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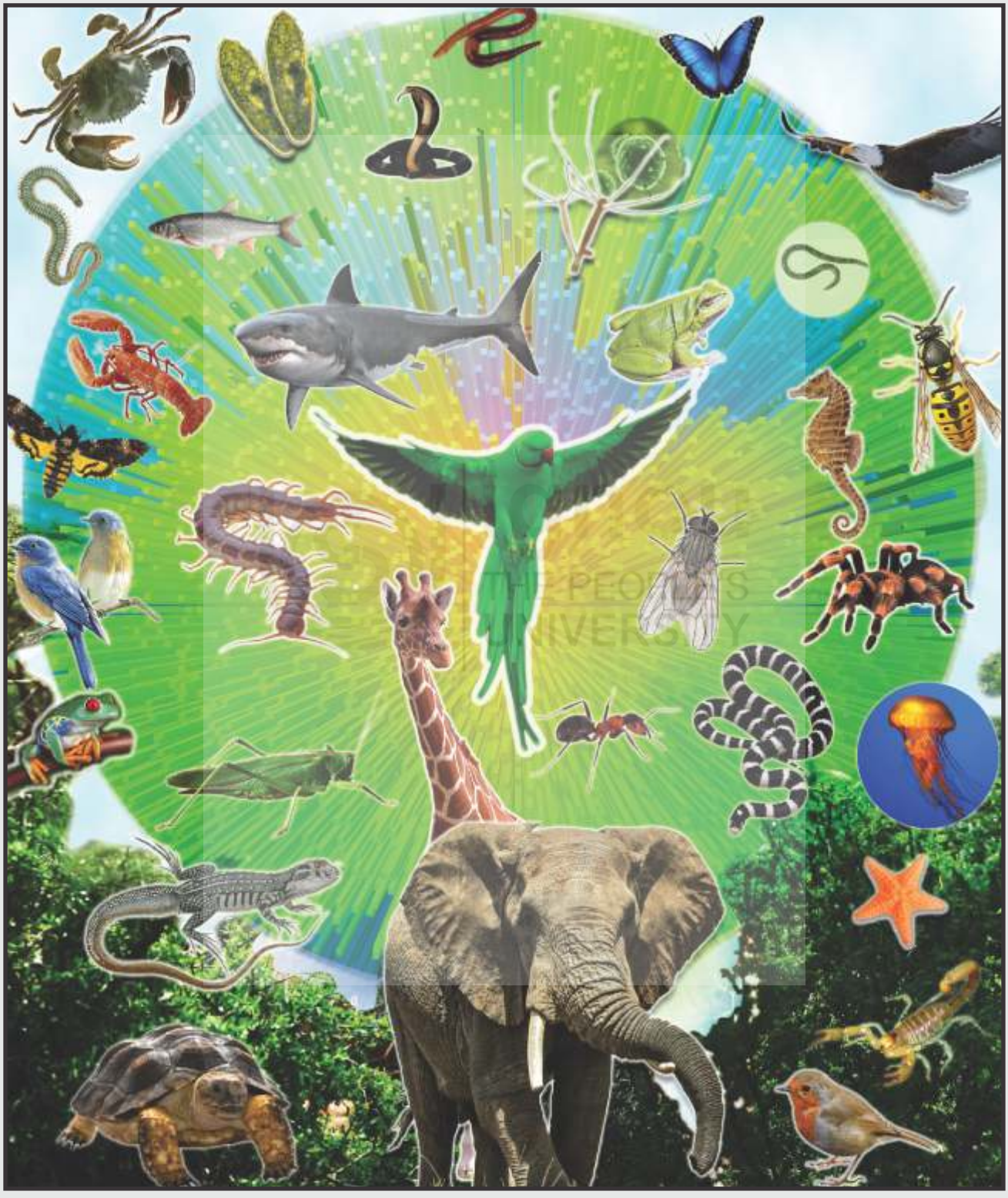

AMNIOTA

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"शिक्षा मानव को बन्धनों से मुक्त करती है और आज के युग में तो यह लोकतंत्र की भावना का आधार भी है। जन्म तथा अन्य कारणों से उत्पन्न जाति एवं वर्गगत विषमताओं को दूर करते हुए मनुष्य को इन सबसे ऊपर उठाती है।"

— इन्दिरा गांधी

"Education is a liberating force, and in our age it is also a democratising force, cutting across the barriers of caste and class, smoothing out inequalities imposed by birth and other circumstances."

– Indira Gandhi

Indira Gandhi National
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School of Sciences

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Block

4

AMNIOTA

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Acknowledgement: Mr. Manoj Kumar for word processing and Mr. Ajit Kumar for art works.

September, 2019

ISBN : 978-93-89668-04-9

Further information on the Indira Gandhi National Open University courses may be obtained from the University's office at Maidan Garhi, New Delhi-110 068 or the official website of IGNOU at www.ignou.ac.in.

Printed and published on behalf of Indira Gandhi National Open University, New Delhi by Prof. Poornima Mital, Director, SOS, IGNOU.

Laser Typeset by : Rajshree Computers, V-166A, Bhagwati Vihar, (Near Sec. 2, Dwarka), Uttam Nagar, New Delhi-110059

Printed by : M/s. Hi-Tech Graphics, D-4/3, Okhla Industrial Area, Phase-II, New Delhi-110020

AMNIOTA

The living amniotes show vast structural and functional diversity and are adapted to different environments and modes of life. However, they all share certain characteristic features as a result of their common ancestry and these have undergone progressive modifications during the course of evolution. In this block, we have four units which present an overview of the defining features and classification of the amniotic vertebrate which will also enable you to understand how they have evolved.

