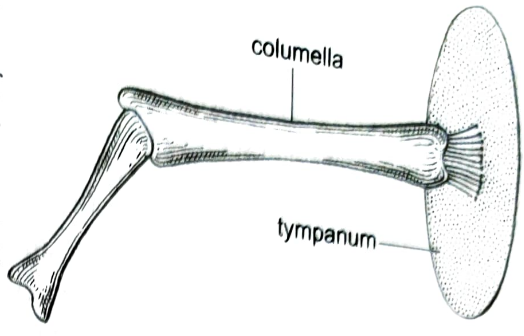

Fig. 18.59. Frog. Columella auris.

The three semicircular canals arise from the utriculus, are placed at right angles to one another, these are anterior and posterior vertical semicircular canals, while the third is a horizontal semicircular canal. The anterior and posterior canals have their adjacent limbs dorsally united and open into the utriculus through a common opening, whereas the horizontal semicircular canal opens into the utriculus at either end. Each semicircular canal at its distal end is dilated to form a small round **ampulla**. The ampullae of the anterior and horizontal semicircular canals are found at their anterior ends and that of the posterior canal is at its posterior end.

The entire **membranous labyrinth** is hollow and is filled with a fluid called **endolymph** which contains pieces of calcium carbonate forming **otoliths** or **ear stones**. The various parts of the membranous labyrinth are innervated by the fibres of the auditory nerve.

Histology of membranous labyrinth. The wall of entire membranous labyrinth is made of dense fibrous connective tissue and is lined with cubical epithelial cells. The epithelial lining is modified at certain places to form receptors of the labyrinth which are called **sensory patches** or **acoustic spots**. There is one acoustic spot in each ampulla, one spot in the utriculus, one in the sacculus and one in the lagena. The acoustic spots of the ampullae are called **cristae**, while those of the utriculus, lagena and sacculus, **maculae**. The macula of utriculus is a large **pars neglecta** and that of the lagena is called **basilar papilla**. The **cristae** and **maculae** have the same structure as they are made of **sensory hair cells** and the **supporting cells**. The sensory cells have stiff and tapering hair-like processes at their inner free ends, while their lower ends are connected with nerve fibres of the auditory nerve.

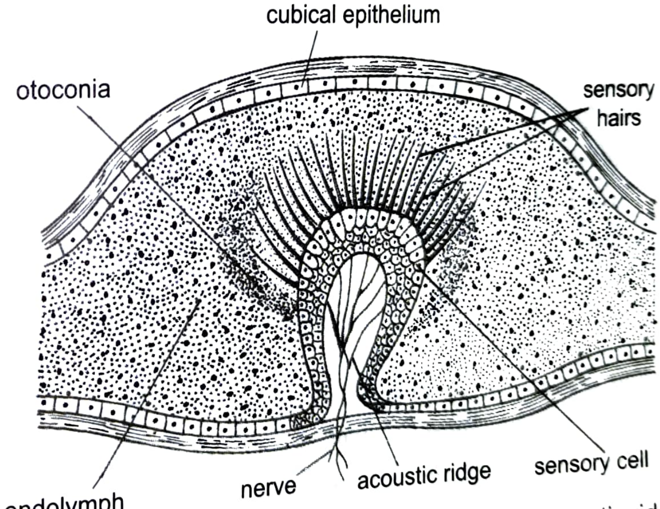

Fig. 18.60. Frog. V.S. of ampulla through an acoustic ridge or crista.

Working of the ear. Ears have two functions, hearing and equilibrium. The membranous labyrinth of the frog functions primarily as the organ of balancing and secondarily as the organ of hearing.

(a) Equilibrium. The semicircular canals along with their ampullae and the utriculus are concerned with the balancing of the body. On any change in the position of the animal the endolymph and the otoliths start movement and also exert pressure due to which the three cristae and one macula are stimulated. From which the impulses of change of position are transmitted by nerve fibres of the auditory nerve to the brain which sends the impulses to muscles concerned to bring the correct position.

***(b)* Hearing.** The sacculus and the lagena are the main structures of the membranous labyrinth which are concerned with the hearing. In hearing the sound waves strike the surface of the tympanic membrane and set it to vibrate. The columella which is extended from the tympanic membrane directly to the **stapedial plate** transmits these vibrations to the perilymph and then to the endolymph of membranous labyrinth. These vibrations stimulate the sensory hair cells of sacculus and lagena. These sensory cells transmit the impulses to the brain by the auditory nerve, produce the sensation of sound. Thus, columella is meant only for the transmission of sound waves across the tympanic cavity. It also concentrates the sound waves to a point.

2. Interoceptors. These are certain muscles and tendons of the body and also the alimentary canal which respond to stimuli as they are very much supplied with nerve fibres called **interoceptors**. The interoceptors found in the alimentary canal and viscera are called **interoceptors**, whereas those found in the muscles and joints are called **proprioceptors**.

Interoceptors provide information about the hunger, thirst, pain or comfort in the alimentary canal. **Proprioceptors** provide information about pains in viscera and tension in the muscles of the body.

URINOGENITAL SYSTEM

SENSE ORGANS

The sense organs of *Uromastix* have not been studied. The following description is of *Lacerta*. The external organs of taste are completely lacking in Reptilia. The sense of taste is confined to the mouth only.

1. Olfactory organs. The olfactory organs are more complex than those of Anura. The nasal cavities open at the end of the snout by the **external nares** and into the cavity of the mouth by a pair of slit-like **internal nares** situated near the middle line of the palate. The external nare opens itno the vestibule through which air passes to the sensory epithelium of the nasal or olfactory cavity proper. The nasal cavity contains a convoluted **turbinal bone** over which the mucous membrane

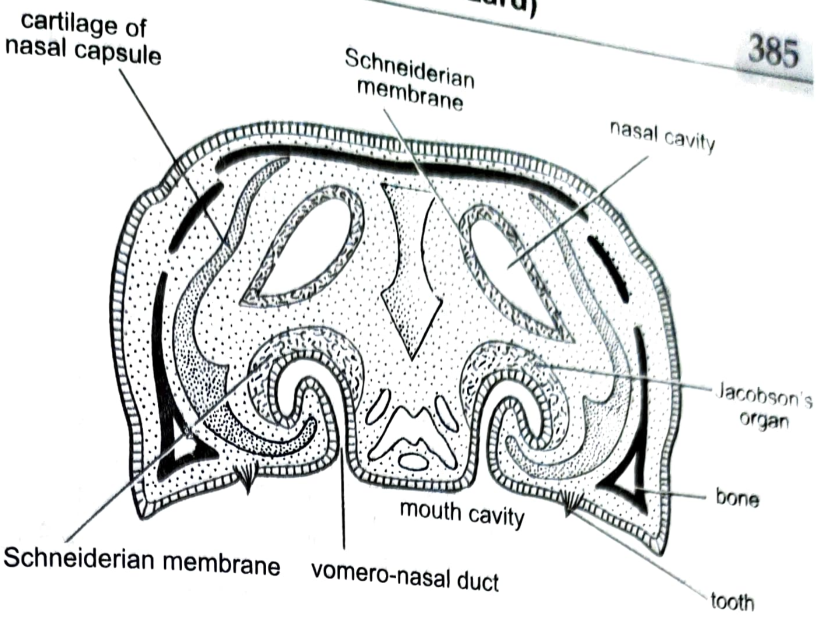

Fig. 21.32. *Uromastix*. T. S. of head showing Jacobson's organ and nasal sacs.

extends. Its cell are sensitive to chemicals in solution. The organs of chemical sense are better developed in reptiles. In reptiles, there are a pair of **vomero-nasal organs** or **organs of Jacobson**. The organs of Jacobson are well developed sac-like chambers lying below the nasal cavity but above the buccal cavity. Each organ consists of a blind sac lined with olfactory epithelium. It develops as a ventral hollow outgrowth of the nasal cavity. They are lined with olfactory epithelium. Each sac opens into the buccal cavity by a narrow duct a little in front of the internal nare.

2. Jacobson's organs. The organ of Jacobson is innervated by branches of the olfactory and the trigeminal nerves. This sense organ is important in most lizards and snakes and appreciates scent particles introduced into it by the tongue tips. These organs serve to smell the food when it has been taken into the buccal cavity. In some reptiles, they play a part in activities such as trailing prey and locating members of the opposite sex. Paired ducts communicate with the buccal cavity, probably enabling the olfactory appreciation of substances held in the mouth.

3. Eyes. The eyes of *Uromastix* exhibit some advancement over those of the amphibians due to the transition from water to land. Although both the eyelids are movable but the lower eyelid is more movable in comparison to the upper eyelid. The eyelids close the eyes to protect them from the dust, heat and rain. There is a third eyelid, the **nictitating membrane**, in the anterior corner of the eye which develops and lies folded beneath the lower eyelid. It is really a double fold of conjunctiva and is not homologous with that of the frog. The nictitating membrane can be drawn rapidly over the moist cornea and, thus, it protects and cleans the eye. There are glands which keep the eyelids and cornea moist and clean. The **Harderian gland** lying on the anterior side of the eyeball lubricates the nictitating membrane, and the **lacrymal gland** lying on the posterior side of the eyelid keeps the eye moist and clean. The tears (water fluid) are passed from the eye into the nose through a lacrymal duct.

The eye of *Uromastix* consists of the usual three layers, *viz.*, (*i*) the outer **fibrous tunic** or **sclerotic**, (*ii*) the middle **uvea** or **choroid** and (*iii*) the inner **retina**.

