any way

3.7. ■ Brain in Vertebrates

The general structure of brain and its specialization in different Classes of vertebrates has already been described in Articles - 2.3.12, 2.6.8, and 2.9.8. The present discussion deals with the evolution and comparative anatomy of different parts of brain in different vertebrates.

3.7.1. Embryological Development of a Vertebrate Brain

The vertebrate central nervous system is hollow, a result of the fusion of two raised neural folds within the ectoderm. In the brain, the central canal enlarges into fluid-filled **ventricles** that are connected spaces located within the centre of the brain. Within the anterior neural tube, three embryonic regions of the brain differentiate into the **prosencephalon, mesencephalon,** and **rhombencephalon**. These give rise to three regions of the adult brain: **forebrain, midbrain,** and **hindbrain**. The brain and spinal cord are wrapped in **meninges** (sing., *meninx*) derived in part from neural crest. In mammals, the meninges consist of three layers: the tough outermost **dura mater,** the web like **arachnoid** in the middle, and the innermost **pia mater**. The pia mater contains blood vessels that supply the underlying nervous tissue. **Cerebrospinal fluid (CSF)** is a slightly viscous fluid that flows slowly through the ventricles of the brain, the subarachnoid space beneath the arachnoid, and the central canal. The **choroid plexus,** small tufts of blood vessels associated with ependymal cells, projects into the ventricles at specific sites and is the primary source of cerebrospinal fluid. This fluid is reabsorbed into venous sinuses. Although cerebrospinal fluid is derived from the blood and returns to it, it is devoid of red blood cells or any other large formed elements. Cerebrospinal fluid forms a cushion of fluid around the brain and spinal cord to support the delicate nervous tissues and absorb shocks from concussions. The average human has about 150 ml of cerebrospinal fluid, less than a cup, that is replaced several times per day, flushing the central nervous system.

In fishes, the meninges consist of a single membrane, the **primitive meninx,** wrapped around the brain and spinal cord. With the adoption of terrestrial life, the

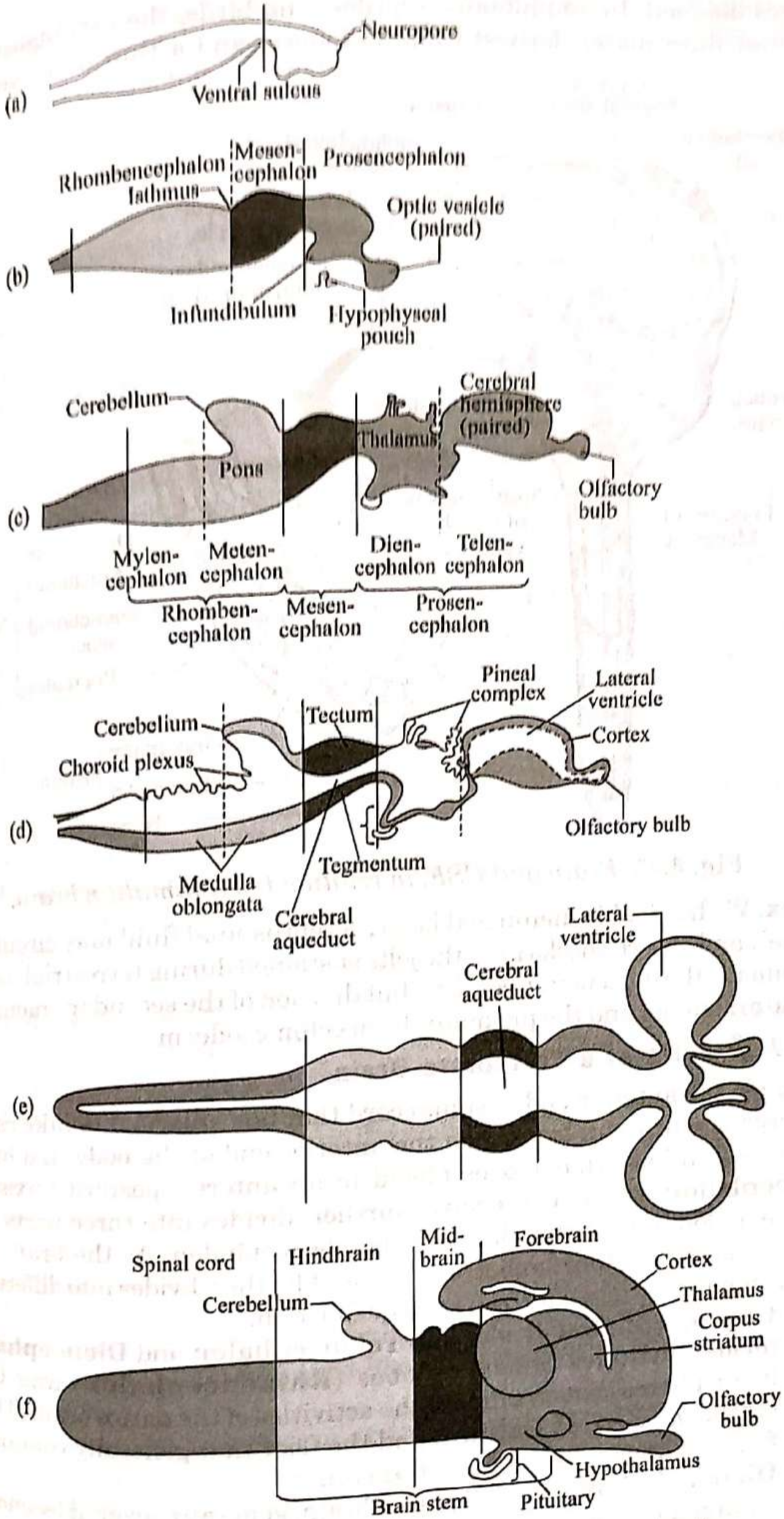


Fig. 3.44. *Development stages (a–f) of vertebrate brain.*

meninges doubled. In amphibians, reptiles, and birds, the meninges include a thick outer dura mater derived from mesoderm and a thin inner secondary

