

## Comparative Account of Brain in Vertebrates

The brain is an organ that serves as the Centre of Nervous System in all Vertebrate animals. It is located in the head, usually close to the sensory organs for senses such as vision.

All vertebrate brains share a common underlying form which appears most clearly during early stages of development. In its earliest form the brain appears as three swellings at the front end of the neural tube; these swellings eventually become the forebrain, midbrain and hindbrain (prosencephalon, mesencephalon and rhombencephalon resp). In the initial stages of brain development, the three areas are roughly equal in size. In many classes of vertebrates, such as Fish and Amphibians, the three parts remain similar in size in the adult, but in Mammals the forebrain becomes much larger than the other parts, and the midbrain becomes very small.

### Functions of Brain

1. **Olfactory lobes:** Sense of smell.
2. **Cerebral hemispheres:** Seat of intelligence and memory.
3. **Diencephalon:** Controls the general metabolic functions of the body.
4. **Optic lobes:** Sense of vision.
5. **Cerebellum:** Co-ordinates the movements of voluntary muscles.
6. **Medulla oblongata:** Controls the involuntary functions of the body.

Brain of all vertebrates, from Fish to Man, is built in series in different vertebrates in accordance with the habits and behavior of the animals.

### Cyclostomes:

The brain exhibits the typical pattern that is found throughout the Vertebrate series. Some of the structures that are well developed in the higher forms occur in a relatively primitive condition. The brain is divisible into three primary parts viz; Forebrain, Midbrain and Hindbrain. The forebrain includes large paired olfactory lobes. The Cerebral hemispheres are small attached to the diencephalon. The midbrain possesses a pair of large optic lobes rather dorsally placed. The hind brain is differentiated into a small transverse dorsal band, the Cerebellum and much larger ventral Medulla Oblongata. The ventricles within the brain are four as in other vertebrates. In fundibulum bears a hypophysis and pituitary body.

ce—Cerebellum. Ol.b.---Olfactory bulb. di---Diencephalon. Op.l---Optic lobe. Ol.l----Olfactory lobe.

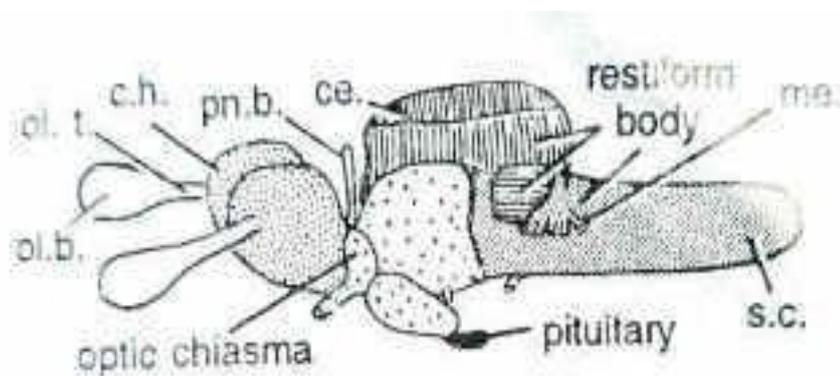


## Fishes

Brain of Fishes is more advanced than Cyclostomes. However, subdivisions of brain are seen in their primitive relations.

### Elasmobranchs (Cartilaginous Fishes)

In Cartilaginous Fishes, the olfactory organs are enormous so that olfactory lobes of brain are correspondingly large, attached to Cerebrum by short but stout olfactory tracts. Optic lobes and pallium are relatively moderate in size. Midbrain cavity is quite large and extends into optic lobes. Pineal apparatus is well developed. Features of Hindbrain are less pronounced. Cerebellum is especially large due to active swimming habit.

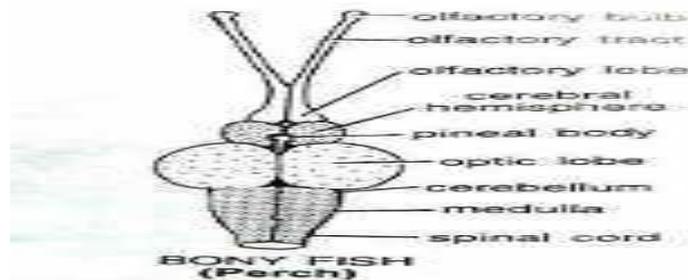


c.h.---Cerebral hemisphere. pn.b.---Pineal body.c.e.---  
Cerebellum.ol.t.-Olfactory tract. ol.b.---Olfactory bulb. s.c.---  
Spinal cord. me---Medulla