(*i*) Fibrous tunic. The thick and tough fibrous tunic protects the eyeball and maintains its form. The fibrous tunic is distinguished into two distinct regions : an anterior, small, transparent and exposed portion called the **cornea** and a posterior, large, opaque cartilaginous portion called the **sclerotic** lying hidden in the orbit. A small anterior portion of the sclerotic, the cornea is, however, visible and is commonly called the **white** of the eye. The cornea is supported by a ring of eleven small **sclerotic bones**, or **ossicles**, present around the iris. The cornea is curved and provides the main refracting surface. A thin transparent epithelial layer is fused to the outer surface of the cornea. It is known as **conjunctiva**. The conjunctiva is continued over the inner surface of the *(ii)* **Uvea.** Uvea is differentiated into three regions : (*a*) A greater part of it is thin, vascular and pigmented and lies in close contact with the sclerotic. It is called the **choroid**. It serves to darken the eye. (*b*) At the junction of the sclerotic and cornea, the uvea forms a thick ring which constitutes a part of the **ciliary body**. (*c*) Just in front of the cavity of the eye, forming a part of the circular partition is the **iris**. The iris is perforated at the centre by an aperture, the **pupil**. The iris possesses circular and radial muscles to reduce and enlarge the pupil respectively. The iris contains pigment cells, which impart it its characteristic light-orange colour.

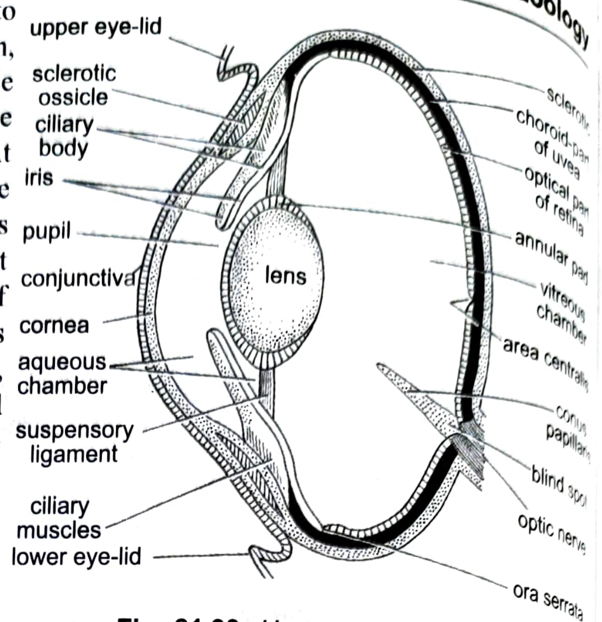

Fig. 21.33. *Uromastix*. V.S. of eye.

(iii) **Retina.** Retina lies inside the entire uvea and is differentiated into three distinct regions: (*a*) Its portion lying in contact with the choroid is thick and sensitive and is called the **optical part of retina**. It contains more cones than rods, thus, there is a good daylight vision and probably good colour perception. This condition is found in most lizards (diurnal types) and many turtles. The double cones of turtles and lizards may serve to detect polarized light (**Underwood**, 1970). This portion is protected from excessive exposure to light by yellow droplets found over this portion. (*b*) Remaining retina is thin and non-sensory. It lines the iris and ciliary body. The part forming the ciliary body is known as the **ciliary part** and that to the iris as the **iridial part**. The junction of the optical and ciliary parts of the retina is irregular and is called **ora serrata**.

The **lens** is a biconvex, transparent body lying immediately behind the iris. It is more convex behind than in front. A ring of soft tissue, the **annular pad**, surrounds the circumference of the lens. The lens is suspended and held in position by radially arranged fibres which arise from the ciliary body and are attached to the annular pad and form the **suspensory ligament**. The suspensory ligament is formed of ciliary muscles and ciliary processes. The lens and its suspensory ligament divide the cavity of the eye into two unequal compartments, *viz.*, the anterior small **aqueous chamber** and the posterior large **vitreous chamber**. The aqueous chamber is further divided by iris into anterior and posterior parts containing a clear watery fluid, the **aqueous humour**, and are continuous through the pupil. The aqueous humour keeps the eyeball taut or stretehed for distinct vision.

The optic nerve arises from the inner surface of the retina and joins the brain after piercing through all the three eye-coats at the back of the eyeball. The point of origin of optic nerve is called the **blind spot**. No image is formed at this point. A small part of the retina opposite the centre of the lens is the place of the most distinct vision. It is called the **area centralis** or **yellow spot**. A peculiar pigmented, blackish brown, highly vascular, cushion-like rod, the **conus papillaris**, projects into the vitreous humour from the blind spot. Probably it provides nutrition, like the pecten of birds.

Accommodation for near vision is usually produced by the striated ciliary muscles, so arranged that they cause the ciliary process to squeeze the lens, making its anterior surface more rounded.

Ear. The ear of *Uromastix* consists of two principal parts : the **middle ear** and the **internal ear**. External ear is absent.

Middle ear. The middle ear comprises an air-filled cavity called the **tympanic cavity**. It is bounded externally by the tympanum and internally by the auditory capsule. The tympanus lies behind the jaws, sunk a little below the surface. From the lower part of the tympanic cavity a narrow passage, the **Eustachian tube**, extends downwards and inwards to open into the posterior part of the pharynx.

A slender rod-like ear ossicle, the **columella auris**, stretches across the tympanic cavity. The columella auris is divided into two parts : the inner bony **stapes** fitting into a small membrane covered aperture, the **fenestra ovalis**, and the outer cartilaginous **extrastapes** is attached to the inner surface of the tympanum.

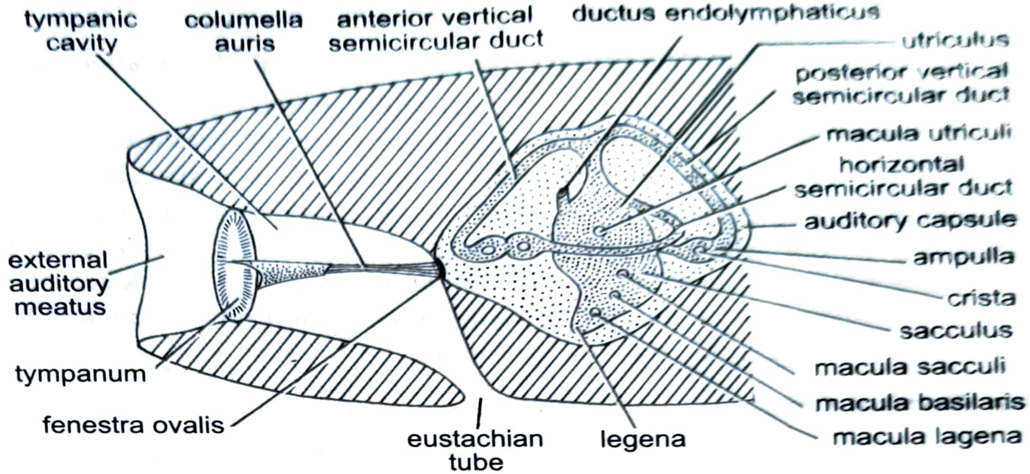

Fig. 21.34. *Uromastix*. Ear.

Internal ear. The internal ear is situated in the auditory capsule. It is a soft, delicate and complicated structure known as **membranous labyrinth** or **vestibule**. Its upper cylindrical part is known as the **utriculus** and the lower large and rounded **sacculus**.Three semi-circular ducts (2 vertical and 1 horizontal) open into the utriculus at both of their ends. The two vertical ducts join together by their adjacent ends before opening into the utriculus. One end of each semicircular duct is enlarged to form an ampulla. The sacculus gives rise to a small lobe, the **pars lagena**, which represents the cochlea of mammalian ear. It is an uncoiled tube and hearing is performed by it. Its wall, known as the limbus, is strengthened by a peculiar form of connective tissue. The receptor hairs (organ of Corti) are carried on a basilar membrane and are in contact with a tectorial membrane attached to the limbus. Hearing is good in some lizards which also produce sounds for communication. Snakes respond mainly to earth-borne vibrations through the quadrate attached to the stapes (tympanum is absent in snakes and some lizards also). A narrow **ductus endolymphaticus** extends dorsally from the saculus and ends in a small blind sac over the hindbrain.

the spinal ... supply chiefly the urinogenital, alimentary, respiratory and circulatory systems.

SENSE ORGANS

The pigeon, like other vertebrates, has receptors or sense organs for touch, smell, taste, sight and hearing which are stimulated by the environment. These sense organs are termed external receptors or **exteroceptors**. The pigeon possesses following exteroceptors :

1. **Tactile organs.** These are poorly developed in birds due to feathery covering of the body. Tactile organs of pigeon remain confined to the bill and tongue of pigeon. The **cere** is a sensitive soft fold of skin at the base of the upper beak in pigeons, is said to have a stimulating effect during love making. The **corpuscles of Grandry** in the bill of ducks and other birds are probably tactile receptors. They are composed of cells with a flattened nerve ending between cells. These are comparable to Meissner's corpuscles in mammals. **Merkel's corpuscles** are also found in many birds.The **corpuscles of Herbst**, resembling Pacinian corpuscles of mammals, are found in the dermis, are vibration receptors, sensitive to mechanical deformation by rapid pressure changes. They are found in great numbers in the beaks of all birds and also in the feather follicles, between tibia and fibula and in the tip of the tongue of woodpecker. Tactile nerves are also present at the base of the feathers, especially those of the wings and tail.

2. **Gustatory organs (Chemoreceptors).** Sense of taste and smell are little developed. The sense organs of taste, the **taste buds**, occur in limited number on the dorsal surface of tongue. The sense of taste is poorly developed in pigeons.

3. **Olfactory organs.** Birds are usually unable to distinguish delicate odours, and on the whole their **sense of smell** is very poor, as flying animals cannot depend on smell. The nasal cavity is large but the olfactory epithelium is restricted. Birds use the nose to test air coming from the internal nostrils. In kiwis, olfactory sense is well developed. These birds are nocturnal and terrestrial.