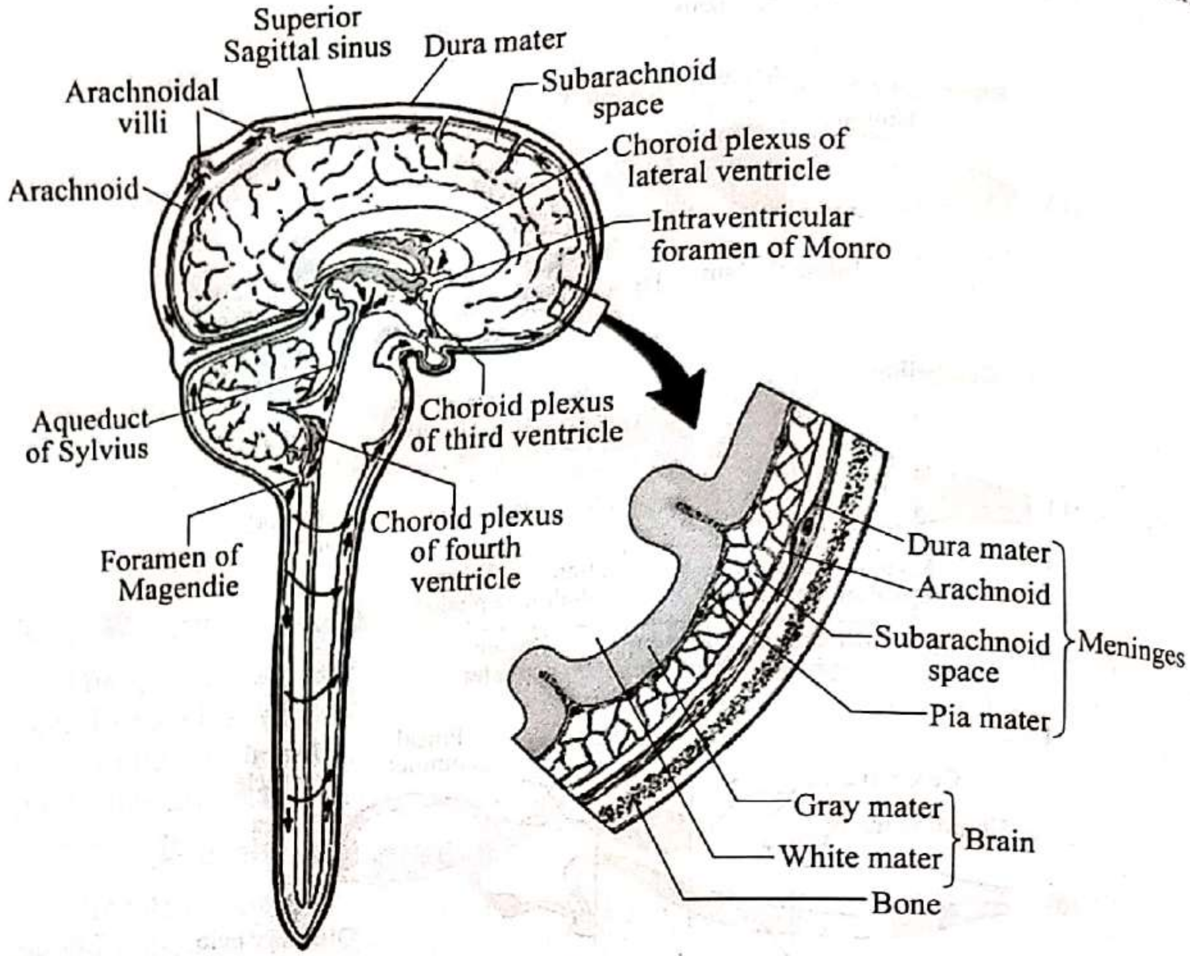


Fig. 3.45. *Brain and CSF, in relation to mammalian brain.*

meninx. With a double meningeal layer, cerebrospinal fluid may circulate more effectively and absorb shocks from the jolts sustained during terrestrial locomotion. In mammals, the dura mater persists, but division of the secondary meninx yields both the arachnoid and the pia mater from ectomesoderm.

3.7.2. Parts of a Vertebrate Brain

Brain is the anterior end of spinal cord that has enlarged to take care of the sense organs which are located on the anterior end of the body in a bilaterally symmetrical animal that moves ahead in an anterior-posterior axis. This is called **cephalon**, which as it evolves further, divides into three parts, namely, prosencephalon, mesencephalon and rhombencephalon. As the brain develops further by increasing the number of neurons, it further divides into different parts, each one having assigned its own specific function.