Unit 15 Reptiles describes how members of Class Reptilia for the first time evolved characteristic features that enabled them to become completely terrestrial vertebrates, that were able to survive well and even reproduce out of water. Far-reaching changes were needed for life on land. There was the evolution of the amniotic egg consisting of, amnion, chorion, allantois and yolk gland, all of which became enclosed after fertilization within a protective shell. The amnion, chorion, allantois and yolk gland surrounded the developing embryo and formed a life sustaining environment for its development. The other important adaptations for life on land was the progressive changes in the jaw that allowed the reptiles new ways of feeding and also in the limbs, which were more suitable for a terrestrial life. Dinosaurs that once roamed the earth are the best known and most spectacular examples of reptiles. This unit also gives the classification of extant reptiles, upto order level and discusses how cladists on the basis of common features of reptiles and birds place them in the same clade, namely reptiles. Cladists refer to the traditionally classified reptiles as non-avian reptiles however, in this unit we have kept to the traditional classification for reptiles and aves. In this unit you will also become familiar with the main features of each order of reptile.

Unit 16 Aves describes the defining features of members of Aves (birds) and also gives the classification of extant members upto order level. You will also learn in brief the charactersic features of each order of Aves. In this unit you will also learn about the various adaptations that have occurred in their feature for enabling them to fly. Birds are highly specialised for constant activity and for flight. Since their origin birds have become adapted to many different habitats and adopted various adaptations for their requirement of flight. They are the only terrestrial vertebrates capable of moving over long distances.

In **Unit 17 Mammals** you will study the important characters of mammals which have been responsible for their success on the earth. This unit gives an interesting account of both non-placental and placental extant mammals and describes their various adaptive features.

In **Unit 18 Evolutions and Classification of Mammals**, you will read about the course of evolution of mammals and their classification upto the level of order. You will also learn in brief the features of each order of mammals.

The geological time periods featuring the biological evolution have been given as Appendix-I at the end of this block. We would strongly advice you to keep referring to them as you read through the course.

Objectives

After studying this block, you will be able to:

- list the characteristic features possessed by all amniote groups;
- describe the characteristic features that differentiate the amniote vertebrates consisting of reptiles, birds and mammals from each other;
- list the salient feature of extant orders, belonging to class Reptilia, Aves and Mammalia and describe their adaptations for occupying various habitats;
- describe the important adaptation found in amniote vertebrates for a life on land; and
- briefly explain the progress of evolution of amniote vertebrates.

UNIT 15

REPTILES

Structure

15.1 INTRODUCTION

You have already read in the previous unit (Unit 13, Block 3 of this Animal Diversity course (BZYCT-101) about Super class Pisces, members of which are completely dependent, throughout their life on water. You have also studied in Unit 14 about the amphibians, some of which may be able to live on land but have to go back to the water to breed, indicating that they are not totally adapted to a terrestrial mode of life. In this unit and the next three units you will learn about those vertebrates which are adapted for living on land, and do not need to go back to the water to lay eggs or to produce young ones.

The present unit discusses the amniotes that are placed in class Reptilia (rep-til'ea—L. repto, to creep). In this unit you will learn about the evolution, classification and characteristic features of reptiles, particularly those features that have enabled reptiles to adapt to a terrestrial mode of life. Reptiles today are a dominant part of any major ecosystem. Of the several groups of reptiles that have existed on earth you will familiarise yourself with the identifying characters of only the four extant (living at present) orders of Class Reptilia: Tesudines (Chelonia), Sphenodonta, Squamata (Rhyncocephalia) and Crocodilia. Members of these orders are found in all the continents except the Antarctica.

In this unit you will also be able to learn about the remarkable feeding strategies of reptiles, specifically those of snakes and lizards. The unique feeding mechanism of these two groups, especially snakes is possible because of the presence of a kinetic skull in them, which enables them to eat preys that are larger than their mouths.

This unit will also help you learn how to distinguish between non venomous and venomous snakes.

Objectives

After studying this unit, you should be able to:

- describe briefly the evolution and affinities of reptiles which are also referred to as non-avian reptiles and are placed in the Class Reptilia;
- describe the main features of reptiles;
- give the classification of reptiles on basis of their distinguishing features;
- describe the salient characteristic features of the extant orders of class Reptilia namely, Testudines (Chelonia), Sphenodonta (Rhynchocephalia), Squamata and Crocodilia;
- describe the structural modifications of a kinetic skull in venomous (poisonous) and non-venomous (non-poisonous) snakes, used by them for biting and swallowing preys larger than their mouths; and
- distinguish between venomous and non-venomous snakes.

All four-footed animals that belong to vertebrate groups higher than fishes are termed as tetrapods.

15.2 EVOLUTION OF AMNIOTES

In Unit 14 you had studied about the first tetrapods the amphibians which belong to the group "Anamniota", which is one of the two major groups of tetrapods. They were the first group of vertebrates to move to land, but despite some adaptations for a terrestrial life, they needed a moist or watery environment to complete their reproduction and development. Even the adult amphibians of primitive times similar to adult amphibians of the present day had no real protection from the extremes of temperature or dry conditions.