Structure of olfactory organs. The nostrils, overhung by cere, lead into the small, paired **olfactory sacs** or **nasal chambers** in the base of upper beak.The two chambers are separated medially by mesethmoid and bounded externally by ectoethmoid. The ectoethmoid produces inwards three scroll-like **turbinal processes** to increase the olfactory surface. The nasal chamber has an anterior **non-sensory respiratory** part and a posterior **sensory** part. The non-sensory part or **vestibulae** contains the anterior turbinal covered by laminated epithelium. The sensory or **olfactory** part contains the middle and posterior turbinals invested by the one-layered olfactory mucous epithelium or **Schneiderian membrane**, which is made of basal cells, supporting cells and elongated neurosensory cells. The neurosensory cells remain connected with olfactory nerve. Both the olfactory chambers remain communicated to the pharynx by the internal nares.

4. Auditory organs or ears. The sense of hearing is acute in most birds. Its auditory sense organs, the **ears**, serve their dual function of **equilibrium** and **hearing**. Auditory organs consist of a fundamental ear, the **internal ear** or **membranous labyrinth** and **middle ear** or **tympanic cavity**, like mammals. But, unlike mammals they lack **external ear**.

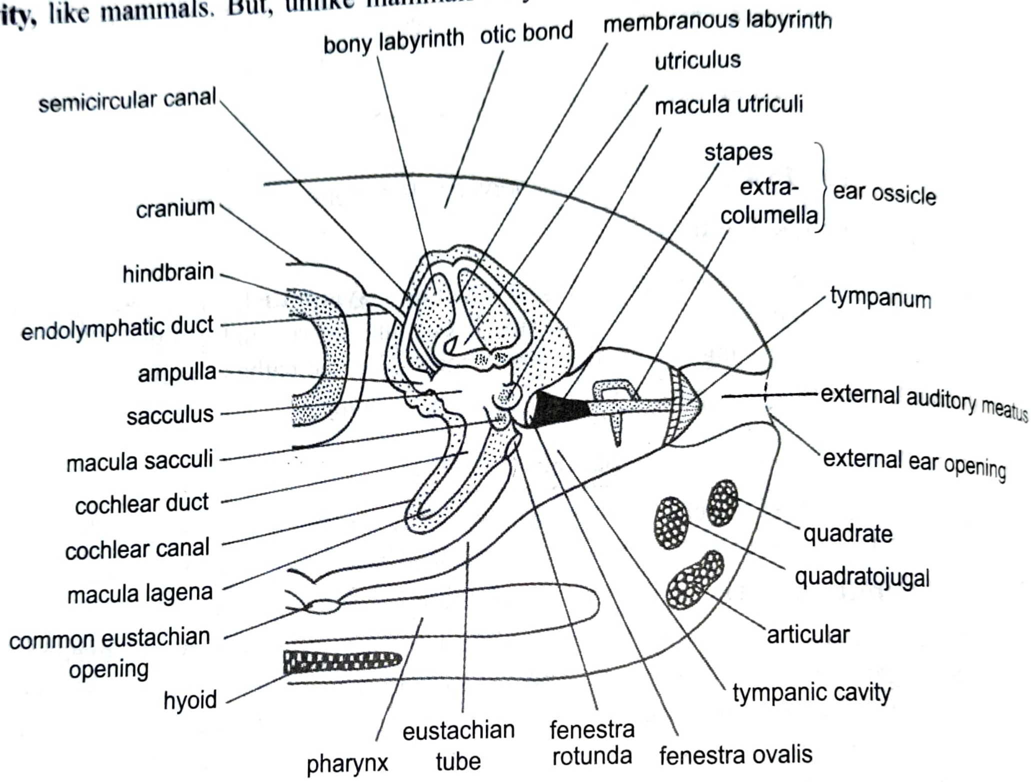

Fig. 26.41. Pigeon. T.S. head through internal ear.

Internal ear. The **internal ear** or **membranous labyrinth** lies embedded in a dense ivory-like bone in the side wall of the skull and is surrounded with a **perilymph** fluid. Membranous labyrinth is filled with a dense fluid, called **endolymph**. It contains a high concentration of potassium as in mammals, maintained by the activity of a tegmentum vasculosum, which also absorbs sodium. It consists of three **semicircular canals** (one horizontal, one anterio-vertical and one posterio-vertical), relatively small **sacculus** and **utriculus** and a short blind tube, the **cochlear duct** or **lagena**. Lagena is larger than in reptiles and less developed than in mammals. The proximal limbs of anterior and posterior semicircular canals unite to form a **crus commune**. The sacculo-utricular connection is narrow. From the sacculus arises an endolymphatic duct which ends in the duramater.

The cochlear duct, with its surrounding bony labyrinth or **cochlear canal**, is called **cochlea**. The cochlear duct is a slightly curved tube, surrounded by a perilymphatic space within a bony tube. In a transverse section, the cochlea shows three chambers : an upper **scala vestibuli**, a middle **scala media** and a lower **scala tympani**. The scala media is the actual cochlear duct and contains endolymph, while other two scalae are filled with perilymph. At the apex of the cochlea (scala media) the scala vestibuli and scala tympani are continuous, this junction is known as the **helicotrema**, near it the scala media ends blindly. At the inner end of cochlea, scala vestibuli is continuous with fenestra ovalis, while the scala tympani with the fenestra rotunda. The floor of scala media is formed by the **basilar membrane** and the roof by the **Reissner's membrane**. The basilar membrane consists of tall auditory hair cells (40), together constituting an **organ of Corti**. The organ of Corti is sensitive to sounds of higher frequencies. The free ends of the auditory cells bear hairs, which are embedded in a **tectorial membrane**, lying above the organ of Corti. From the basal ends of the cells arise nerve fibres which unite to form the **cochlear branch** of the auditory nerve. The cochlear duct at its apical end has another set of auditory hair cells, their hairs embedded in a gelatinous **cupola terminalis** having minute calcareous **otoliths**. At the tip of the cochlear duct is the **lagena**. Groups of auditory cells are called **cristae** and **maculae**. Those present in the ampullae of three semicircular canals are called **cristae ampullares** which possess the sense of direction and equilibrium. One macula is present in utriculus and one in sacculus. One macula is present in the lagena (tip of cochlear duct). Macula lagena is separated from the other maculae by a long cochlear duct. It perceives low frequency sounds.

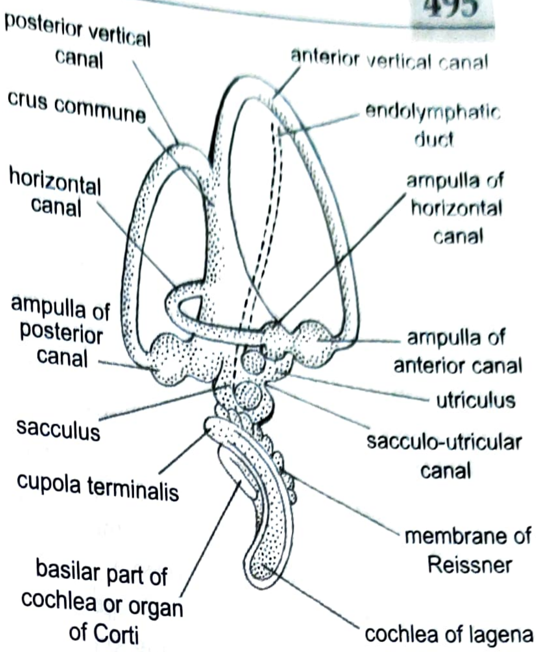

Fig. 26.42. Pigeon. Internal ear (membranous labyrinth).

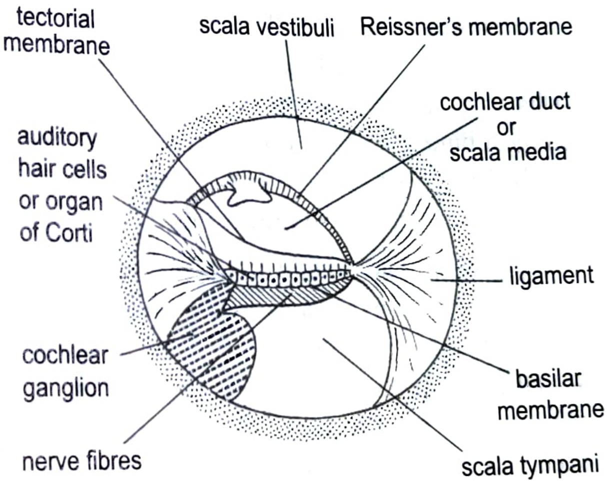

Fig. 26.43. Pigeon. Cochlea in T.S.

Middle ear. A circular **external ear opening** lies on each side of the head, behind the eyes concealed beneath **auricular feathers.** It leads into a short canal, the **external auditory meatus**, at the base of which lies a thin, transparent, vibrating septum, called **tympanum** or **ear-drum**. The ear-drum is followed by the cavity of **middle ear** or **tympanic cavity**. From the tympanic cavity arises a **eustachian tube** which unites with its fellow to open by a common aperture in the pharynx. The eustachian tube serves to equalise the air pressure on both sides of the tympanum.

Across the tympanic cavity lies a single rod-like bone, the **columella auris**, which transmits sound waves from tympanum across the tympanic cavity to the **fenestra ovalis** of the inner ear. The outer end of columella auris has three rayed cartilaginous processes called **extra columella** connected to the inner surface of tympanic membrane, and its inner disc-like bony part, the **stapes**, is wholly occluded the fenestra ovalis. Columella auris (stapes) is derived from the hyoid arch. Sound is transmitted from the tympanum by the columella auris (stapes). Extra columella reduce the amplitude and increase the force of vibrations. There is single middle ear muscle attached to columella and tympanum and innervated by facial nerve. Acoustic vibrations are transmitted to an oval window and so around cochlea to a round window, as in mammals.

The equilibratory and auditory parts of ear of pigeon are well developed. Ability to localise sound in birds is high. Owls and other birds probably find their prey largely by ears. For the purpose of direction-finding they have developed very long cochleas and an asymmetrical arrangement of ear cavities (*Strix*) or asymmetrical external ears (*Asio*). Cave birds have the power of avoiding obstacles by echolocation, *Steatornis* (oil bird), *Collocalia* (swiftlet). These birds emit clicks.