(i) **Prosencephalon** divides into **Telencephalon** and **Diencephalon**; the former includes olfactory lobes (**Rhinencephalon**) and Cerebral hemispheres that coordinate the activities of the entire brain. The roof of cerebrum is called **Pallium** and the floor that generally contains nerve fibres is known as **corpus striatum.**

(ii) **Diencephalon** is a small part of brain, generally covered by enormously enlarged cerebral hemispheres. This is an extremely important part of brain which functions as switch board to cerebrum. Dorsal part of diencephalon is called **epithalamus** and the ventral part **hypothalamus** while the lateral parts are called thalami that contain relay centres to connect dorsal and ventral parts of thalamus.

(iii) Anterior part of **epithalamus** contains a glandular area called anterior **choroid plexus (Tela Choroidea)** which secretes cerebrospinal fluid. Two dorsal processes of epithalamus, the anterior **paraphysis** supports parietal body and the posterior **epiphysis** bears pineal body. These two bodies function as photoreceptors in lower vertebrates and gradually transform into endocrine organs and biological clock in higher vertebrates.

(iv) The ventral **hypothalamus** has the optic chiasma (crossing of optic nerves) on the anterior side and a ventral median evagination called **infundibulum** which supports **pituitary** gland or hypophysis. There is an olfactory area, **mammillary body** on the posterior side of hypothalamus.

(v) **Mesencephalon** is concerned with sight and hearing. Its dorsal side is called **Tectum** and the ventral fibre bundles are called **Crura cerebri** or cerebral peduncle. The tectum has a pair of bulging optic lobes on the anterior side and a pair of auditory lobes on the posterior side. In lower animals, auditory lobes are insignificant and optic lobes are prominent. This is called **corpora bigemina**. Higher vertebrates such as mammals and snakes have **corpora quadrigemina,** which means they have optic and auditory lobes of equal size.

(vi) **Metencephalon** is called **cerebellum** which is quite enlarged in active animals. In mammals, cerebellum contains bundles of branching fibres of white matter called **Arbor Vitae**. The bulging ventral side of cerebellum is called **pons varolli** and it contains criss-crossing fibres of neurons.

(vii) **Myelencephalon** or **medulla oblongata** is the posterior part of the brain which does not undergo much modification in vertebrates since it controls the autonomic functions of body. The ventral side contains **RAS** (Reticular Activating and Inhibiting System) which keep the brain attentive and awake. Dorsal side exhibits the **posterior choroid plexus,** which secretes cerebrospinal fluid that flows into the brain ventricles and to meninges through a median **Foramen of Magendie** and the paired **Foramina of Luschka.** Medulla is attached with cranial nerves which bring sensory impulses from the body.

(viii) Brain is hollow inside; the cavities are called ventricles which are lined by ciliated epithelium, **ependyma**. Ventricles of the two cerebral hemispheres are called lateral ventricles, or Telocoel or I and II ventricles which are connected together with a **foramen of Monro.** The third ventricle extends from diencephalon to mesencephalon and the IV ventricle is larger inside metencephalon and myelencephalon. The third and fourth ventricles are connected together by a tube-like connection called **Iter** or **aqueduct of Sylvius.**

(ix) **Meninges :** Meninges are protective layers around the brain. The outermost layer is fibrous **dura mater** (meaning *tough mother)* which, though tightly attached to the periostial layer of skull, still encloses a narrow **epidural space** that is filled with perimeningeal fluid. The second layer under dura mater is **Arachnoid**, so named because of spider web like appearance due to presence of villi for the absorption of cerebrospinal fluid. Between the dura mater and arachnoid exists the **subdural space** and between arachnoid and the lower pia mater is the **subarachnoid space**. The innermost layer of meninges is the delicate **pia mater** which is intimately attached with the brain tissue and extends deep into the sulci and fissures. It carries blood vessels and nerves. The three separate meningeal layers are found in mammals only, while in amphibia, reptiles and birds, arachnoid and pia mater fuse to form a single pia-arachnoid layer below the subdural space. Fishes have a single **primitive meninx** that is separated from the skull bone by perimeningeal tissue.

3.7.3. Evolution of Vertebrate Brain

According to Nothcutt [Understanding Vertebrate Brain Evolution; Integr. Comp Biol. (2002) 42 (4): 743-756.]- In thinking about brain evolution in vertebrates, or the evolution of any structure in any group, it is useful to consider what questions can be asked about the topic. In the case of brain evolution, there are four major questions - (1) *What* changes in brain organization and function have occurred over time ? (2) *When* did these changes occur ? (3) *How* did these changes occur (*i.e.*, what were the underlying mechanisms responsible for them) ? and (4) *Why* did these changes occur ?