In the later part of the Carboniferous period a group of tetrapods evolved important adaptations that enabled them to live successfully on land completely or for a major part of their lives. This group of tetrapod forms the other major group of tetrapods known as **"Amniota"**. Before the end of the Paleozoic era, the tetrapods with their adaptations for life on land diverged into several lineages and gave rise to all those tertrapods–reptiles, birds and mammals(collectively called as amniotes) that became terrestrial for their entire life cycle.

The first amniotes were small and lizard-like but by early Permian period they had diverged into several lineages that varied in form, feeding, biology and in the use of different habitats. Skull structure, particularly the skull fenestrae (openings) and the attachment of jaw muscles is one of the important ways to distinguish the various lineages of animal groups that diverged from the first amniotes.

15.2.1 Morphological Features for Identification of Amniote Skull Types

The amniote skull, on the basis of two main features can be categorised into three skull types (Fig. 15.1). The two main features of the skull used for categorising them are as follows:

1. The pattern of fenestrae (singular: fenestra) which are are openings and are called the temporal openings, are located in the temporal region of the skull (the area behind the eye socket). Jaw musculature is accommodated in this region of the skull; and

2. The position of bones of the temporal arches or bars present in the skull.

15.2.2 Types of Skulls in Amniotes

The skulls of extant amniotes, on the basis of the two characteristics discussed above are classified into three types– I) Anapsid, II) Diapsid and III) Synapsid skulls which are described below:

I) **Anapsid (Greek- an: without + apisis: arch) skull.** This type of skull does not have any opening in the temporal area of the skull. As a result the skull is completely roofed over by dermal bones (Fig.15.1a). Anapsid type of skull was present in the earliest amniotes. Such amniotes are placed in the Subclass Anapsida. The diapsid and synapsid amniotic skulls have evolved from the ancestral anapsid skull.

II) **The Diapsid (Greek- di: double + apsis: arch) skull.** This type of skull has two pairs of temporal openings which are separated by a temporal bar due to which: (i) one pair of openings are present low on the cheeks below the temporal bar and (ii) another pair of openings are located above the temporal bar, in the roof of the skull (Fig. 15.1b).

III) **Synapsid (Greek- syn: together + apsis: arch) skull.** This skull is characterised by the presence of a single pair of temporal openings, located low on the cheeks and bordered by a bony arch (Fig.15.1 c). The synapsid skull is found in the Subclass Synapsida which includes the mammals and their extinct relatives (You will study about mammals in Units 17& 18). Among the amniotes, the synapsids were the first to undergo extensive adaptive diversification and were the dominant, large amniotes present in the late Paleozoic era.

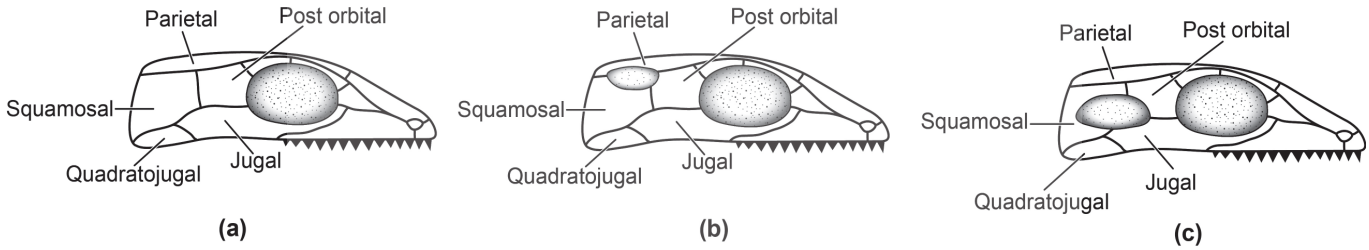


Fig. 15.1: Three types of Amniote Skulls: a) Anapsid skull from which all amniote skulls have evolved; b) Diapsid skull; and c) synapsid skull. Diapsid and synapsid skull are often highly modified by the fusion or reduction of skull bones.

15.2.3 Division of Reptile and Bird Groups on Basis of Diversification of Diapsid Skull

Diapsid skulls are present in all birds and all those amniotes that are traditionally considered reptiles. Thus lizards, snake, crocodiles, turtles and birds are all placed in the Subclass Diapsida. Turtles till very recently were thought to belong to Subclass Anapsida because the skulls of extant turtles do not have temporal openings. However, recent morphological and genetic evidences indicate that turtles have evolved from ancestors that did have two pairs of temporal fenestrae but which were secondarily lost during the course of evolution. As a result turtles are now placed in the Subclass Diapsida instead of Anapsida.

In many living diapsid lizards, snakes and birds one or both of the bony arches and openings have been lost secondarily, perhaps for the purpose of development of a skull that has kinesis and so is called a kinetic skull. “Skull kinesis” in reptiles refers to the movement of skull bones relative to each other as well as movement of the bones at the joints between the upper and lower jaws of the skull. The jaw bones in a kinetic skull are extremely flexible, allowing the animal to open the mouth very wide. This type of skull occurs in all snakes and some lizards. Kinetic skull is highly developed in snakes and so you will read about its features and mechanism of biting and swallowing in sub-section 15.7.2 of this unit.

The earliest diapsids diversified into at least 5 morphologically distinct groups of terrestrial tetrapods which are as follows:

1. Tesudines (Chelonia) - which consists of turtles and tortoises. Tesudines on their basis of their molecular and genetic studies are now considered

to be diapsids rather than anapsids. Scientests at present, believe that the fenetrae in the skull of Tesudines have been secondarily lost during the course of evolution.