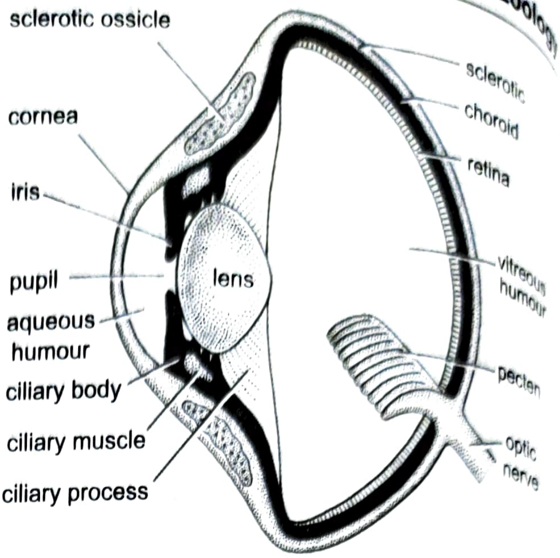

Fig. 26.44. Pigeon. Eye in sagittal section.

5. Visual organs or eyes. Birds depend more on their eyes than on the other senses. The eyes are extremely large. The eyes of hawks and owls are larger than in man. The eyes of pigeon are well developed and are very large in correlation with an aerial life for a precise vision over considerable distances.

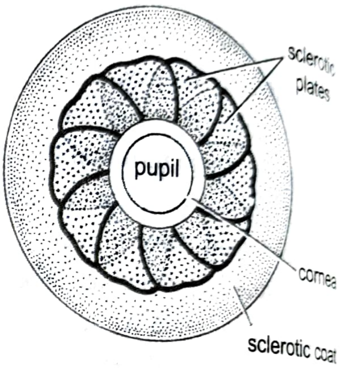

Fig. 26.45. Pigeon. Eye in outer view showing sclerotic plates.

Shape. The eyeball is not spherical, the lens and cornea bulge forwards in front of the posterior chamber. This form is maintained by a ring of bony sclerotic plates. In most birds the whole eye is thus broader than it is deep. Eyeball is longer in those birds whose sight is very acute and in some eagles and crows it is tubular.

Eyelids. The eyebrows or eyelashes are absent. There occur two inconspicuous eyelids, a slightly movable **upper eyelid** and a more movable and well developed **lower eyelid** which rises upwards to close the eye during the sleep. A semi-transparent **third eyelid** or **nictitating membrane** occurs as a fold at the anterior angle of the eye. It can be drawn posteriorly over eye with great rapidity. It cleans the eyeball and also protects the eyes from wind and during flight and from water during swimming in aquatic birds. It also protects the eyes from glare of the sunlight during day in nocturnal birds.

Glands. The nictitating membrane is lubricated by the oily secretion of a **Harderian gland** occurring in the inner angle of the eye. The tear gland or **lacrymal glands** are also well developed and lie below the outer angle of lower eyelid. Their watery secretion nourishes the non-vascular cornea, and also keeps it clean.

The wall of hollow eyeball consists of three usual layers, namely, an outer **sclerotic**, a middle **choroid** and an inner **retina**.

Sclerotic. The external coat of the eyeball is sclerotic. In the posterior hidden part of the eye, it is opaque, white, dense and cartilaginous. In front in the exposed part of the eye, it bulges out to form a convex, transparent and horny **cornea** of connective tissue. The cornea is externally covered by a thin, transparent, sensitive and vascular epithelial membrane, the **conjunctiva**, which is formed by modified epidermis and is continuous with the mucous lining of the eyelids. Anteriorly, at the junction of cornea and sclerotic coat, the latter is strengthened by a ring of 10–12 small overlapping bony, **sclerotic plates** or **ossicles**.

Choroid. The sclerotic coat is followed by the middle layer, the **choroid**, which is thin, dark pigmented and highly vascular. The choroid closely lines the sclerotic, but it separates in front to form a circular, pigmented diaphragm, the **iris**, perforated by a rounded aperture, the **pupil**. The iris regulates the amount of the entering light. It contains intrinsic circular and radial smooth muscles, the circular muscles contract the pupil, while radial muscles dilate it. Along the peripheral margin of the iris, the choroid forms a ring-like **ciliary body** which is a thickened fold containing smooth ciliary muscles. From ciliary body arises striated **ciliary processes** or **suspensory ligaments** and attached to the lens. The ciliary muscles are divided into anterior **Crampton muscles** and posterior **Brucke muscles**. The Brucke muscles draws the lens forward into the anterior chamber so that since the shape of the eye is fixed by the sclerotic plates, the lens becomes more curved and, hence, accommodated for near vision. Contraction of the iris sphincter assists in this process. At the same time the Crampton muscles pull the cornea reducing its radius and further assist in accommodation.The circular and radial muscles of the iris and ciliary muscles are under the control of the autonomic nervous system receiving sympathetic and parasympathetic fibres.

Retina. The innermost coat of the eyeball is a thin, light sensitive nervous layer called **retina**. It is transparent, devoid of blood vessels, thick and consists of nerve fibres, nerve cells and minute **rods** and **cones**. Pigeon, being a diurnal bird, has largely more cones than rods. The high resolving power and high powers of discrimination and of movement detection depend on the great density of the cones, as many as 1 million per square millimetre in the fovea of a hawk. Nocturnal bird's retina is composed mainly or completely of rods.

Sensitive spots. The retina has two sensitive spots or **fovea**. The **central fovea**, which lies near the centre of retina as a slight depression, is more sensitive and used for lateral or **monocular vision**. The second fovea, the **temporal fovea**, lies more towards the outer side of the eye and is used for forward or **binocular vision.** The foveae have comparatively more cones and give more distinct vision. The cones of birds often contain carotenoid oil droplets, which are also found in frogs, turtles and marsupials. In diurnal birds, they are red, yellow, orange or colourless, but in nocturnal ones pale yellow or colourless. Colour droplets may produce narrow-band sensitivity channels for the mediation of colour discrimination. The lower part of retina contains yellow droplets and upper part (dorso-posterior) contains red droplets. These droplets serve as filters and increase the colour vision of birds up to great degree. The red may provide finer colour discrimination of objects in feeding.

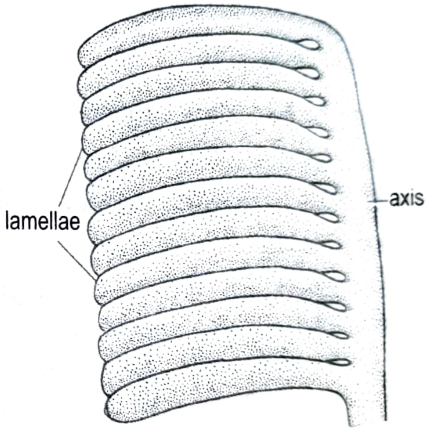

Fig. 26.46. Pigeon. Pecten.

Lens. The lens is biconvex, soft, pliable, crystalline, colourless, transparent and is surrounded by a fibrous capsule. It remains suspended just behind the iris by suspensory ligaments. It divides the eye cavity into a small anterior **aqueous chamber** and a large posterior **vitreous chamber**. The aqueous chamber is filled with a colourless watery fluid, the **aqueous humour**, while vitreous chamber contains a thick colourless, gelatinous **vitreous humour**. The two humours keep the eyeball tight or tense and also serve to focus the light rays on the retina.

Pecten. Pecten (Fig. 26.46) is a pleated, strongly pigmented vascular fold projecting into the cavity of the eye from the entrance of the optic nerve. It is large and much pleated in predatory birds, which detect minute movements at great distances, and is small and smooth in nocturnal birds. It is also well developed in diurnal birds (pigeon). Except kiwi, all birds have pecten.

Functions of pecten. There are many speculations about the function of pecten but none is known definitely. Probably its main function is to bring oxygen and nourishment to the retina which in birds has no capillary circulation. It helps in accommodation, it is not likely that it actually assists in focussing, for instance, by pressing forward the lens, and no changes have been seen in it during accommodation. However, it might possibly assist by adjusting the intraocular pressure, which must be increased by the extensive changes in the lens during accommodation.

Vision. In pigeon, because the cornea projects outwards and the posterior part is expanded, so the eye is broader than deep. Due to expansion of retina over the broad posterior portion, the distant objects are sharply focussed on it. Further, though the eyes are lateral in position, there is an overlapping of the two visual fields to some extent. This is called **binocular vision.** It is worth noting that there occurs little movement in pigeons' eyes due to ill-development of extrinsic eyeball muscles and that is compensated by flexibility of neck which turns the neck very quickly.

ENDOCRINE GLANDS

are chom... ...ction of pupil. Parasympathetic fibres ... constriction o...

SENSE ORGANS

The **sense organs** or **receptor organs** of rabbit are essentially similar with that of the frog except in some details. The sense organs detect the changes in the external and internal environments. The changes in the environment are known as **stimuli**. The various sense organs of rabbit are :

1. Organs of touch — Cutaneous (Skin) receptor.
2. Organs of taste — Gustatoreceptors (Tongue)
3. Organs of smell — Olfactoreceptors (Olfactory sacs or nasal chamber)
4. Organs of sight — Photoreceptors (Eyes)
5. Organs of hearing and equilibrium — Statoacoustic receptors (Ears)

1. Organs of Touch (Skin)

The skin of mammals is highly sensitive which is provided with several types of receptors. These receptors are microscopic and are of various types situated beneath the epidermis. Each receptor is concerned with a particular stimulus.

1. **Free nerve endings.** Sense of touch, cold, warmth, pressure and pain, etc., are perceived by free nerve endings. The fine branching fibres of sensory nerves lie just beneath the epidermis of skin. These fibres also extend into the epidermis.

2. **Basket nerve endings.** These are concerned with sense of touch. A fine network of branching sensory nerve fibres are found around the hair follicle. Sense of touch is perceived by touching the hair.