(i) **What changes have occurred in brain?** After several years of anatomical descriptions and experimental anatomical and physiological studies, there are considerable data regarding *what* changes have occurred in vertebrate brains. Given this extensive body of information on brain variation, it is possible to reach at least three major conclusions regarding

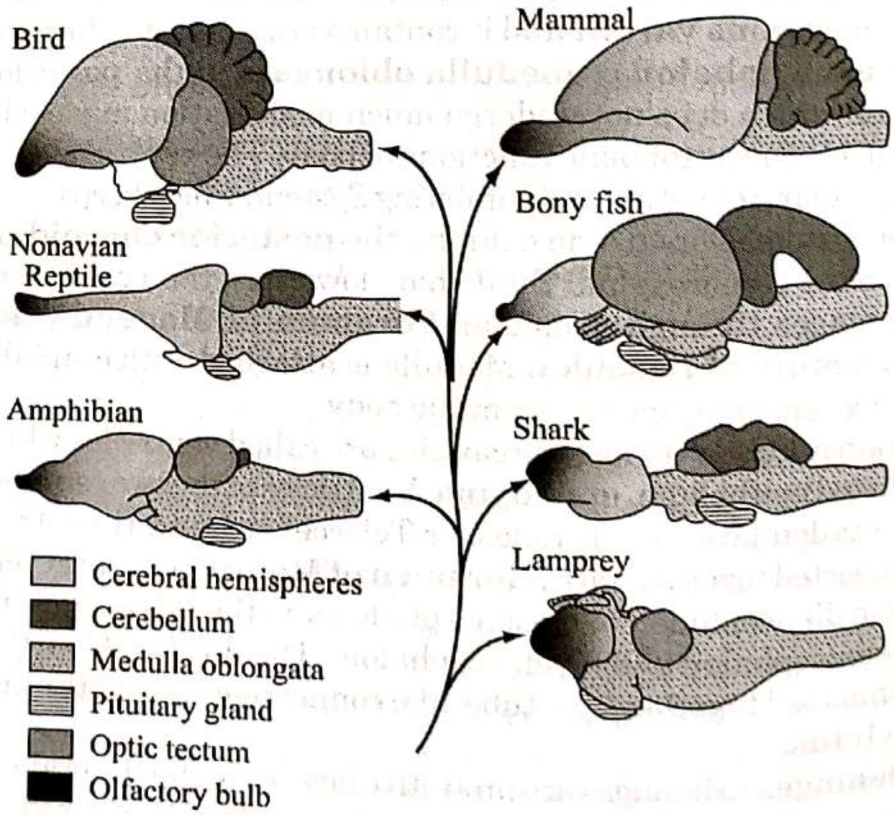


Fig. 3.46. *Evolution of vertebrate brain.*

brain evolution in vertebrates : (1) All vertebrates, with the exception of the agnathans, which appear to lack a cerebellum, have the same number of brain divisions ; (2) Brain size has increased independently in some members of each vertebrate radiation ; and (3) Increases in brain size have frequently resulted in increases in the number of neural centres, increases in the number of neuronal cell classes within a centre, and probably, increases in behavioural complexity.

Even a superficial examination of the external anatomy of the brains of each vertebrate radiation reveals that most vertebrates possess the same number of brain divisions. The absence of a cerebellum in hagfishes and lampreys appears to be the only exception. The conservative nature of major brain divisions across living vertebrates suggests that much of the organization of these brains must have arisen with the origin of vertebrates or shortly thereafter.

The relationship between brain size and body size is highly ordered. In most vertebrate radiations, brain size varies approximately 10-fold, and brain size increases with body size, although this increase is not proportional. Rather, it is allometric, with slopes ranging from 0.21 (agnathans) to 0.74 (mammals). Both birds and mammals have brains that are 6–10 times larger than the brains of reptiles of the same body size. Among birds, the largest brains for body size are seen in perching birds, woodpeckers, and parrots, while the relatively smallest brains are found in pigeons and chicken-like birds (van Dongen, 1998). Similarly, mammals have brain sizes that are 10 times larger than those in reptiles of the same body size. Primates and cetaceans have the largest brains for their body size, while non-placental mammals, marsupials, insectivores, and rodents have the relatively smallest brains. Much of this variation in relative brain size among mammals may be due to developmental constraints, in that selection for an increase in the size of a single brain centre is likely to lead to an overall increase in brain size (Finlay and Darlington, 1995).

(ii) **When do brains change ?** The question of *when* brains change can be answered in a mechanistic and/or historical context. Mechanistically, brains change either by chance or in response, directly or indirectly, to a change in selective pressures. Historically, changes in brain size or organization are correlated with phylogenetic changes, in particular the origin of a new radiation.

(iii) **How do brains change ?** Phylogenetic changes in brains occur only by changes in an ancestral ontogeny. If this is the case, how can changes in an ancestral ontogeny be reconstructed, since the ancestors of most craniate radiations are extinct? If a taxon is of interest because of particular traits, and there is a well corroborated hypothesis of phylogeny for that taxon, it is possible to do an out-group analysis of the development of those traits. Although the development of any trait is a continuous process, stages of that development must be designated in order to describe it. For example, development of the telencephalon can be divided into these stages: neurectoderm, neural plate, neural tube, forebrain vesicle, evaginated hemispheres, etc.