### Osteichthyes (Bony Fishes)

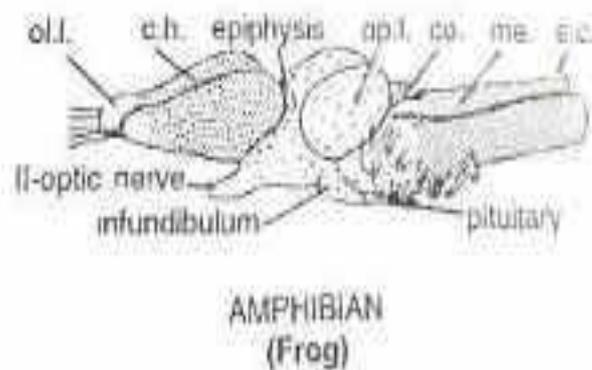
In bony Fishes brain is more specialized than in Elasmobranchs. Olfactory lobes, Cerebral hemispheres and Diencephalon are smaller while optic lobes

and cerebellum larger than in a shark. The anterior part of the Cerebellum forms valvula cerebella which extend under the optic lobes; it is characteristic of bony Fishes and controls active movements. The medulla oblongata is well developed with special lobes for entry of lateral line nerves.



## Amphibians

The brain of Amphibians is remarkably unspecialized and is scarcely more advanced than that of cartilaginous fishes and lung fishes. The cerebral hemispheres are more separate from one another than in fishes, so they share little common ventricle. Smaller olfactory lobes and larger optic lobes indicate a greater reliance on sight rather than smell. **Corpus striatum** (floor of cerebrum) receives greater number of sensory fibres projected forward from thalamus than in fishes. The walls of midbrain are thickened and reduce the lumen into a narrow passage called **aqueduct**. Medulla is small and cerebellum is poorly developed. A small pineal body is present in all the modern Amphibians.



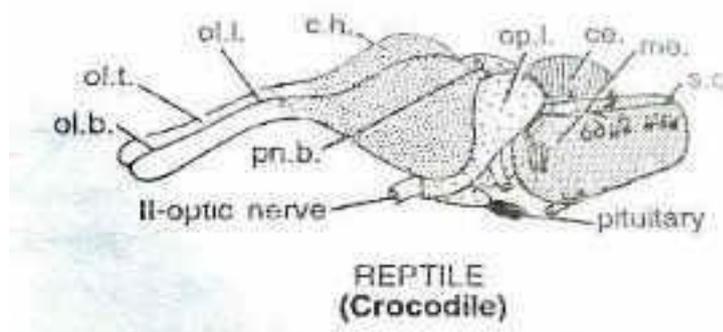
Ol.l---Olfactory lobe. C.h.----Cerebral hemisphere. Op.l. Optic lobe.

Ce.---Cerebellum. me.---Medulla. s.c.---Spinal cord.

## Reptilians

Reptilian brain shows advancement in size and proportions over that of Amphibians because of complete terrestrial mode of life. The brain is a

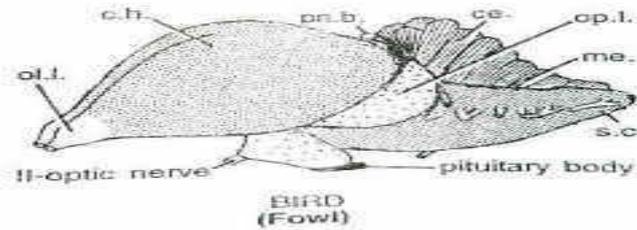
narrow elongate, and nearly straight. Olfactory bulbs tend to be smaller than for fishes. Olfactory tracts are long. A fine **vomer nasal nerve** from the organ of **Jacobson** goes to the olfactory bulbs. A pair of auditory lobes is found posterior to optic lobes which are not hollow. The Cerebrum is large because of the expansion of the **corpus striatum** and associated neocortex. Cerebellum is somewhat pear shaped and larger than in Amphibians.



ol.l.---Olfactory lobe. c.h.---Cerebral hemisphere. op.l.---  
Optic lobe ol.t.---Olfactory tract. ol.b.----Olfactory bulb.  
pn.b.---Pineal body

## Birds

Avian brain is proportionately larger than that of a Reptile, and is short and broad. Olfactory lobes are small due to poor sense of smell. Two cerebral hemispheres are larger, smooth and project posteriorly over the diencephalon to meet the cerebellum. The enlargement of cerebral hemispheres is due to very large and complex **corpora striata** which are characteristic of birds. The cerebral hemispheres are responsible for an intelligent behavior in birds, and they control the reflex behavior governing the lives of birds. The dorsal thalamus is even more developed than in Reptiles. Optic nerves, chiasma and tracts are large. Optic lobes are particularly large and are layered within. They have connections from all sense organs and with the cerebrum. Squeezed between the cerebrum and cerebellum, the optic lobes have uniquely lateral position. The Cerebellum is larger than in other vertebrates except some mammals. It is highly convoluted, and the organ is high and narrow. Related to the marked development of the cerebellum are the appearance of the **pons** under the brainstem and enlargement of the **olivary nuclei** within the broad medulla.