3. **Encapsulated nerve endings.** These are in the form of capsules, *e.g.,* Meissner's and Pacinian capsules. **Meissner's capsules** are found just beneath the epidermis. There are formed of a naked axon surrounded by a sheath of connective tissue capsule. These are sensitive to touch. **Pacinian capsules** are found in dermis and several internal organs. Each capsule is formed of a core of single axon ending in an ovoid bulb, which is surrounded by a sheath of connective tissue. These detect pressure.

4. **Neuromuscular bundles or spindles.** These are found inside the body, *i.e.,* in skeletal muscles, tendons and joints. These are called **kinaesthetic** receptors and apprise the central nervous system about the degree of muscle tension. It is formed of nerve ending in bulb or end organ, called the **neuromuscular bundle** or **neuromuscular spindle**.

The tactile organs are characteristically known as **corpuscles**. These corpuscles are ovoid bodies supplied with nerve-endings. Each corpuscle is formed of a sheath of connective tissue arranged in concentric rings around the **core of a nerve fibre**. The corpuscles are **tangoreceptors**, **frigidoreceptors**, **caloreceptors** and **algesireceptors**, *i.e.*, sensitive to touch, cold, warmth or heat and pain respectively. However, the pain receptors (algesireceptors) are without special corpuscles and only in the form of fine nerve fibres. These corpuscles are also responsible for sensitiveness to humidity and pressure, etc.

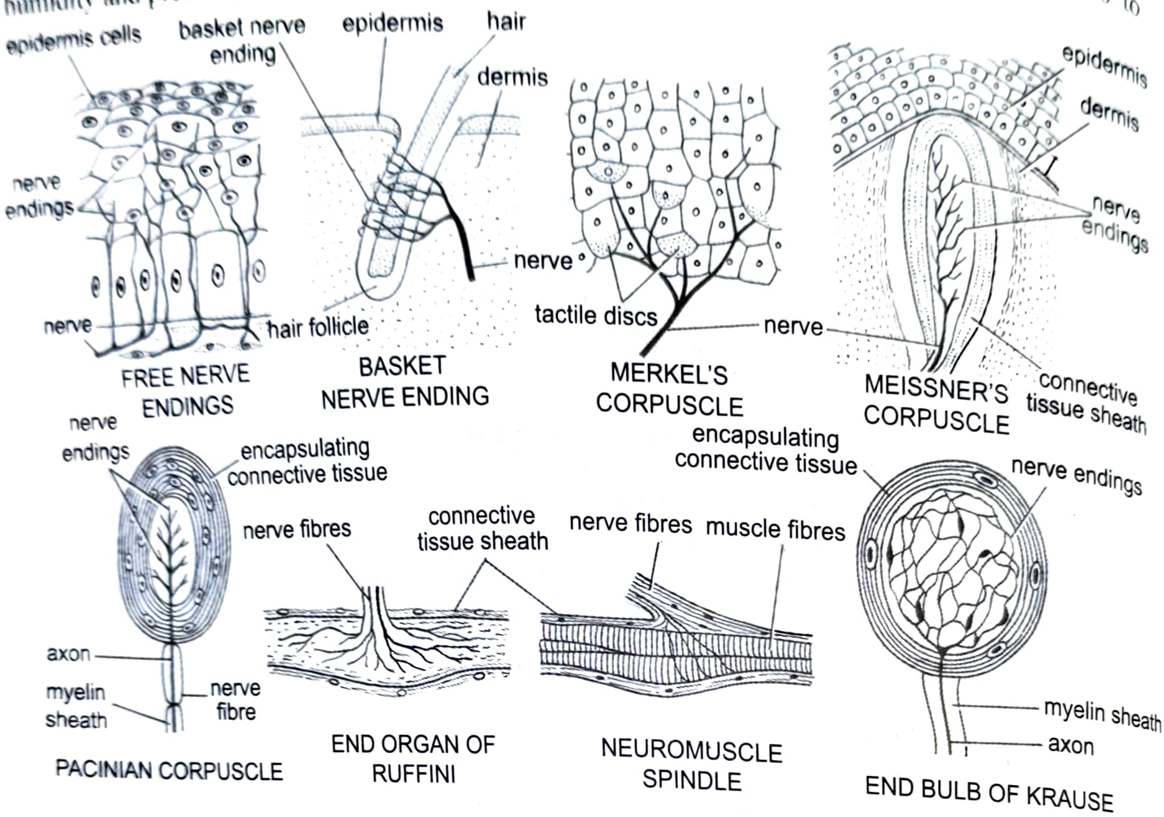

Fig. 29.57. Rabbit. Various types of cutaneous receptors.

2. Organs of Taste (Gustatoreceptors)

These are the **taste-buds** found on the tongue papilla and on the soft palate (roof of the buccal cavity). The taste bud is barrel-shaped and made of two kinds of cells, the **neurosensory cells** (gustatory cells) and **supporting cells**. The gustatory cells are elongated, spindle-shaped and provided with sensory hairs projecting in a depression between tongue-papillae called **taste-pore**. The inner ends of neurosensory cells are supplied by the nerve fibres from VII and IX cranial nerves. These cells are stimulated by the substances dissolved in the mucous and saliva and the sensation of bitter, sweet, salty, sour, etc., finally reaches to the brain.

3. Organs of Smell (Olfactoreceptors)

The nasal passage is provided with scroll-like turbinal bones, known as **ethmoturbinals**, **maxilloturbinals** and **nasoturbinals** on the basis of their origin. These turbinals and roof of nasal chambers are covered over with **olfactory epithelium** or **Schneiderian epithelium**. The olfactory organs have spindle-shaped olfactory cells, mucous cells and columnar supporting cells. The olfactory cells externally bear several delicate olfactory hairs and their inner ends are connected with nerve fibres which enter the olfactory lobes of the brain. The mucous cells produce mucus which keeps back particles of dust and it also dissolvs **odoriferous** substances which are in gas form and stimulate the neurosensory cells or olfactory cells. The sense of smell is well developed in rabbits. The rabbit in embryonic condition bears **Jacobson's organ** in the roof of buccal cavity, in the form of a groove on the lower medial aspect of each nasal cavity. Its duct is separate from the nasal apparatus and opens into the mouth cavity. It is not found in adults.

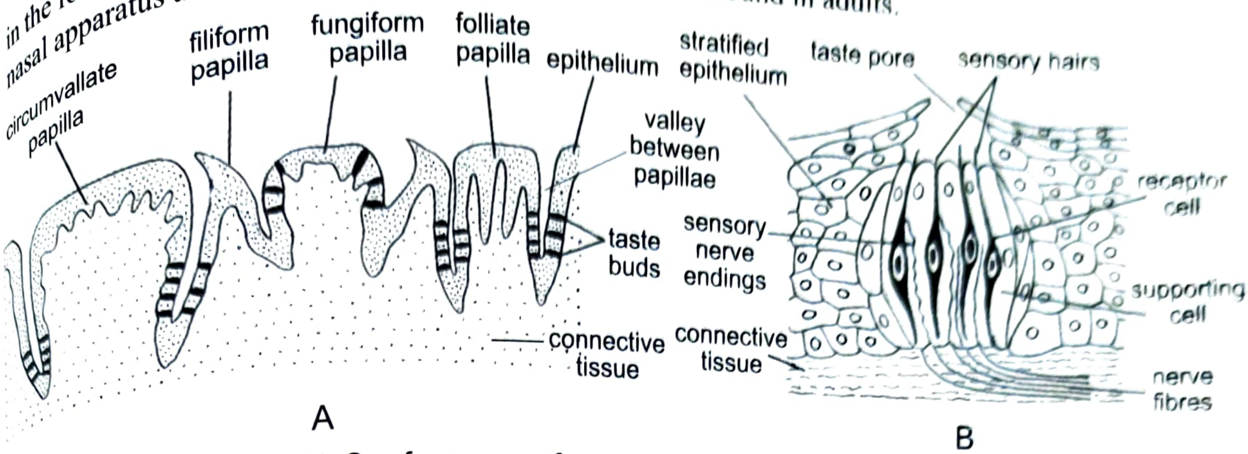

Fig. 29·58. Rabbit. A – V. S. of upper surface of tongue showing four types of papillae; B – A single taste bud in V.S.

The epithelium of ethmoturbinals actually constitutes the olfactory region which is sensory to smell. The epithelium of maxilloturbinal moistens and warms the air on its way to lungs and is not sensory. The epithelium of nasoturbinals has no olfactory cells.

Each nasal passage has an ovoid sensory pad having minute papillae and ridges. These pads are tactile and serve as distance receptors for testing air.

4. Organs of Sight or Eyes

The eyeballs are spherical photoreceptor organs, situated one on either side of the head in the **orbits**. The eyes of mammals are similar in their structures.