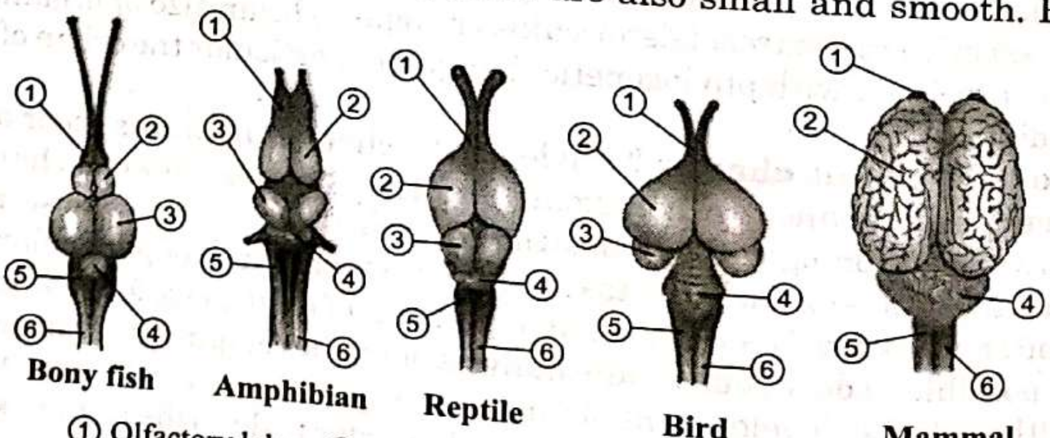
(iii) **Why do brains change ?** Why neural changes have occurred is the most difficult question and one that has been the most ignored, in large part because its investigation requires a broad interdisciplinary approach involving both behaviour and ecology.

3.7.4. Brain in Different Vertebrates

A Cyclostome brain : Cyclostome brain is very primitive owing to their parasitic and detritus feeding habits. Cerebral hemispheres are small and smooth. Olfactory lobes are well developed as these animals detect suitability of their hosts by acute sense of smell. For the same reason **thalamus**, which contains olfactory relay centres, is enlarged with a prominent median olfactory area called **habenula**. Optic lobes are small because of primitive or rudimentary eyes. Cerebellum which is related with balance and posture is reduced due to parasitic mode of life. Medulla oblongata is quite well developed and receives six pairs of cranial nerves but there is no pons Varolli on the ventral side. Pineal and parietal bodies are present in lampreys but absent in hag fishes.

B Fish brain : Active bony fishes and sharks have well developed brain but bottom dwelling fishes have reduced brain organs. Olfactory lobes are large in sharks and they can detect their injured prey by the smell of blood from a distance of about a kilometre. But in majority of bony fishes, optic lobes are reduced. Cerebral hemispheres are quite large but smooth and white. Pineal and parietal bodies are generally reduced in fishes. On the ventral side of diencephalon, there is **succus vaculosus** posterior to the pituitary that serves as sense organ. Optic lobes are well developed as most fishes are gifted with large eyes but in deep sea fishes they are reduced. Cerebellum is highly enlarged in sharks as well as in active bony fishes and also has lateral extensions called **restiform bodies** or **auricular lobes** which connect medulla with cerebellum. They help in maintenance of balance. Cerebellum is smaller in rays, lung fishes, ganoid fishes and deep-sea fishes. Medulla oblongata has no particular variation except in deep sea fishes in which there are large **vagal lobes** on the lateral side which receive impulses from taste buds that are scattered all over the body as pit organs.

C Amphibian brain : Urodele brain is primitive and reflects their sluggish nature and under-developed sense organs. Olfactory lobes, optic lobes and cerebellum are reduced and cerebral hemispheres are also small and smooth. Pineal and



① Olfactory lobe ② Cerebrum ③ Optic lobe ④ Cerebellum ⑤ Medulla ⑥ Spinal cord

Fig. 3.47. *Brain of different vertebrates.*

parietal bodies are present but reduced. There is no succus vaculosus and corpus striatum is weak. **Frogs and toads** possess a better developed brain as compared with urodeles. Olfactory lobes are large and fused at base that gives better sense of smell to frog. Cerebral hemispheres are larger with a centralized grey area called **archipallium** that controls olfactory sense, while the lateral areas are white and are called **paleo-pallium**. Parietal body is reduced but pineal is well developed and probably a photoreceptor. Ancient amphibians possessed a third eye over the pineal-parietal complex. Optic lobes are well developed but there are no auditory lobes and hence the mesencephalon is called corpora bigemina. Cerebellum is reduced but medulla is enlarged to make the brain a reflex brain or spinal brain.

D Reptilian brain : Brain becomes large by the enlargement of corpus striatum. Cerebral hemispheres are large and oval but the surface is white and smooth except in crocodiles which develop grey matter called **neopallium** similar to mammals. Olfactory lobes are well developed in snakes and lizards which have olfactory sense organs on the tongue, but reduced in turtles and crocodiles. Parietal body is well developed in lizards and in Sphenodon it lies under a lens-like transparent area called the third eye. Pineal body is lacking in crocodiles. Optic lobes are well developed in all reptiles and **corpora quadrigemina** is found only in snakes. Cerebellum is reduced in all reptiles owing to their creeping habit.

E Avian brain : Bird brain is characterized by enormous enlargement of cerebral hemispheres, optic lobes and cerebellum. Cerebral hemispheres become enlarged owing to enlargement of **corpus striatum** which is called hyperstriatum but pallium is thin and surface has only white matter. Olfactory lobes are highly reduced, attached to the anterior end of the cerebral hemispheres. Optic lobes are enormous as birds are gifted with the best eye sight in animal kingdom. Parietal body is absent and pineal small in most of the birds. Being bipedal and flying animals, birds need good control over muscles and tendons, which comes from a trilobed highly enlarged cerebellum. The middle lobe of cerebellum is called vermis as it has transverse folds and the lateral lobes are called **flocculi**. Birds' brain is instinctive brain that can carry out complex but stereotype functions such as nest building. Spinal cord still has equal control over the body.