2. Lepidosaurs - which contain the tuataras, lizards and snakes.
3. Archosaurs - that include the extinct, terrestrial dinosaurs (see Box 15.1) and the flying pterosaurs with membranous wings. It also includes extinct and extant crocodiles and birds.
4. Sauropterygians - which consists of an extinct group of marine diapsids that includes the long necked plesiosaurs which had paddle-like limbs.
5. Ichthyosaurs which consists of the extinct, marine dolphin like forms with large eyes and vertical tails.

All these early amniotes evolved derived characters that enabled them to live successfully on land and to be more energetic than the anamniotes .Let us now examine these remarkable adaptations in amniotes and the first terrestrial group namely the class Reptilia.

15.2.4 Main Adaptation in Amniotes for a Terrestrial Life Style

The major adaptation of reptiles, aves (birds) and mammals for living on land was made possible by the following featurs: 1) evolving a different reproductive strategy from the anamniotes, 2) evolving morphological and physiological characters that would prevent water loss from the body, 3) using ribs for ventilation during respiration and 4) evolving a more developed brain for terrestrial living and 5) evolving stronger jaws.

1. The reproductive adaptations of the amniotes, freed their eggs and corresponding larval stages completely from dependence on external water sources for development. Reptiles, birds and mammals adopted a mechanism, of internal fertilization. The egg referred to as cleidoic or amniotic egg was fertilized within the body of the mother where it

(a) (b) (c)

Fig. 15.2: The egg shell could be a) leathery as in reptile or b) calcareous as in birds and c) in the mammalian platypus.

developed further, till in the case of reptiles, birds and mammalian monotremes it could be laid outside the body of the mother as an egg

containing the developing embryo within and covered with a hard, protective shell which could be laid on land where it could develop further (Fig. 15.2). In case of mammals except for monotremes however, the females give birth to young ones.

2. Amniotes also evolved a set of four extra embryonic membranes that enclosed the developing embryo, forming a complete set of life support system for them. The four extra embryonic membranes (Fig. 15.3 a and b) are described as follows:

   i) The inner most membrane known as amnion encloses the developing embryo in a liquid filled-space which can be said to be a replica of the ancestral pond. The liquid enclosed by the amnoin membrance is called the amniotic fluid and it protects the embryo from injury and dehydration as its amniotic fluid absorbs shock and prevents the embryo from drying. The group name Amniota is given to all those terrestrial tetrapods which share the presence of the innermost extra embryonic membrane the "amnion". Fig.15.3 a shows a generalised figure of the "naked" fertilized egg, referred to as the anamniotic egg of fishes and amphibians. This fertilized egg is laid in water and so is exposed and vulnerable to the external environment. In contrast Fig. 15.3 b, shows the fertilized amniotic eggs of reptiles, birds and mammals. respectively, with their four protective extra-embryonic membranes within which the embryo either develops within the safety of body of the mother or within a protective hard shell.

   ii) The second membrane is called allantois. It forms a vascularised (having blood vessels) sac. Allantois stores the excreted metabolic wastes, mainly the nitrogenous wastes (chiefly uric acid) of the embryo. As the embryo grows larger the allantois also participates in gas exchange.

   iii) The third membrane is the chorion. It lines the inner surface of the shell and so externally covers both the embryo and yolk. The chorion is permeable to gases and thus participates in the exchange of oxygen and carbon dioxide between the embryo and the outside air. It acts as an extra embryonic lung.

   iv) The fourth membrane is the yolk sac which encloses enough yolk for providing nourishment to the developing embryos of reptiles, birds and prototherians. Yolk is a mixture of proteins and lipoproteins and is the sole source of food for the developing embryo until hatching. In human beings however, yolk sac is vestigial and so nourishment is provided to the embryo by the mother via the placenta.

3. The changes in the skin morphology of the amniotes gave them further protection from desiccation. Amniote skin is thicker, more keratinized and less permeable to water than that of the anamniotes. Furthermore, a wide variety of structures such as scales, hairs and feathers cover their body and so protect them from dehydration. Hairs, feathers, nails and claws project from the skin. The lipids in the skin prevent water loss and keratin gives protection from injuries.

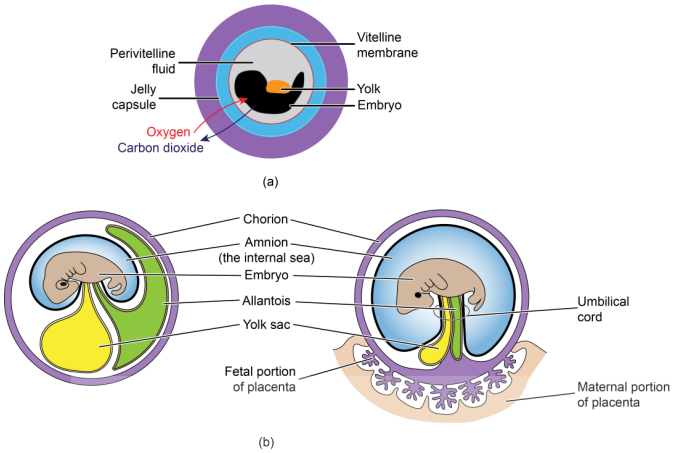


Fig.15.3: The Anamniote and Amniote eggs: a) The anamniote egg is laid in an aquatic medium and is vulnerable to the external environment; b) the amniote egg i) in reptiles and birds and ii) in mammals. In amniotes the embryo grows within a self-contained "pond" (amniotic fluid) which is one among the four extra embryonic membranc. All the four membranes as seen in figure surround the developing embryo and are responsible for sustaining the embryo. The embryo and the four extra embryonic membranes are further protected from the external environment by the presence of a tough, protective yet permeable outer shell which permits gases to pass between the egg and the outside environment.