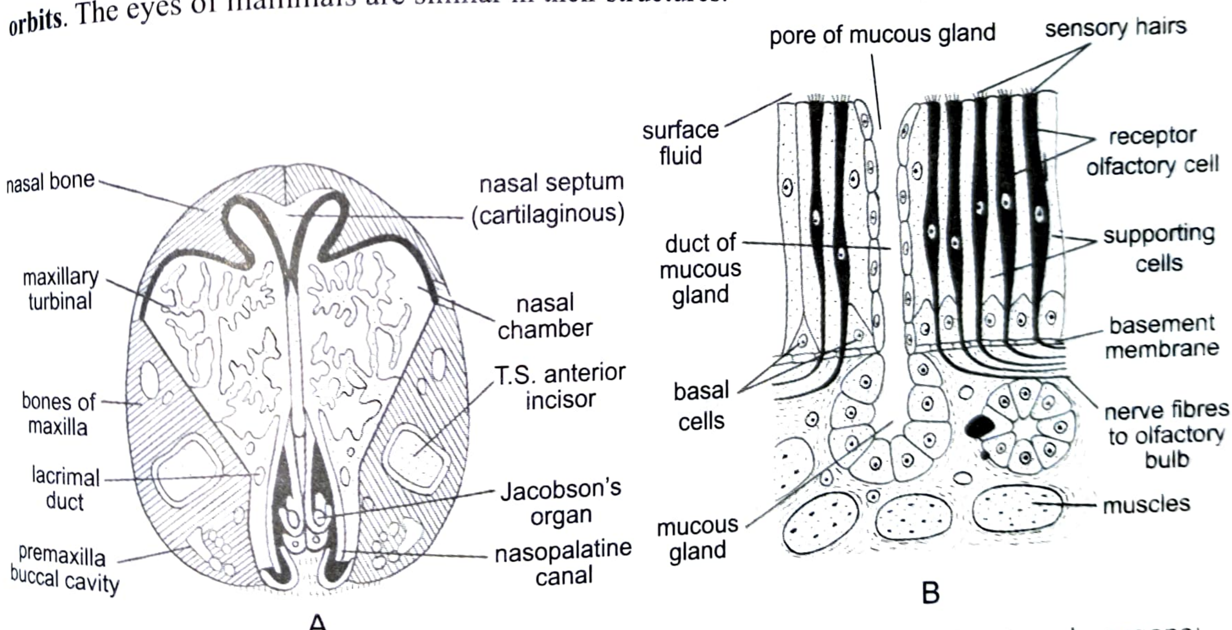

Fig. 29·59. Rabbit. A – Snout in V. S. through nasal chambers and Jacobson's organs; B – Olfactory epithelium with mucous glands in section.

External structure. The eyeball is spherical and hollow. Its about one-fifth part is visible externally and the remaining part remains hidden within the body orbit. Each eyeball is provided with six sets of muscles which move the eyeball in the orbit. Out of the six sets, four sets are **rectus muscles** and two sets are **oblique muscles**. These muscles are attached on one side with the eyeball and on the other side with the orbit. The exposed part of the eyeball is known as **cornea** which is well protected by two movable **eyelids** the upper and lower. Both the eyelids are provided with stiff hairs or **eyelashes** on their margins. These eyelashes protect the eyes from dust particles, rain water and sweat, etc. A transparent **nictitating membrane**, the third eyelid is present in inner corner of the eye and can cover the whole cornea in rabbit. Its function is to clean and protect the eye from dust particles. In human beings it is rudimentary in the form of pink mass.

Glands. There are three types of glands in each eye : Meibomian, Harderian and lacrimal.

Meibomian glands are sebaceous glands placed in both the eyelids beneath the conjunctiva and open on the free edges of eyelids. They secrete an oily secretion for lubricating the eyelids. The **Harderian glands** are situated at the inner side below the lower eyelids and open in connection with nictitating membrane at the inner angle, whose secretion keeps the conjunctiva moist. The **lacrimal gland** has several openings on the conjunctival surface below the upper eyelid, towards the outer side of eye. These glands secrete a saline watery fluid, the **tears**, on the surface of the eye (conjunctiva). It keeps the eye moist, soft, clean and free from bacteria. The excess of tears accumulate towards the inner corner of eye and are drained by a **naso-lacrimal duct** into the nasal chamber. Harderian glands are absent in primates.

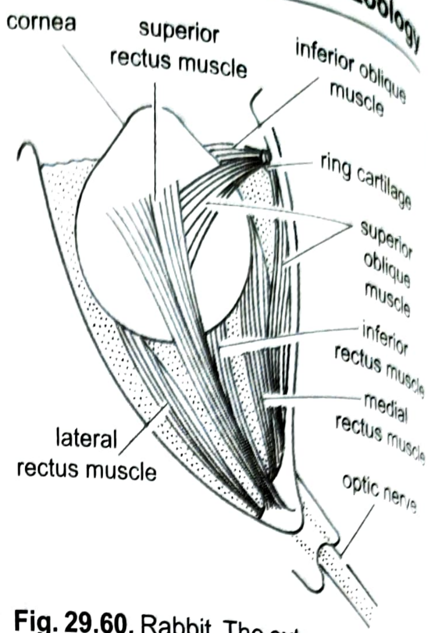

Fig. 29.60. Rabbit. The extraocular muscles of eye.

Internal structure. The internal structures of the eyeball can be well explained with the help of its vertical section as shown in the diagram. Its wall consists of three coats : an outer **sclerotic**, middle **choroid** and **inner retina**.

(*i*) **Sclerotic.** The sclerotic is a tough layer of thick, white and opaque dense fibrous connective tissue. The sclerotic layer maintains the form of the eyeball and covers the greater part of it. The front exposed part of sclerotic layer is transparent through which light enters, and bulged a little to form the **cornea**. The cornea is covered by a thin delicate, transparent, epithelial layer, the **conjunctiva**. The conjunctiva is continuous with the epidermis lining the eyelids. It contains blood capillaries and free nerve endings.

(*ii*) **Choroid.** The choroid is the middle layer formed of loose, pigmented and highly vascular connective tissue. This layer helps in darking the cavity of the eyeball to check the internal reflection of the light. Its blood capillaries provide nourishment to the retina. The choroid is found beneath the posterior part of sclera. In front at the junction

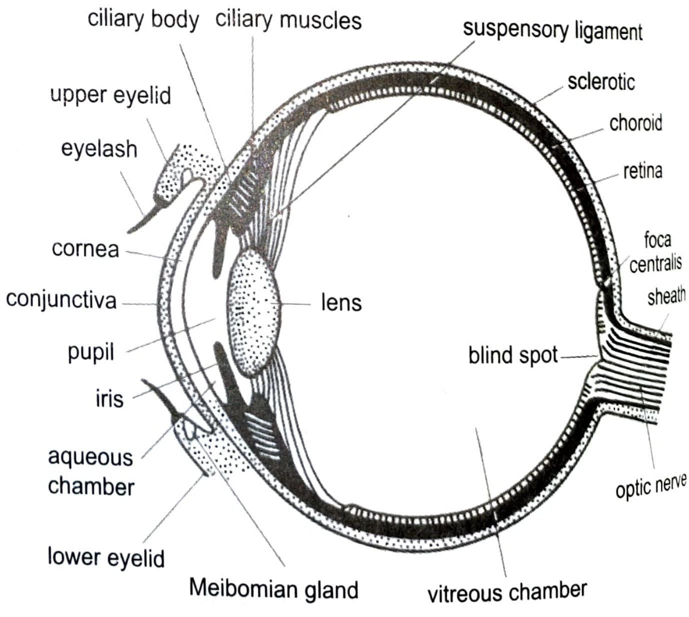

Fig. 29.61. Rabbit. Diagrammatic V.S. of eyeball.

of sclerotic and cornea the choroid swells and bends inwards into the cavity of the eyeball forming the **ciliary body** which is provided with **ciliary muscles** which project into vascular **ciliary processes** or **folds**. These secrete aqueous humour. In front of ciliary body, the choroid becomes separate from the cornea or at the corneal margin the choroid is continued as **iris**, which is separated by a space (**anterior chamber of eye**) from the cornea. In this region its pigmentation gives the characteristic colour to the eye. It is perforated by a circular aperture, the **pupil**. In the iris are present two sets of smooth muscle fibres : radiating fibres for dilation and circular fibres for contraction of the pupil. Thus, the diameter of the pupil is controlled by the contraction and relaxation of the muscles of the iris.

Lens. Just behind the iris is a solid biconvex lens enclosed in a lens capsule. Lens is formed of concentrically arranged transparent fibres. Lens capsule is thin, transparent and elastic. Lens is supported by the **suspensory ligaments** attached with the ciliary bodies.

***(iii)* Retina.** The retina is the innermost transparent layer of the eyeball whose outer layer is pigmented and closely applied with the choroid and the inner nervous layer which is sensory layer. The nervous layer is provided with an outer layer of **rods** and **cones** which are photoreceptor cells. The outer pigmented layer is of simple cuboidal or columnar epithelium. The inner layer is also a simple cuboidal epithelium in the **pars iridica** (beneath the iris) and in the **pars ciliaris** (in the region of ciliary body). Retina beneath the iris is also pigmented. This part of retina is not light sensitive and relatively simple in structure. Only the posterior part of retina (**pars optica**) is light sensitive and highly complex, containing light-sensitive elements and nerve cells and fibres. Light-sensitive elements are rods and cones. Their inner ends connect with small bipolar nerve cells which in turn connect with large nerve cells **(ganglion cells)**. From the ganglion cells arise fibres, all of which converge on a small circular area, towards nasal side of the posterior pole of eyeball, called **optic disc**, and here they pierce the coats of eyeball to become optic nerve.

The **rods** are more sensitive to low intensity of light and contain a pigment **rhodopsin**. They are suitable for dark (night vision). The **cones** are sensitive to high intensity light and more suited for day vision. They produce a sharp image. Cones are also sensitive to light of relatively narrow frequency bands. Thus, they are associated with recognition of colours, which is only found in primates.

Rods are more towards the periphery, while cones are more concentrated towards the centre. The site where all the nerve fibres converge and unite to form the optic nerve and then leave the eye is called the **blind spot**. It is without any photoreceptor cells and, therefore, does not produce any impression. Just above the blind spot in the retina in line with the optical axis is a slight, oval, depression called **yellow spot** or **area centralis**. **Moghe** (1957), however, has described that yellow spot is not found in the eyes of rabbit. The oval depression in the area centralis, called **fovea**, is the region for most distinct vision. Here rods are absent and only cones are present.