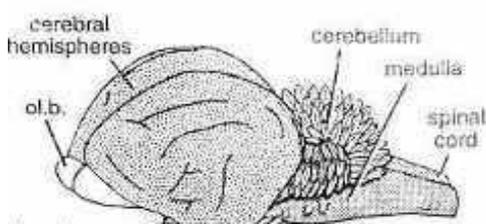
Ol.l. ---Olfactory lobe. c.h.---Cerebral hemisphere. pn.b.---Pineal body.

Me.---Medulla. s.c.---Spinal cord. Op.l. ---Optic lobe.

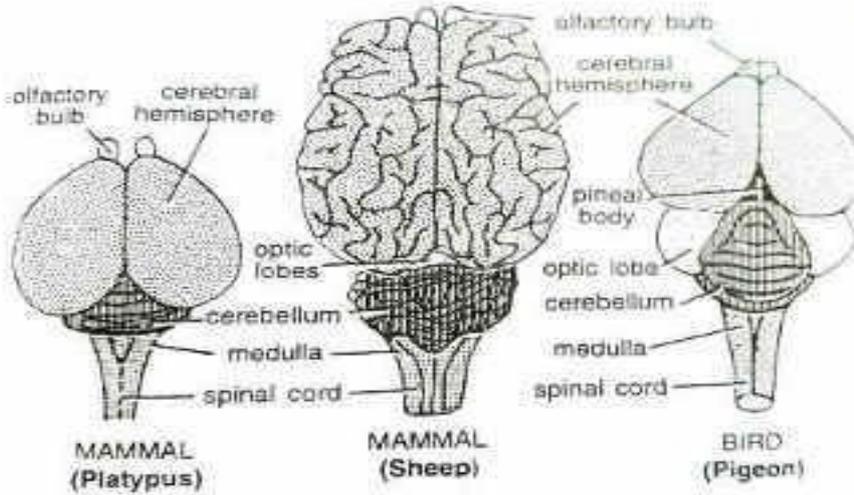
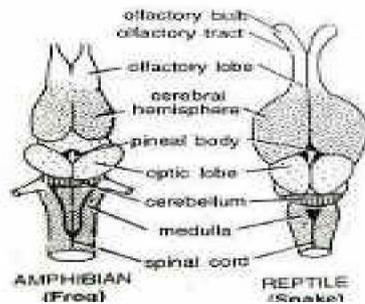
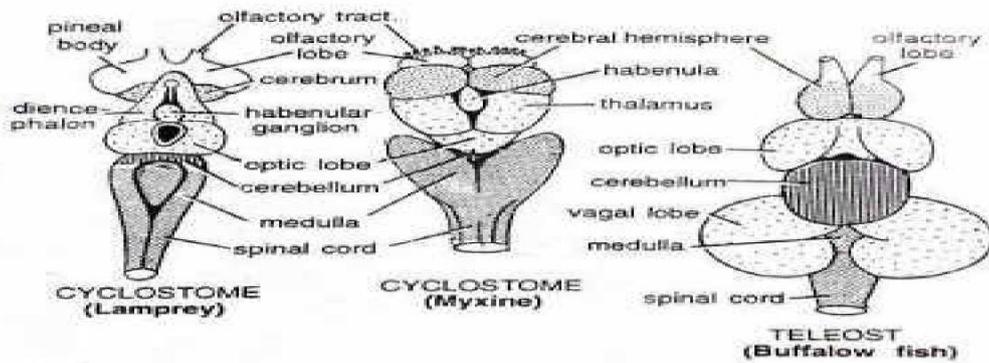
## Mammals

The brain reaches its highest development in mammals with better integration and mastery over the environment, the cerebral hemispheres reaching the status of a dominant integrating part of the brain and acting as coordinating centers of the brain. The cerebral hemispheres are smaller and smooth in

**Prototheria** and larger in **Metatheria** and become greatly enlarged and divided into lobes in **Eutheria**. In mammals such as man and sheep, surface of cerebral hemispheres is immensely convoluted with a number of elevations separated by furrows. This folding increases the surface area or gray matter containing nerve cells, resulting in greater intelligence without adding to the size of the brain. Olfactory lobes are relatively small but clearly defined and covered by the hemispheres. Diencephalon and midbrain are also completely covered by the cerebral hemispheres. Characteristic of mammals are 4 solid optic lobes, called **corpora quadrigemina**, on the roof of the midbrain. The third ventricle or **iter** of midbrain is a laterally compressed vertical passage, called cerebral aqueduct. Cerebellum is also large, conspicuously folded and may overlie both midbrain and medulla. Usual folds are a median vermis, two lateral flocculi and their mushroom-like projections, the paraflocculi. The other chief topographical features of mammalian hindbrain include the pyramids carrying voluntary motor impulses from higher centers, the pons varoli with crossing fibres connecting opposite sides of cerebrum and cerebellum, and the trapezoid body of transverse fibres relaying impulses for sound. The medulla oblongata lies ventrally and is much thickened. It has centers which control respiration, heart beat and blood vessels; it also has conduction pathways for impulses passing from the cerebral hemispheres to the spinal cord and again in the opposite direction. The hindbrain contains centers for the regulation of digestion, respiration and circulation.