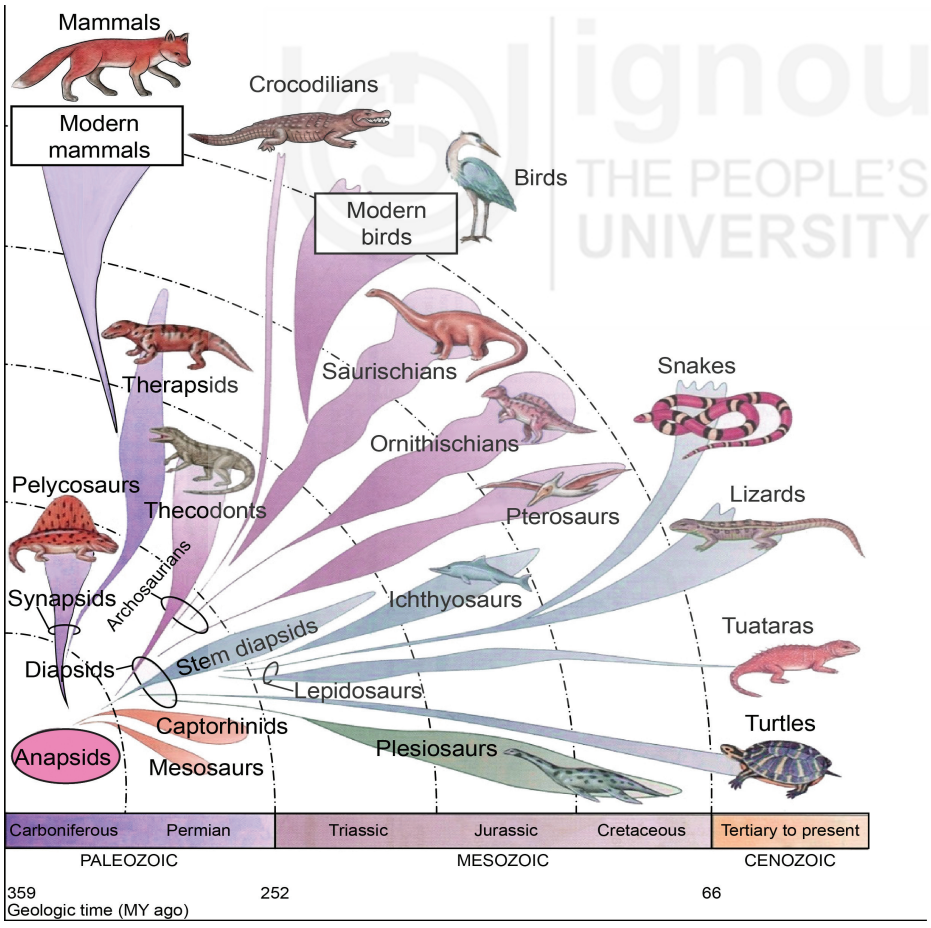


Fig. 15.4 Evolution of amniotes. The earliest amniotes evolved an amniotic egg, which allowed them move to more dry habitats. The living amniotes consist of reptiles (non avian reptiles), birds, and mammals. All living amniotes evolved from a lineage of small, lizard like forms that retained the anapsid skull of the early, anamniote tetrapods. (see also the Appendix given at the back of the block)

Box. 15.1: Dinosaurs and their Extinction

The Mesozoic Era lasted from 245 to 65 million years ago and is divided into the three periods: i) Triassic, ii) Jurassic and iii) Cretaceous period. The Mesozoic Era is also known as the "age of dinosaurs" as shown in the figure given in this box. Dinosaurs were formally named and placed in the taxon Dinosauria in 1842, by paleontologist Sir Richard Owen. Dinosaurs were a diverse group of reptiles that first appeared during the Triassic period. The exact origin and timing of the evolution of dinosaurs is still a subject of active research. At present, scientists place their origin between 231 and 243 million years ago. The first dinosaurs branched off from the reptiles and colonised the land, air, and water. Dinosaurs were the dominant terrestrial vertebrates after the Triassic period and their dominance continued throughout the Jurassic and Cretaceous period. Dinosaurs are phylogenetically, defined as the group consisting of Triceratops, Neornithes, their most recent common ancestor (MRCA), and all their descendants. It should be noted however, that other prehistoric animals during this period like the mosasaurs, ichthyosaurs, pterosaurs, plesiosaurs, and Dimetrodon, which are often thought to be dinosaurs, are not taxonomically classified as dinosaurs because none of these animals had the erect hind limb posture characteristic of true dinosaurs. The Dinosaurs are generally known for their large size. However, many Mesozoic dinosaurs were human-sized or smaller. For example, dinosaur Xixianykus (pronounced: zizionakus), whose findings was reported on 29/03/2010 was only about 50 cm (20 in) long. Recent studies have indicated that instead of being cold blooded reptiles as thought earlier all dinosaurs were active animals with elevated metabolism. Furthermore, dinosaurs had numerous adaptations for social interaction and some were herbivorous while others were carnivorous. Evidence also suggests that traits like egg laying and nest building were shared by all dinosaurs.The dominance of the dinosaurs ended suddenly about 66 million years ago due to their mass extinction. The cause of the mass extinction is still a scientific mystery. The extinction wiped out all the dinosaurs except for birds which escaped extinction and today represent the only dinosaur lineage that were able to survive. Birds are considered the sole surviving lineage of theropod dinosaurs. Scientists tend to focus on two probable theories to explain the Cretaceous extinction of dinosaur. They believe that either1) the earth was hit by an extraterrestrial asteroid or comet or 2) there was a massive bout of volcanic eruption on the earth. Both these events would have resulted in the earth and skies being covered and choked with debris causing the earth to be starved of the sun's energy. This would have prevented photosynthesis and drastically destroyed the food chain. Furthermore, once the dust would have settled the greenhouse gases would become locked in the atmosphere which would cause a massive rise in temperature. The swift change in climate would destroy much of the life that survived the prolonged darkness. Some scientists think that both these events may have contributed to the extinction, and others suggest that the real cause was a more gradual shift in climate and changing sea levels. Regardless of what caused the extinction, it marked the end