F Mammalian brain : Mammalian brain is highly developed and keeps complete control over the body functions. Cerebral hemispheres are enormously enlarged and the surface is folded into depressions (**sulci**) and raised portions (**gyri**) so that large surface area can be accommodated in the small space of the skull. Grey matter has spread to the surface which is called **neopallium.** Two cerebral hemispheres

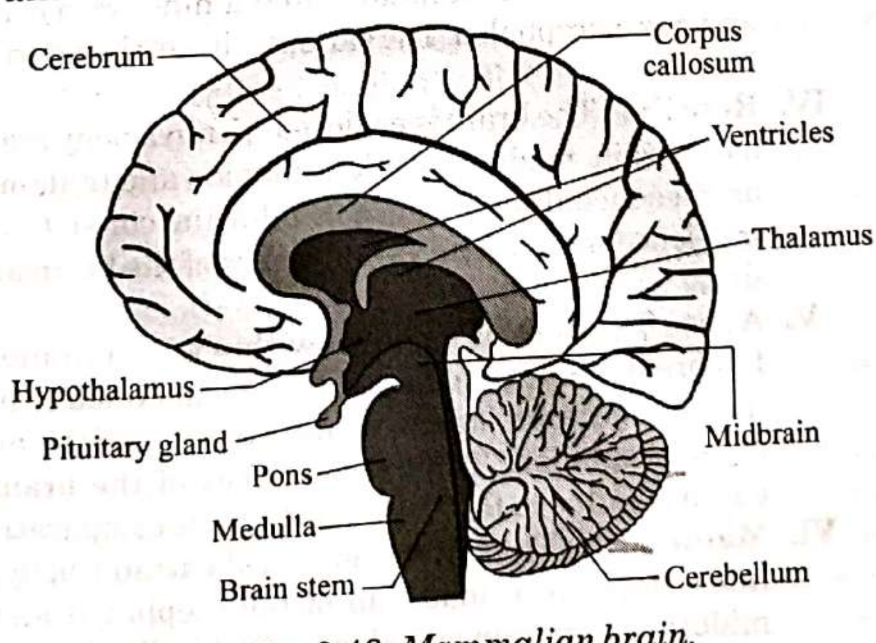


Fig. 3.48. *Mammalian brain.*

are connected by thick bundles of nerve fibres called **corpus callosum,** which is not found in monotremes and marsupials. Olfactory lobes are highly enlarged, so that mammalian brain is sometimes called nose-brain. Parietal body is absent and pineal is usually present except in animals like *Armadillo,* Sirenia and Edentates. Mammals being active animals, cerebellum is highly enlarged and trilobed and all lobes possess gyri and sulci. Nerve cells form bundles of branching fibres called **Arbor Vitae**. Medulla is short as compared to the large brain but **pons varolli** is enlarged.

The **limbic** brain emerged in the first mammals. It can record memories of behaviours that produced agreeable and disagreeable experiences, so it is responsible for what are called emotions in human belings. The main structures of the limbic brain are the **hippocampus,** the **amygdala,** and the hypothalamus. The limbic brain is the seat of the value judgements that we make, often unconsciously, that exert such a strongh influence on our behaviour. Emotional likfe is largely housed in the limbic system, and it has a great deal to do with the formation of memories.

3.7.5. Comparative Account of Parts of Brain of Different Vertebrates

A Overview :

I. Elasmobranch : The brain is enclosed within a cartilaginous cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated in a straight line.

II. Teleost : The brain is enclosed within a bony cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated in a straight line.

III. Amphibia : The brain is enclosed within a bony cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated in a straight line.

IV. Reptilia : The brain is enclosed within a bony cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated in a straight line.

V. Aves : The brain is enclosed within a bony cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated at some curvature due to flexures. The brain is comparatively compact.

VI. Mammalia : The brain is enclosed within a bony cranium. It is divisible into a forebrain, made up of telencephalon and thalamencephalon; a midbrain or mesencephalon and a hindbrain consists of metencephalon and myelencephalon. The various lobes of the brain are situated at some curvature due to flexures. The brain is comparatively compact.

B Olfactory lobes :

I. **Elasmobranch :** The two olfactory lobes are large and anteriorly connected with the cerebral hemispheres by a stalk-like olfactory peduncle. It is concerned with the sense of small. The nasal sacs are large. Evidently, the olfactory sense is highly developed. The corpus striatum is bulging.

II. **Teleost :** The telencephalon has a non-nervous roof and the olfactory bulbs are placed in front of the cerebral hemispheres. It is concerned with the sense of smell.

III. **Amphibia :** The telencephalon has a non-nervous roof and the olfactory bulbs are placed in front of the cerebral hemispheres. It is concerned with the sense of smell.

IV. **Reptilia :** The telencephalon has a non-nervous roof and the olfactory lobes are connected with the anterior ends of the cerebral hemispheres by long and slender peduncles.

V. **Aves :** The telencephalon has a non-nervous roof and the olfactory lobes are connected with the anterior ends of the cerebral hemispheres, which are comparatively more developed.

VI. **Mammalia :** The telencephalon has a non-nervous roof and the olfactory lobes are connected with the anterior ends of the cerebral hemispheres, which are well developed.

C Cerebral hemisphere :

I. **Elasmobranch :** It is undivided and without any median groove. The cerebral hemisphere is thickened both in the floor and in the roof. It is the seat of memory, intelligence and consciousness.