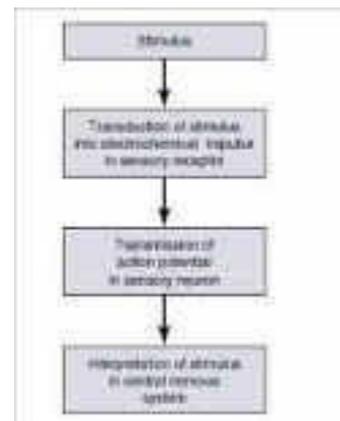
**Diagrammatic Representation of Comparative Account of Brain in Vertebrates**



## Receptor Organs in Vertebrates

Organisms are subjected to many influences from their surroundings constituting the environment. All changes in the environment, both external and internal, are known as stimuli. Organs of the body that detect these changes or stimuli are called receptors or sense organ. They receive information from the environment in the form of energy (mechanical, chemical, electrical, thermal or radiant ) and change it into nerve impulses which are transmitted to the brain or spinal cord via afferent or sensory nerve fibers to which they are connected. Thus, sense organs have dual functions: (1) they detect environmental changes or stimuli and then (2) transmit this information in the form of nerve impulses to the central nervous system. In turn, the central nervous system (CNS) integrates the incoming information and sends out messages via efferent or motor nerve fibers to effector organs which respond in appropriate manner.

**The path of sensory information.** Sensory stimuli must be transduced into electrochemical nerve impulses that are conducted to the brain for interpretation.



## Classification of Receptors or Sense Organs

Sense organs are classified in many ways.

- **General Receptors.** Various minute sense organs are distributed widely upon or within the body especially the skin. These cutaneous sense organs are collectively termed general receptors, for their exact functions are not clear and any one of them cannot be related to a single sensation alone.
- **Special Receptors:** On the other hand, the tongue, nose, eyes and ears are termed special receptors. They are concentrated in small areas particularly on the cephalic end of the body. They respond to particular types of stimuli or special senses and their functions are better understood.

- **Receptors according to stimuli:** In a broad sense, we can recognize the following types on the basis of the stimulus to which they are sensitive.

**(a)Mechanoreceptors:** These are stimulated by touch and pressure (skin), vibrations or sound and balance (ears).

**(b)Chemoreceptors:** These are sensitive to smell, that is chemical substances or odors in air (nose), and o taste, that is substances in solution (tongue).

**(c) Photoreceptors:** These are sensitive to light waves or sight (eyes).

**(d) Thermoreceptors:** Sensitive to heat and cold (skin).

**(e)Nerve endings:** Sensitive to pain (skin).

- **Receptors according to location:** Receptors may also be classified according to the location of stimulus.

**(a)Exteroceptors.** These receive environmental stimuli from outside the organism and supply information about the surface of the body (touch, pressure, taste, heat, etc.).These include eyes, ears, nose, taste buds and cutaneous sense organs. The exteroceptors inform the organism about food mate or enemy.

**(b) Proprioceptors:** These are stretch receptors present in the muscles, joints, tendons, connective and skeletal tissues. They supply information about the so-called kinesthetic sense of equilibrium and orientation. They act like pressure gauges and are responsible for the maintenance of body posture.

**(c)Interoceptors:** These lie in various internal organs. They provide information about the internal body environment, such as CO<sub>2</sub> concentration, blood composition, pain, fullness, etc. They are responsible for maintaining an appropriate internal body environment necessary for the continued survival of the organism.

- 5. Somatic and visceral receptors.** Exteroceptors and proprioceptors are also called somatic receptors. Similarly, ineroceptors are called visceral receptors.