of *Tyrannosaurus rex's* reign the most dominant dinosaur of the Mesozoic Era. It thus, took a catastrophic, environment-changing event to happen which allowed the mammals to rapidly diversify and occupy newly opened niches.

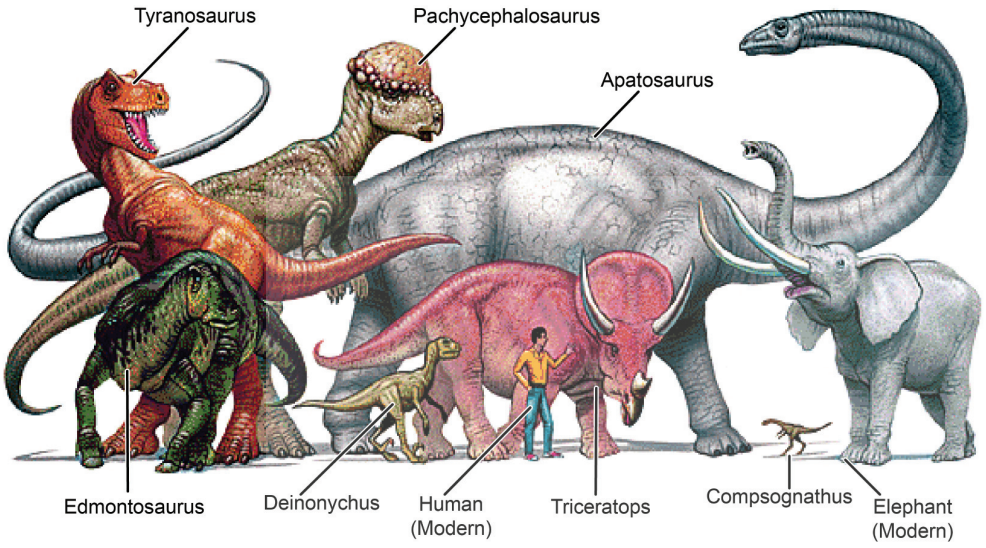


Fig. 15.5 : The comparative size of vairous dinosaurs against human and the largest extant terresrial mammal the elephant.

4. The lungs of amniotes have more surface area for respiration and so inhalation of oxygen from the atmosphere and exhalation of carbon dioxide to the atmosphere is more efficient in amniotes. Amniotes use their rib cage to ventilate their lungs. For this purpose the thoracic cavity is expanded in order to draw in air into the lungs.

5. Amniotes have stronger jaw muscles that help to catch and masticate food. They have an expanded and more developed brain and sense organs which gives them an advantage in finding food, mates and protecting themselves from enemies.

Thus these adaptations acquired by the reptiles, enabled them to become the first truly terrestrial amniotes. Reptiles continued the colonisation of land begun by the crossopterygian fishes and amphibians and became well adapted for existence on land. Birds and mammals the other terrestrial amniotes have evolved from reptilian ancestors as shown in Fig. 15.4.

SAQ 1

State whether the following statements are true or false.

a) The archosaurs gave rise to the snakes. True/ False

b) Fishes and amphibians are called amniotes. True/ False

c) Birds and crocodiles belong to a monophyletic group. True/ False

d) All anamniotes lay their eggs or produce young ones on land. True/ False

e) The synapsids gave rise to mammals. True/ False

15.3 CHARACTERISTIC FEATURES OF REPTILES

Reptiles were the first truly terrestrial amniotes as they developed various features that allowed them to become well adapted for existence on land. The various characteristic features of reptiles are as follows :

1. Reptiles are amniotes and have evolved a cleidoic egg (Refer again to Fig. 15.3).
2. Shape of the reptile body may be compact in some and elongated in others (Fig. 15.5).