II. **Teleost :** These are two, almost round, and well developed and are the seat of memory, intelligence and consciousness. The roof of the cerebral hemisphere is thin.

III. **Amphibia :** These are two, elongated oval and well-developed. Cerebral hemispheres are divided by a longitudinal fissure. The roof of the hemisphere is thick, smooth and nervous. Corpora striata are poorly developed and are connected by anterior commissures. Lumen of each hemisphere is reduced by the thickening of its lateral and median wall. Cerebrum is the centre for intelligence, consciousness and control of voluntary muscles.

IV. **Reptilia :** These are two, almost semi-circular and well developed. Cerebral hemispheres are larger than amphibians. The two hemispheres are elongated and are separated medially by a deep fissure. The dorsal surface of the hemispheres is smooth and thin but the lateral and ventral walls are thick that constitute the corpora striata. Due to accumulation of large amount of grey matters the roof of cerebral hemispheres is called neopallium.

V. **Aves :** These are two, large and extend behind to meet the cerebellum, covering the thalamencephalon dorsally. These are the seat of memory, consciousness and intelligence. Corpora striata are prominent that reduces the lateral ventricles to very narrow spaces. The corpus striatum is differentiated into hyper-striatum, mesostriatum and palaeostriatum. The roof of cerebral hemispheres is called neopallium. The neopallium is un-convoluted. The diencephalon is inconspicuous and completely covered by cerebral hemispheres and cerebellum.

VI. Mammalia : The two cerebral hemispheres are large, long and narrow in front and posteriorly cover the optic lobes. The surface of the hemispheres is marked into convolutions by depressions or Sylvian fissures and the lobes are frontal, temporal, parietal and occipital. The two hemispheres are connected by a transverse band of fibres, the corpus callosum. Corpus striatum is another band of connective nerve tissue below the ventricles. These are the seat of memory, intelligence and consciousness. Neopallium is highly developed. Presence of corpus albicans.

D Thalamencephalon: It is the part of the diencephalon including the thalamus, metathalamus, and epithalamus.

I. Elasmobranch : It is posterior to the fore brain. On the non-nervous vascular roof is a small rounded pineal body representing the third ancestral eye. The floor bears the infundibulum with a pituitary body. The pituitary body is glandular and secretes different hormones of varied functions. The two sides of the infundibulum bear two thin walled oval sacs, the lobi-inferiores, which are produced posteriorly into sacci vasculosi. It is believed to act as pressure receptor. An optic chiasma is present in front of the infundibulum.

II. Teleost : It is well developed and the sides are produced into optic thalami, the seat of vision and possibly balance also. The floor and roof both are thin. On the roof, is a small rounded pineal body, representing the third ancestral eye. It is attached to the epiphysis. The floor bears a hypophysis with a pituitary body, which is glandular and secretes different hormones of varied functions. The two sides of the hypophysis bear two thin-walled oval sacs, the lobi-inferiores, which are produced behind the pituitary body and meet each other in the middle line. A pair of sacci vasculosi are present. The optic nerves do not form a chiasma, but simply cross one another or decussate. On leaving the brain, the right nerve goes to the left and left one goes to the right eye.

III. Amphibia : It is well developed and the sides are produced into optic thalami, the seat of vision and possibly balance also. The floor and the roof both are thin. On the roof, is a thin stalk, the epiphysis bearing a small rounded pineal body, representing the third ancestral eye. On the floor, is a hypophysis bearing a pituitary body, which is glandular and secretes different hormones of varied functions. An optic chiasma is present in front of the hypophysis.

IV. Reptilia : It is well developed and the sides are produced into optic thalami, the seat of vision and possibly balance also. The floor and the roof both are thin. On the roof, is a thin stalk, the epiphysis bearing a small rounded pineal body, representing the third ancestral eye. On the floor, is a hypophysis bearing a pituitary body, which is glandular and secretes different hormones of varied functions. An optic chiasma is present in front of the hypophysis.

V. Aves : It is well developed and the sides are produced into optic thalami, the seat of vision and possibly balance also. The floor and the roof both are thin. On the roof, is a thin stalk, the epiphysis bearing a small rounded pineal body, representing the third ancestral eye.

VI. **Mammalia :** It is small and thick as the side walls are produced into large optic thalami, the seat of vision and possibly balanced also. On the roof, is an epiphysis bearing the pineal body, representing the third ancestral eye. On the floor, is a hypophysis bearing a glandular pituitary body which secretes different hormones of varied functions. A rounded elevation, the corpus geniculatum is placed anterior to each optic thalamus. The hypophysis is prolonged posteriorly into a rounded mass, the corpus mammilare.

E Mesencephalon :

I. **Elasmobranch :** It is very large, bears a pair of oval optic lobes dorsally and longitudinal nerve fibres like crura cerebri of higher animals ventrally. The optic lobes control vision.

II. **Teleost :** It bears a pair of oval optic lobes dorsally and longitudinal nerve fibres like crura cerebri ventrally. The optic lobes control vision.

III. **Amphibia :** Optic lobes are large and hollow ovoid bodies and two in number. Crura cerebri are longitudinally placed nerve fibres-like structures placed ventrally. Optocoels are present.

IV. **Reptilia :** Optic lobes are more developed than those of amphibia and two in number, called corpora bigemina. They are hollow with optocoels. Crura cerebri at the floor and poorly developed.