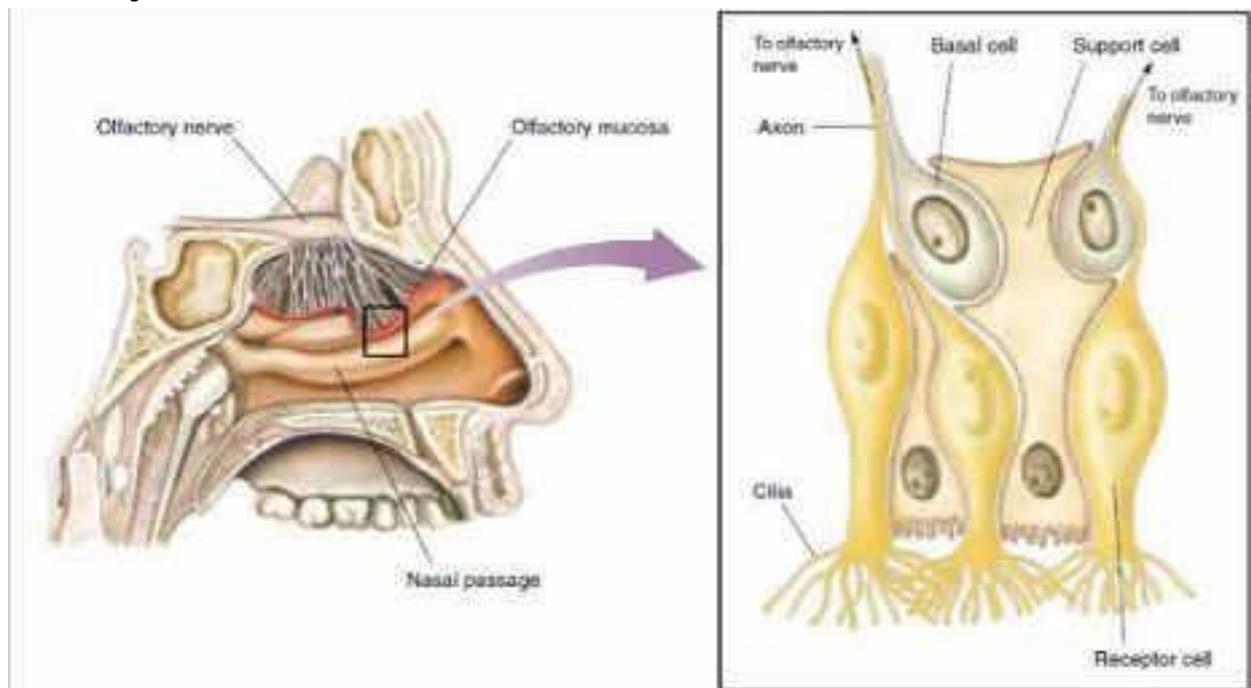
Some sense organs have a dual role. For example, sensory epithelium of nose and taste buds serves both as exteroceptor (somatic) as well as visceral receptor.

## Types of Receptors or Sense organs according to stimuli and location

Sense Organs or receptors	According to type of stimulus	According to location of stimulus	Stimuli	Functions
1. Skin (cutaneous)	Mechanoreceptors Thermoreceptors	Exteroceptors	Contact Temperature	Detecting touch, hot and cold, etc.
2. Muscles (kinesthetic)	Mechanoreceptors	Proprioceptor	Mechanical stretch	Feeling and gauging pressures.
3. Tongue (gustatory)	Chemoreceptor	Exteroceptors	Dissolved chemicals	Tasting
4. Nose (Olfactory)	Chemoreceptor	Exteroceptor	Volatile chemicals and gases in air.	Smelling
5. Eyes (visual)	Photoreceptors	Exteroceptors	Light	Seeing
6. Ears (auditory)	Statocoustic	Exteroceptors	Sound and gravity	Hearing and balancing
7. —	—	Interoceptors	Pain, fullness, CO <sub>2</sub> level, etc.	Maintaining internal body environment.

### Important differences among similar receptors in different classes of vertebrates Olfactory Organs in Vertebrates

Olfactory organs are special visceral chemoreceptors concerned with the sense of smell. These consist of a pair of cavities, the olfactory or nasal sacs, on the anterior end of head. Their external openings are called nares or nostrils. Cyclostomes have a single blind olfactory sac with a single extremal naris, but there are two olfactory nerves. In fishes, olfactory sacs are blind sacs except in all lobe-finned fishes and Dipnoi having internal nares. In all air breathing animals or tetrapods, each olfactory sac has an external as well as an internal nostril. Unlike other receptors, processes of olfactory cells lead directly to brain so that they are termed neuro-sensory cells.