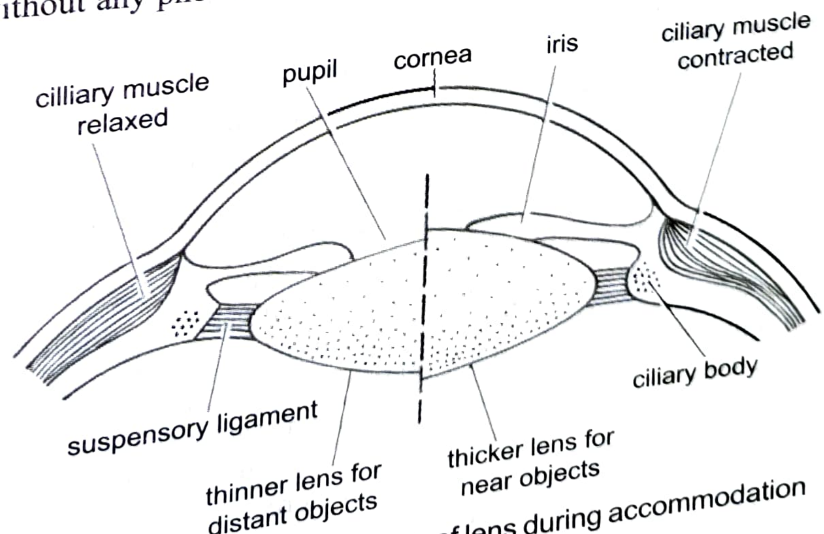

Fig. 29.62. Changes in curvature of lens during accommodation in mammalian eye.

Chambers. The cavity of the eyeball is divided into an anterior and a posterior chamber by the iris, lens and suspensory ligaments. The anterior chamber between lens and cornea is the small **aqueous chamber** filled with a watery fluid, the **aqueous humour**. The posterior chamber lies between lens and retina is large, called **vitreous chamber**. The vitreous chamber is filled with a gelatinous fluid, the **vitreous humour**. The aqueous humour is secreted by the ciliary body and carried through **canal of Schlemm** at the base of cornea. It nourishes cornea and lens and maintains intraocular pressure. The disease **glaucoma** is resulted due to imbalance of intraocular pressure. It damages the retina.

Working of the Eye

Image formation. The cornea, aqueous humour, lens and vitreous body together constitute the dioptric apparatus, which focuses an image of external objects on the retina. The iris is a diaphragm by which amount of light which enters can be regulated. The eye works exactly like that of a photographic camera. The light rays reflected from an object are refracted by the cornea and the rays are then focussed by the lens on retina, so that a sharp, inverted image is formed. The inverted retinal image is interpreted by the brain and the real sensation of sight arises and the animal sees the object in an upright way. However, the inverted retinal image is never reinverted by the brain.

The type of vision which is found in higher mammals is called **binocular (stereoscopic) vision**. In such a vision the fields of vision of the two eyes overlap or even coincide each other and, hence, two images of the same object are not seen. Thus, both the eyes can see a single object in three dimensions, and the animal can estimate the distance also. This type of vision in which distance is also estimated is called **binocular vision**.

But in the lower mammals like rabbit, both the eyes have divergent axes of vision because the fields of vision do not overlap each other. Therefore, the rabbit can see all around by its two eyes, each eye covers a different field of vision. Such type of vision is called **monocular vision**.

Accommodation or focussing. The power of **accommodation** is well exhibited by the eyes of rabbit for the objects situated at various distances. In other words, it can be said that the power of accommodation is an adaptation of seeing the objects situated at various distances. The accommodation is brought about by changing the convexity of the lens because the distance between lens and retina is fixed and unchangeable. Thus, change in convexity of lens is essential for the formation of distinct images on the retina.

In **normal condition** when the eyes are at rest, the lens is kept flattened by the suspensory ligaments and, thus, it is adjusted for seeing distant objects. It is due to relaxed condition of the circular muscles of ciliary body. The diameter of the ciliary body is also much increased due to outward pressure of the fluid of eyeball. It, thus, increases the tension of the suspensory ligament, which pulls the lens capsule making the lens thinner or flattened.

When objects from near is to be viewed, then the ciliary muscles contract, thus, reducing the diameter of the ciliary body. Suspensory ligaments also become relaxed due to lessening of tension over them. Thus, the lens becomes thicker and more convex. The cornea also arches outwards. Thus, the focal length of the lens is reduced and a clear image of the near object is formed on the retina.

Chemistry of vision. The rods in rabbit (mammal) contain **rhodopsin (visual purple)**. In light it breaks up into **retinene** and **opsin** (a protein). This photochemical reaction releases energy that stimulates neurons causing them to send an impulse to the brain through optic nerve. The image formed on retina is inverted but the animal sees the object upright. Later the retinene and opsin rejoin with the help of ATP to form the retinene. Maximum amount of rhodopsin is present is rods in dim light. In bright light, the level of rhodopsin in rods is reduced not immediately but after a short while. This is the reason that a person when comes out from the dark into the day light, becomes dazzled and when he enters from day light into a dark room, he becomes like a blind for a while. This is all due to amount of rhodopsin increase and decrease in rods.

The cones contain iodopsin pigment which is stimulated only during bright light. In dim light one cannot see the colours, they are only distinguishable in bright light.

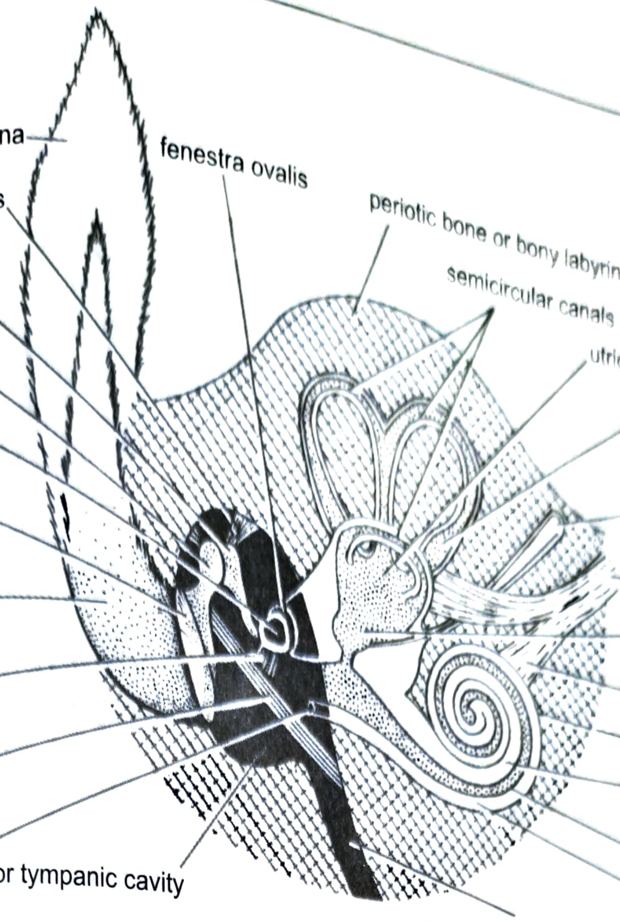

Fig. 29.63. Rabbit. Diagrammatic V.S. of head passing through ear region.

5. Organs of Hearing or Ears

The ears are **stato-acoustic** organs of rabbit, performing the function of **hearing** and **equilibrium** or the ears are sensitive to the frequencies of sound waves and to changes in relation to gravity.

The mammalian ear has three parts, an **external**, a **middle** and an **internal**. The internal ear transforms these sound vibrations into nerve impulses which are communicated to the brain through VIII cranial nerve.

1. External ear. Generally in all mammals a large **external ear** or **pinna** or **auricle** is found which is movable in most animals. It is a skin covered elastic cartilaginous projection from the lateral sides of head. The pinna is a wide-mouthed funnel usually capable of being moved or turned in different directions by its muscles. The opening of the funnel-shaped pinna leads into a tubular passage, called the **external auditory meatus**. It ends into a cone-shaped membrane, called the **tympanum** or **ear drum**. The walls of auditory meatus are covered by skin containing hairs, oil glands and wax glands. The hairs, oil and wax protect the ear drum from the harm caused due to dust and small insects. The odour of the wax inhibits the insects to enter the canal. The function of the external ear is to collect the sound vibrations and to detect the direction of **sound vibrations** and send them to middle ear.

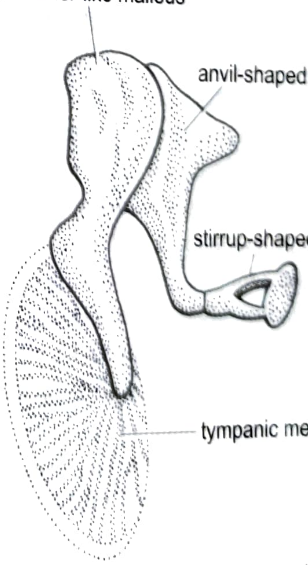

Fig. 29.64. Rabbit. Ear ossicles.

2. Middle ear. The middle ear is the tympanic cavity which starts from the **tympanic membrane** or **ear drum**. It is an air-filled cavity enclosed in the tympanic bone. The ear drum is exposed to the impact of sound vibrations caused due to the sound in air. The tympanic cavity is connected with the pharynx by a tubular passage, the **Eustachian canal** (named after Bartolommeo Eustachio) for equalising the air pressure on both the sides of the ear drum. The tympanic cavity is closed internally by a wall which has two windows, opening into the internal ear. These are the upper oval **fenestra ovalis** and the lower rounded **fenestra rotunda**. The mammalian middle ear is characterised by the presence of a chain of three tiny bones, the **ear-ossicles**, extending from the tympanic membrane to the fenestra ovalis. These ear-ossicles from outside are hammer-shaped **malleus**, anvil-shaped **incus** and stirrup-shaped **stapes**. These bones represent the articular, quadrate and hyomandibular bones of other vertebrates. The ear-ossicles take up the sound vibrations from the tympanic membrane and convey them to the internal ear.