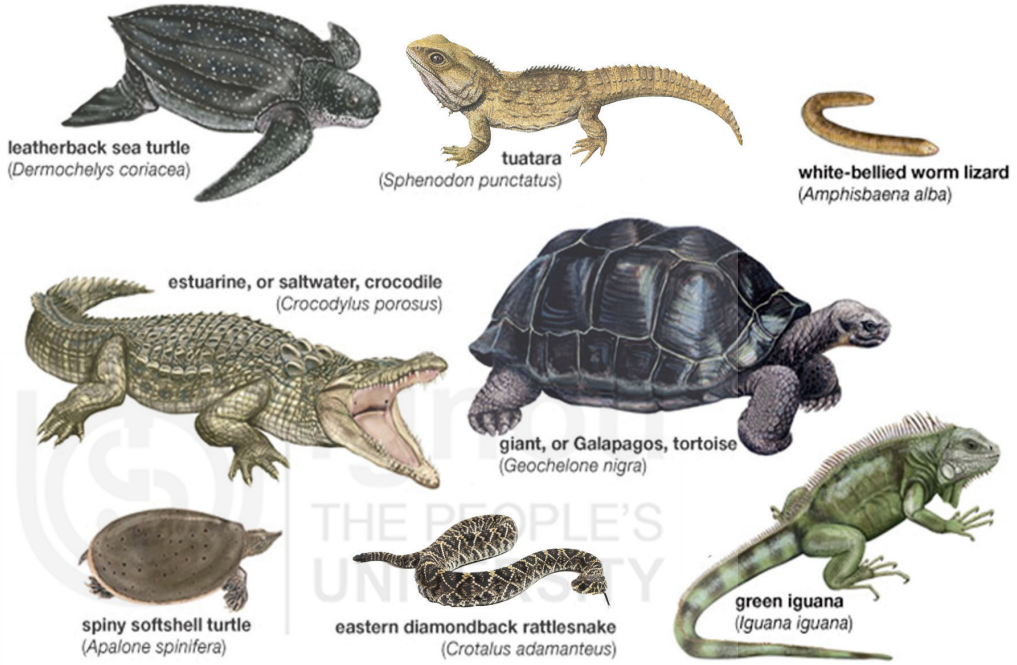


Fig. 15.5: Reptiles are of different shapes.

3. The body of reptiles is covered with an exoskeleton of dry, horny, (not slimy) keratinized skin or integument, usually with epidermal scales or scutes on the surface (Fig. 15.6). Water loss in reptiles is minimised by the dry skin consisting of protective scales and very few mucous secreting glands. This dry, scaly skin of the reptiles however, lacks elasticity and so must be shed periodically as the animal grows Bony dermal plates are present in some reptiles.

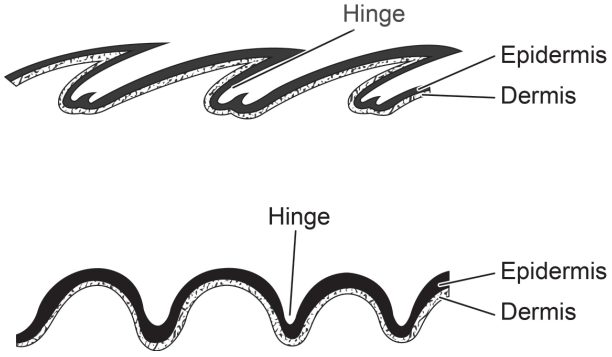


Fig. 15.6: Reptilian skin showing epidermal cells provided with a thin region of epidermis between the scales that acts like a hinge to provide flexibility to the reptiles skin.

4. Endoskeleton is well ossified. Skull is monocondylar (only one occipital condyle is present) in order to articulate with the first vertebrae of the vertebral column. Lower jaw of reptiles consists of several bones.