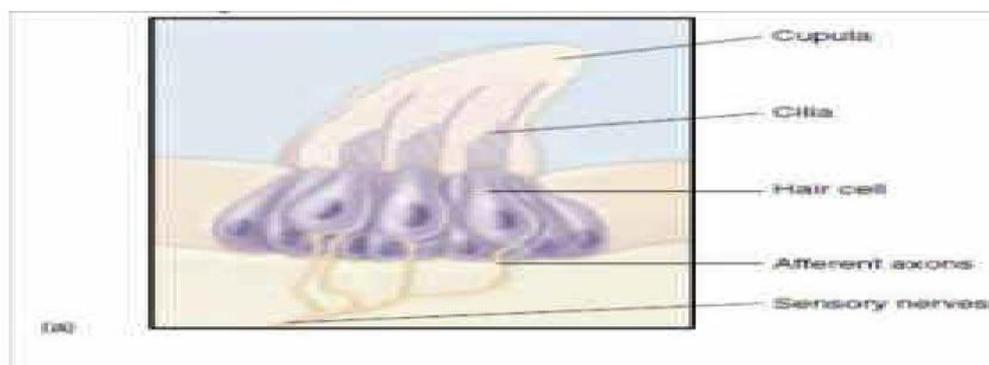
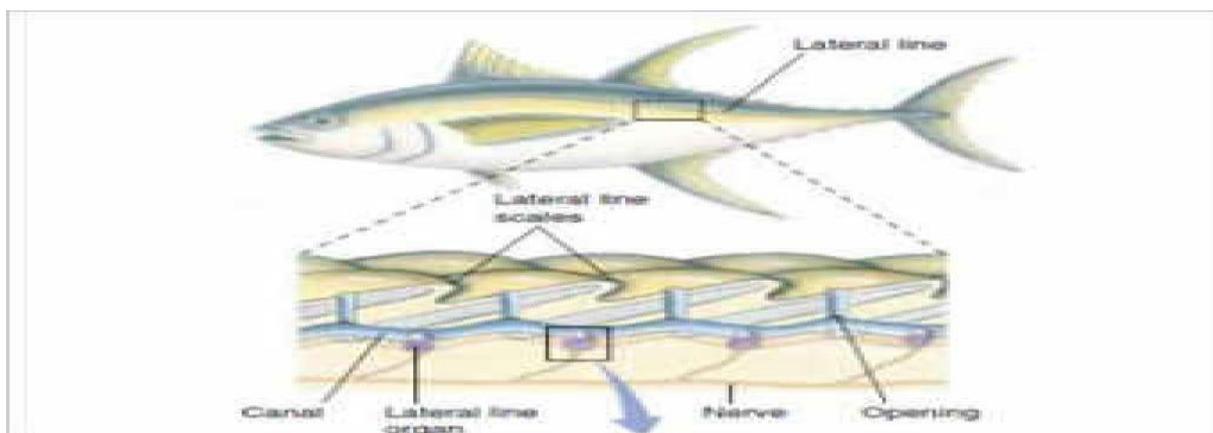


Humans detect smells by means of olfactory neurons located in the lining of the nasal passages. The axons of these neurons transmit impulses directly to the brain via the olfactory nerve. Basal cells regenerate new olfactory neurons to replace dead or damaged cells. Olfactory neurons typically live about one month.

Olfactory sense is well developed in fishes and mammals. But birds are practically devoid of it except in the kiwi. It has been experimentally demonstrated that salmon fishes with plugged nasal sacs are unable to find their home river tributaries in which to spawn. In most vertebrate groups, olfaction provides vital information to search food, predators, mates, and even the way home.

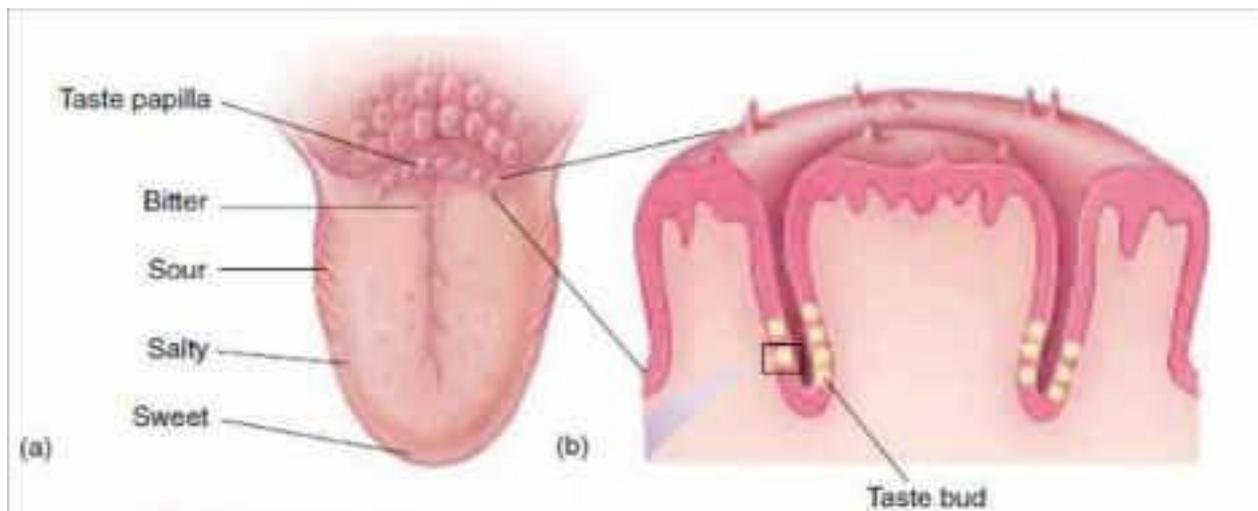
*Organs of Jacobson or vomeronasal organs* are independent chambers below nasal cavities, found in most tetrapods, although they are sometimes vestigial. They are absent in fishes but occur as embryonic rudiments in most vertebrates. In reptiles they are best developed in lizards, snakes and sphenodon, but are absent in other crocodiles.

*Neuromast or lateral line organs* are the sense organs concerned with life under water besides fishes they are found in cyclostomes and aquatic stages of amphibians. These are little groups of receptors supporting ectodermal cells found in lateral line canals these are supplied with nerve fibers and are called rheo receptors or current receptors. They can perceive vibrations of very low frequency and detect disturbances in water.