V. **Aves :** It bears a pair of large, rounded laterally placed optic lobes constituting the corpora bigemina and two longitudinal brand, crura cerebri ventrally. The optic lobes control vision.

VI. **Mammalia :** Optic lobes are small and four in number (corpora quadrigemina) Optocoels are highly developed.

F Metencephalon :

I. **Elasmobranch :** It consists of a very large dorsal cerebellum. It overlaps the optic lobes in front and medulla oblongata behind. It is the centre for coordination of muscular movement and partly for balance also.

II. **Teleost :** It consists of a large cerebellum, the anterior part of which pushes forward under the roof of the mesencephalon to form the valvula cerebelli. This is very characteristic of teleost fishes, and overlaps medulla oblongata behind. It is the centre for coordination of muscular movement and partly for balance also.

III. **Amphibia :** It consists of a narrow, dorsal transverse band placed just behind the optic lobes and known as cerebellum. It is the centre for coordination of muscular movement and partly for balance also.

IV. **Reptilia :** It consists of a small semi-circular flap, the cerebellum which partly overlaps the medulla oblongata posteriorly. It is the centre for coordination of muscular movement and partly for balance also. Floccular lobes and pons varolli are absent. The surface of the cerebellum is smooth.

V. **Aves :** It consists of a comparatively large elongated cerebellum and is divisible into a large middle lobe, the surface of which is marked by grooves and a pair of small lateral lobes or floccule. It is the centre for coordination of muscular movement and partly for balance also. The 4th ventricle is hidden by the cerebellum. Generally, surface is extensively folded.

VI. **Mammalia :** It consists of a comparatively large, elongated cerebellum subdivided into a median vermis and two lateral lobes. The vermis is marked by grooves and the lateral lobes bear floccule. A band of transverse fibres connect the two halves of the cerebellum and is known as pons varolli. The metencephalon is the centre for coordination of muscular movement and partly for balance also. The surface of cerebellum is thrown into numerous folds, called gyri and grooves between the folds called sulci.

C Myelencephalon :

I. **Elasmobranch :** It is also known as medulla oblongata. It gradually tapers behind to end in the spinal cord. Anteriorly, it is produced into ear-shaped lappets, the corpora restiforma.

II. **Teleost :** It is also known as medulla oblongata. It gradually tapers behind to end in the spinal cord. The roof of the myelencephalon is open.

III. **Amphibia :** Medulla oblongata is thick and gradually tapers behind as a spinal cord. It gives rise 4 pairs of cranial nerves. The roof of the medulla oblongata is formed by a thin vascular membrane, called the posterior choroid plexus. The corpora restiformia are absent in medulla oblongata. It regulates the breathing, heartbeat, and metabolism.

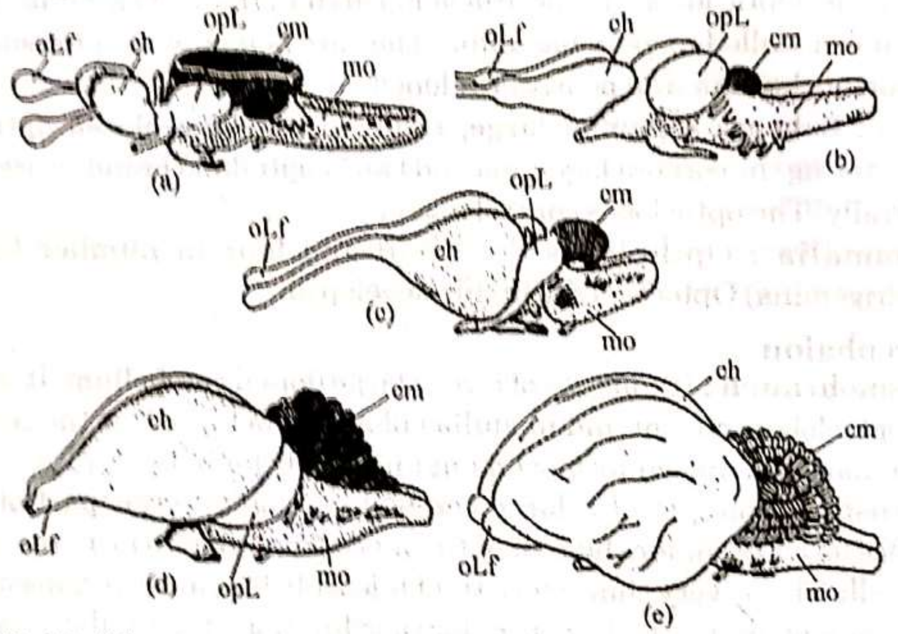


Fig. 3.49. *Modification of vertebrate brains. a = Brain of fish, b = Brain of amphibia, c = Brain of reptile, d = Brain of bird, e = Brain of mammal [olf = olfactory lobe, ch = cerebral hemisphere, cm = cerebellum, opl = optic lobe, mo = medulla oblongata].*

IV. **Reptilia :** Medulla oblongata tapers gradually and joins with the spinal cord. Its roof is thin and vascular that forms the posterior choroid plexus.

V. **Aves :** Medulla tapers and joins with the spinal cord. Posterior choroid plexus is completely covered by cerebellum. Ventral flexure is highly developed.

VI. **Mammalia :** The lateral walls and floor of the medulla are highly thickened. Its roof forms highly vascularized posterior choroid plexus.