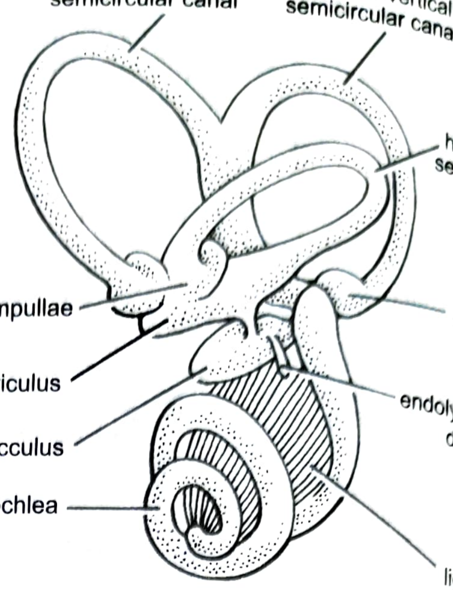

Fig. 29.65. Rabbit. Left membranous labyrinth in outer view.

3. Internal ear. The internal ear is a well-developed and complicated structure, called the **membranous labyrinth**. It is enclosed in a bony **auditory capsule** of the same shape as the membranous labyrinth, formed by the **periotic bone**. The space between the bony capsule and the membranous labyrinth is filled with a liquid, called **perilymph**. A similar fluid is found within the membranous labyrinth, called the **endolymph** having tiny calcareous particles, the **otoliths**. The membranous labyrinth is formed of a larger dorsal **utriculus** and a smaller ventral **sacculus** forming the body proper, and semicircular canals and cochlea.

(*i*) **Utriculus and sacculus.** The utriculus and sacculus are connected together by a small duct, called **sacculo-utricular canal**. A small, narrow endolymphatic duct arises from the sacculus which ends blindly against the cranium into an endolymphatic sac. From the sacculus arises a spirally coiled tube called **cochlear duct** or **lagena**, which is well developed in rabbit and other mammals. Both the utriculus and sacculus have a special group of sensory cells called the **macula**. These cells bear five projecting hairs which are embedded in jelly containing otoliths. Macula of utriculus and salcculus are called **macula utriculi** and **macula sacculi** respectively. The bony labyrinth around the utriculus and sacculus is called the **vestibule**.

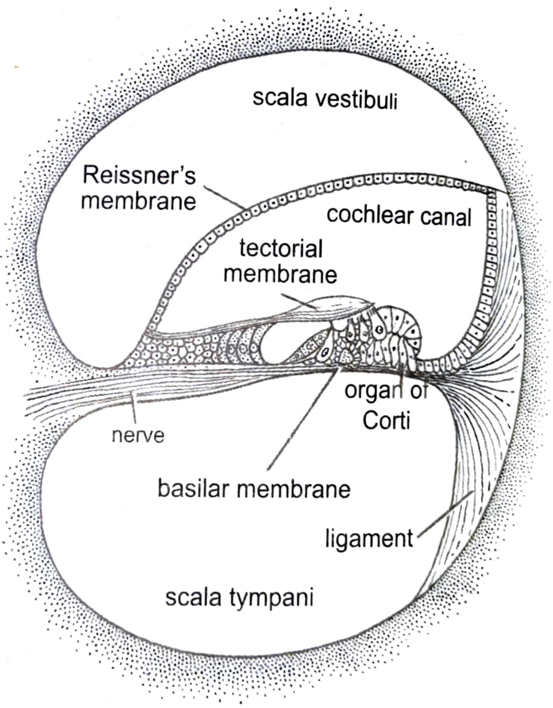

Fig. 29.66. Rabbit. T.S of cochlea.

Semicircular canals. Three semicircular canals connect at both the ends with utriculus. These are **external**, **anterior** and **posterior** semicircular canals, situated at right angles to each other. The anterior and posterior semicircular canals arise from a common canal, after their origin from utriculus are called **crus commune**. Each semicircular canal has a swollen **ampulla** at its lower end.

Each ampulla has a sensory area known **crista ampullaris** which is formed by sensory **hair cells** and **supporting cells**. The hairs are embedded in a jelly cone having no otoliths.

The VIII cranial or auditory nerve supporting to ear divides into two branches, **vestibular branch** supplying to the semicircular canals, utriculus and sacculus and a **cochlear branch** supplying to the cochlea.

(*iii*) **Cochlea.** The spirally coiled watch spring-like **cochlear duct** or **lagena** arising from sacculus is enclosed within the similarly spirally coiled cochlear canal of the periotic bone, which together constitute the **cochlea**. It is the organ of hearing. Thus, the cochlea is a bony tube lined with connective tissue. In cross section the cochlea shows three chambers or canals : Middle chamber or **scala media** is the cochlear duct arising from the sacculus and is filled with endolymph. It terminates blindly at the apex of spiral or cochlea. The upper and lower canals of the cochlea are **scala vestibuli** and **scala tympani** respectively. These are parts of bony labyrinth or cochlear canal and are filled with perilymph. Both the canals are longitudinally separated from each other by a **spiral lamina** but communicate with each other at the tip of spiral by a small opening, called the **helicotrema**. The scala vestibuli and scala tympani communicate basally with the fenestra ovalis and fenestra rotunda respectively.

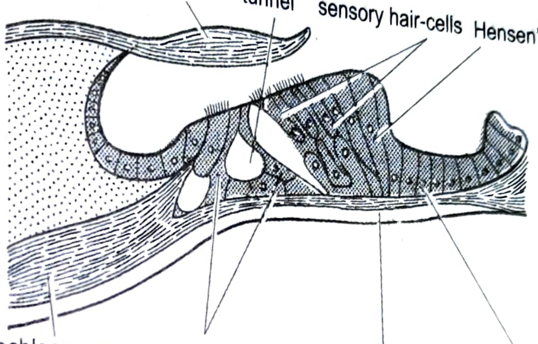

Fig. 29.67. Rabbit. Organ of Corti.

The epithelial wall of the scala media rests above on the **Reissner's membrane** and below on the **basilar membrane**. Basillar membrane is formed of tightly stretched transverse connective tissue fibres. It contains a series of sensory receptor **hair cells** and long columnar supporting cells. Hair cells are basally connected with the nerve fibres of cochlear nerve of auditory nerve. Over the hair cells touching the hairs is found a thin, gelatinous, ribbon-shaped sheet of connective tissue, called the **tectorial membrane**. Both of these are collectively called the **organ of Corti**.

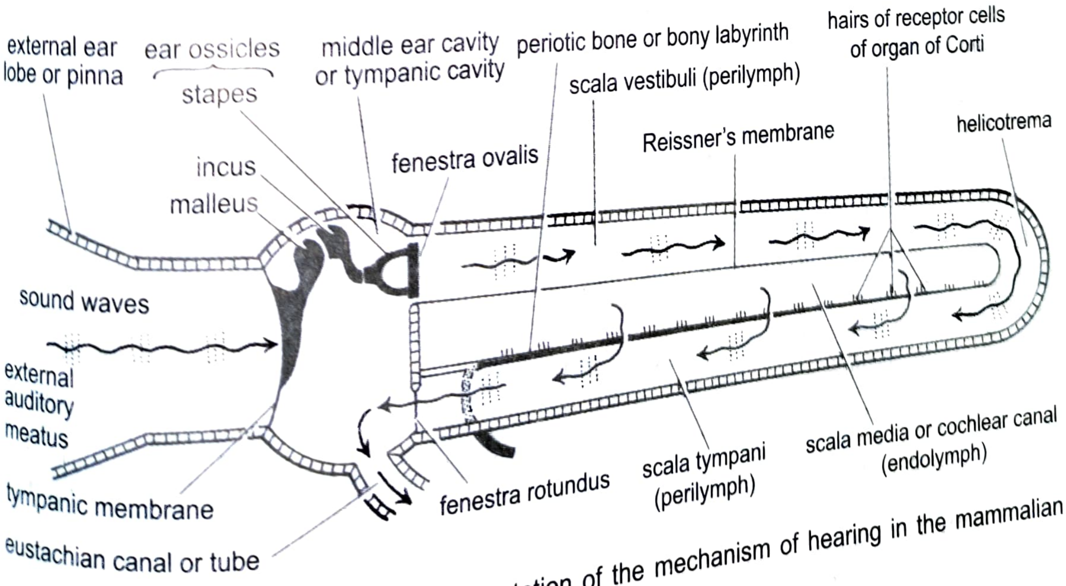

Fig. 29.68. Rabbit. Diagrammatic representation of the mechanism of hearing in the mammalian ear. Arrows indicate pathway and vibrations.

Working of ear. Ear performs two functions : hearing and equilibrium. The cochlear duct of sacculus of the membranous labyrinth is responsible for **hearing**, while maculi of sacculus, utriculus and cristae of semicircular canals help in **equilibrium**.

(*i*) **Hearing.** The sound waves are collected by the movable pinna which travel through the external auditory meatus and cause the ear drum to vibrate. The vibrations are then transmitted through the ear-ossicles of the middle ear and fenestra ovalis into the perilymph of internal ear. The vibrations of the membrane of fenestra ovalis cause alternate increase and decrease in the pressure of the perilymph of scala vestibuli which is transmitted to the scala tympani through helicotrema and escape through the fenestra rotunda back into the middle ear. The membrane of fenestra rotunda due to the pressure bulges out into the middle ear. Thus, it acts as a **pressure-relief valve**.

The vibrations of the perilymph of scala tympani and scala vestibuli cause endolymph of the scala media and basilar membrane to vibrate. These vibrations cause the tectorial membrane floating in the endolymph of scala media to brush the sensory hairs of organ of Corti. Finally the stimulated hair cells of the organ of Corti sends a message through nerve impulses which are carried by the VIII cranial nerve to the brain. Such impulses are interpreted as sound by the brain.

Equilibrium. The sensory patches of the ampulla of semicircular canals called **cristae** and utriculus and sacculus are called **maculae** are responsible for maintaining equilibrium of the body. Any change in the equilibrium (orientation) of the body stimulates the hair cells of the cristae and maculae due to movement in endolymph and otoliths in them. Maculae respond to the change in the posture of head and body. While the cristae respond to the changes in the direction or rotational movements of head. Cristae lack otoliths.

URINOGENITAL SYSTEM