### **Gustatory Organs in Vertebrates**

Sense of taste or gustation is the perception of dissolved substances by small groups of receptive cells called taste buds. These occur in all vertebrates and are fairly uniform in structure. In lower vertebrates, such as fishes, taste buds occur in many parts of the mouth and pharynx, even on the skin of head. In catfish they are abundant on the whiskers. In bottom-feeders or scavengers, they are distributed over the entire body surface.



(A) Four kinds of taste buds in human beings (bitter, sour, salty, and sweet), located on different regions of the tongue.

(B) Groups of taste buds are typically organized in sensory projections called papillae.

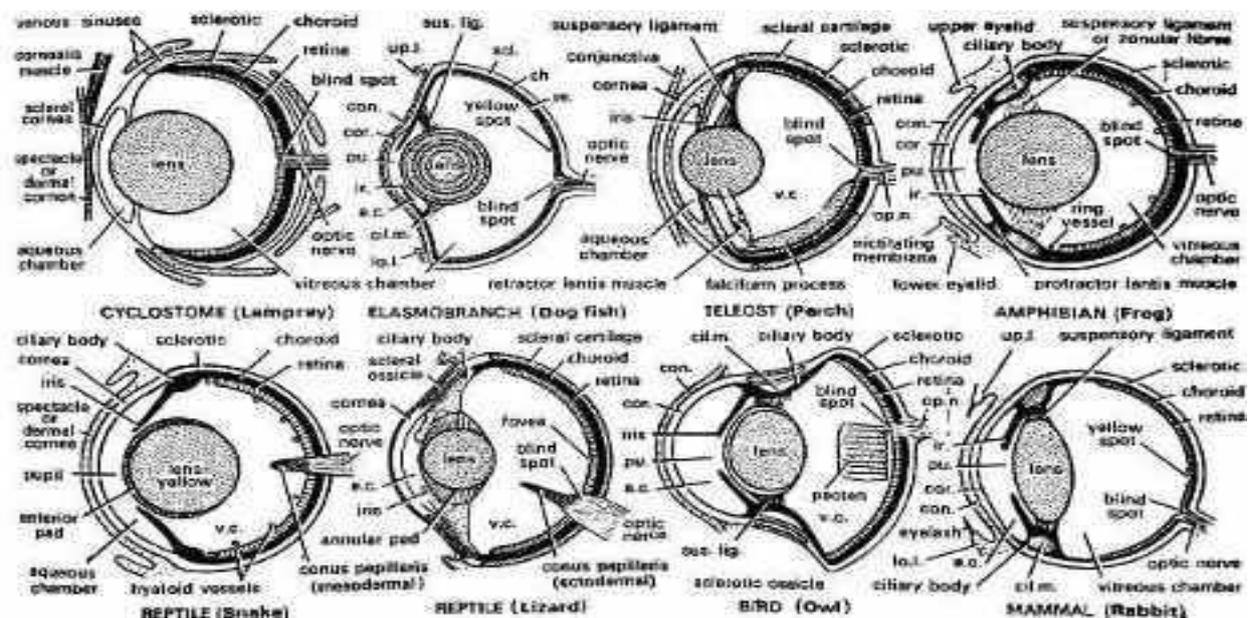
In tetrapods, the taste buds are restricted to the tongue, palate and pharynx. They are most abundant in mammals but least abundant in birds. Taste buds are supplied by V, VII, IX and X cranial nerves. In man, taste buds on tongue can distinguish 4 types of fundamental tastes: sweet, sour, bitter and salty. In some cases, the sensation of taste is in reality due to series of smell. For example, many spices have relatively little taste, but affect the sense of smell powerfully. During bad cold, when access to the olfactory organs in the nose becomes difficult, the food appears tasteless.

### **Photoreceptors or Eyes**

The sense of sight is due to stimulation eyes. Vertebrates have two types of eyes (1) Unpaired median and (2) paired lateral.

**1. Median eyes.** Median eyes were abundant in most ancient fishes, amphibians and reptiles. They are also found in some living vertebrates in

the form of pineal and parapineal organs formed as dorsal evaginations of the diencephalon of forebrain. They are light sensitive in lampreys (cyclostomes). They have a lens and sensory innervation but lack a retina and do not form an image. Pineal and parapineal bodies probably do not serve as light receptors above reptiles. The parapineal of reptiles, when present (Spillenodon), is covered by a translucent tissue. It serves as a third eye and often termed as parietal eye.



**Eyes of different vertebrates**

a.c.— anterior chamber, bl.sp.— blind spot, ch.— choroid, cil.b.— ciliary body, cil.m.— ciliary muscle, con.— conjunctiva, cor.— cornea, fo.c.— fovea centralis, ir.— iris, l.— lens, lo.l.— lower eyelid, nlm.— nictitating membrane, op.n.— optic nerve, p.c.— posterior chamber, pu.— pupil, m.— retina, scl.— sclerotic, sus.l.— suspensory ligament, up.l.— upper eyelid, v.c.— vitreous chamber.

**2. Lateral eyes.** The lateral eyes of all vertebrates are essentially similar.

They are of the "camera type" with a lens which focuses images of external objects on the sensitive retina serving as a photographic film. However, the eyes of lower vertebrates (fish and amphibians) which live in water differ from the eyes of higher vertebrates which live out of water.

Some important differences in the eyes of different groups of vertebrates are as follows

**(a)Eyelids and tear glands.** Water itself cleans and moistens the eye, so that fishes lack movable eyelids and tear glands.

**(b)Refractive index and cornea.** Refractive index of water is nearly the same as that of cornea. Thus the cornea of a fish's eye does not bend light

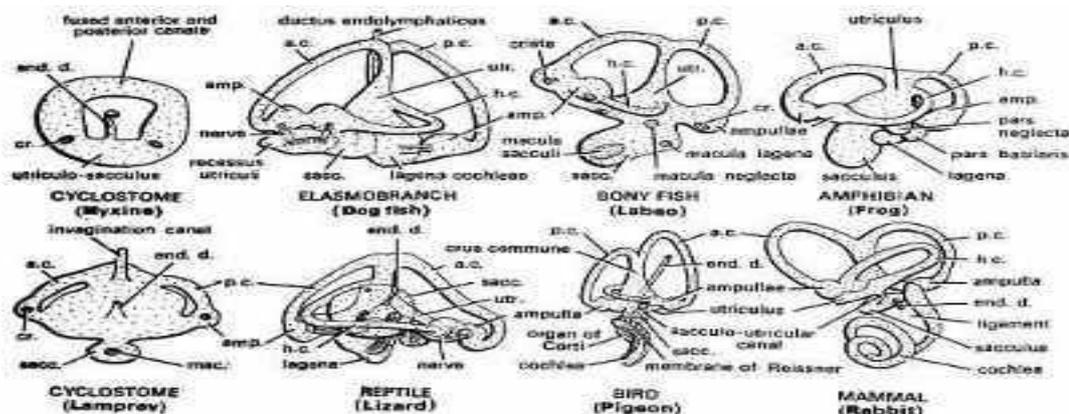
rays. Thus cornea remains flat in lower vertebrates but bulges out in higher vertebrates.

**(c) Shape of lens.** Most refraction is achieved through lens which is nearly spherical in shape with greater refractive power in fishes. On the other hand tetrapods have a flat or oval lens with less refractive power.

**(d) Method of accommodation.** It also differs in lower and higher vertebrates. Fishes, amphibians and snakes focus by moving the lens back and forth in camera fashion. On the other hand, mammals, birds and reptiles other than snakes have tough sclera and immovable lens. However, their lens has elastic properties so that the shape of the lens is changed so as to alter its magnifying power.

### Statoacoustic Organs or Ears

**In fishes:** In fishes, the two senses of hearing and equilibrium are associated with the ears. All the vertebrates possess a pair of inner ears or membranous labyrinths embedded within the otic capsules of the skull lateral to the hindbrain. Each membranous labyrinth consists of 3 semicircular canals (only 1 or 2 in cyclostomes), a utriculus and a sacculus. Sacculus in fishes forms a rudimentary diverticulum, the lagena, which is a forerunner of the cochlea of higher vertebrates, concerned with audition. Teleost fishes of the order Cypriniformes (catfishes, suckers, carps, etc.) utilize an air-filled swim bladder as a hydrophone. Sound waves in water create waves of similar frequency in the gas filled bladder. These are transmitted via a chain of small bones, the Weberian ossicles, to the sacculus. Weberian ossicles are modified transverse processes of the first 4 (occasionally 5) trunk vertebrae.



### Internal ears of different vertebrates

a.c.— anterior vertical semicircular canal. amp.— ampolla. cr.— crista. end.d.— endolymphatic doct. h.c.— horizontal canal. mac.— macula. p.c.— posterior vertical canal. sacc.— sacculus. utr.— utriculus.

**In tetrapods:** In tetrapods, a middle ear cavity is added containing an ear ossicle, the columella auris or stapes, for transmitting sound vibrations from external tympanic membrane to a fenestra ovalis in the otic capsule. An outer ear canal or external auditory meatus is also developed in amniotes. The lagena of fishes becomes a papilla called cochlea in amphibians. It gradually elongates in higher vertebrates into a cochlear duct containing the actual receptive structure, the organ of Corti.

The hearing apparatus of mammals is basically similar but much more elaborate. The cochlear duct is spirally coiled. In most mammals, an external flap, called auricle or pinna, collects and directs sound waves into the external auditory meatus. Instead of a single columella, the middle ear cavity in mammals is crossed by three ear ossicles: malleus, incus and stapes