5. Most reptiles except for snakes have ribs with sternum which form a complete thoracic basket (Fig.15.7a and b).

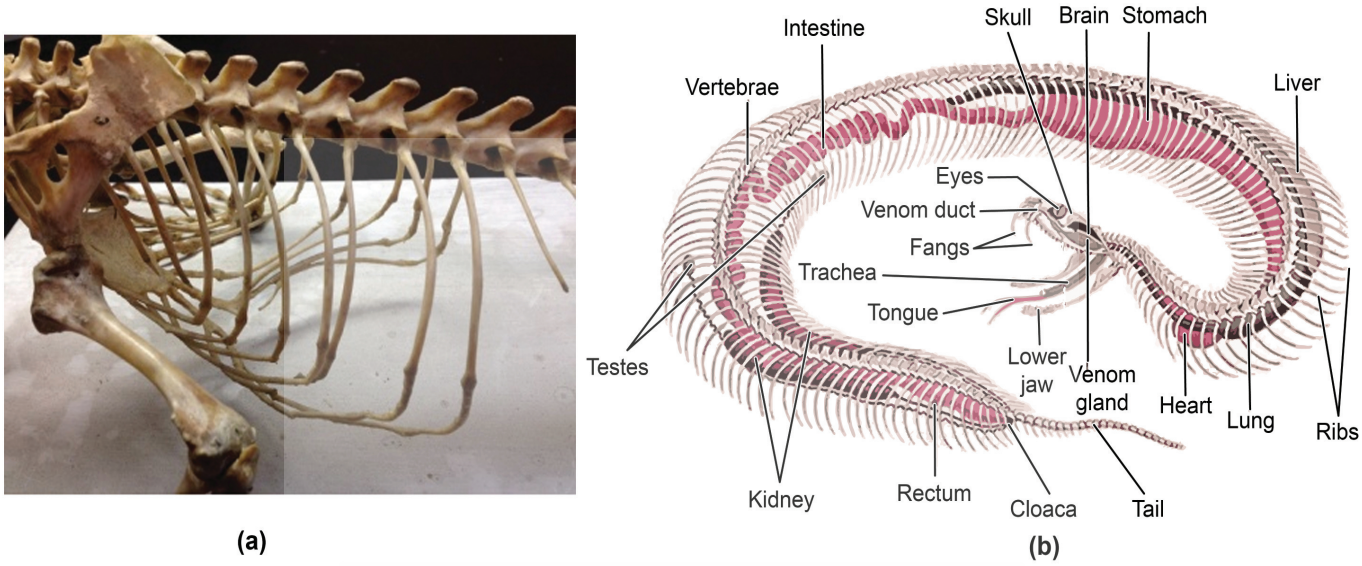


Fig. 15.7: Skeleton of reptiles: a) In lizards (Iguana) a sternum is present to which the ribs attach forming a thoracic basket; b) Internal structure of snake with its skeleton, showing several vertebrae: each vertebrae has its own pair of ribs attached to it which provides an anchor for the several muscles that are needed to manipulate the longer and slender body. Sternum is absent in snakes.

6. Limbs are paired, usually with five digits or toes, each ending in a horny claw and are suited for crawling, running or climbing or in aquatic turtles for swimming. Limbs are reduced in some lizards and are absent in a few other lizards and in all snakes though vestiges of limbs and/ or girdles are seen in certain boas (Fig. 15.8).

7. Teeth when present are polyphyodont (replaced several times) and are usually homodont (all similar in shape and function) with a single point. In turtles however, teeth are absent.

8. Gizzard is present only in crocodilians.

9. The heart of all reptiles has a sinus venosus, Reptiles, except for crocodilians have a three chambered heart, which consists of two atria (also called auricle) and an incompletely divided ventricle. Crocodilian heart is four chambered with two atria and two ventricles (Fig. 15.9 a and b). Pulmonary and systemic circuits are incompletely separated. Red blood corpuscles are oval, biconvex and nucleated (Fig.15.9 c).

10. Cutaneous respiration is negligible in reptiles and they respire mainly by paired lungs. Filling of air in lungs is by aspiration (negative ventilation) which occurs by changing the body size. Pharyngeal and cloacal respiration is also additionally used in some aquatic turtles. In embryonic life, respiration is by branchial arches. Gills are absent in reptiles.

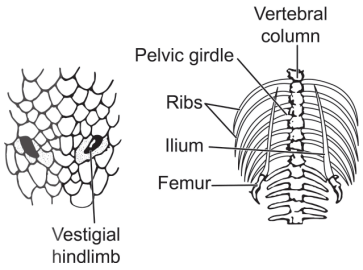


Fig.15.8: Vestiges of hind limbs and pelvic, girdles and only claws of hind limbs are found in pythons and boas: within the body of these snakes the skeleton shows remains of pelvic girdle and of femur (thigh bone).

11. Reptiles are ectothermic (organisms that regulate their body temperature mainly by exchanging heat with their surrounding environment) and heliothermic (obtaining heat from the sun).However, they maintain a relatively high body temperature by behaviourally adjusting their exposure to sun. They are more active than amphibians. Reptiles living in temperate habitats cannot maintain their temperature during extended cold periods and so similar to amphibians hibernate. However reptiles living in tropical climates have thermally a more favourable and uniform environment and so have little difficulty in regulating their temperature.

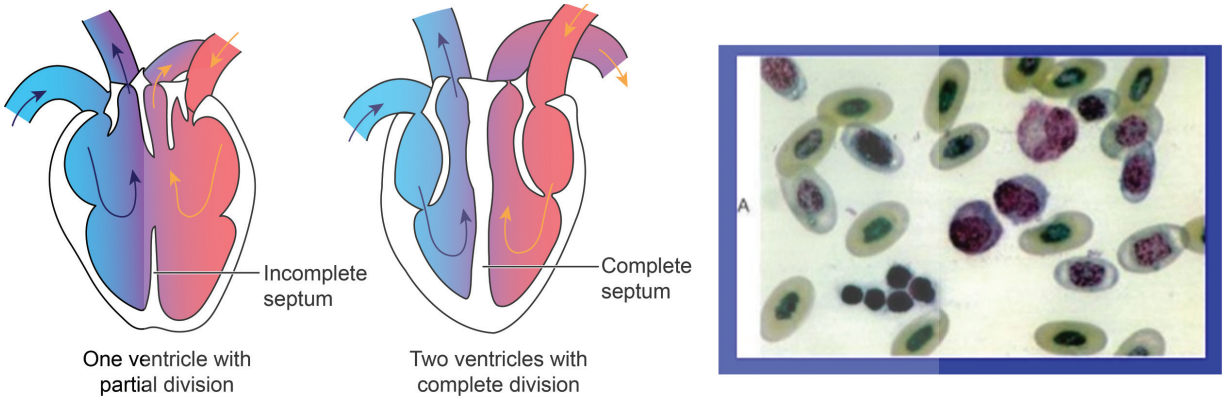


Fig.15.9: a) A three chambered reptilian heart is found in all reptiles except in crocodilians. The three chambered heart consists of two atria and an incompletely separate ventricle but; b) in crocodilians the heart is four chambered, consisting of two atrium and two virtually separated ventricles; c) nucleated red blood cells of reptiles.

12. Excretory system in reptiles (Fig. 15.10) consists of paired metanephric kidneys and ureters. Uric acid is the main nitrogenous waste that is excreted by reptiles.

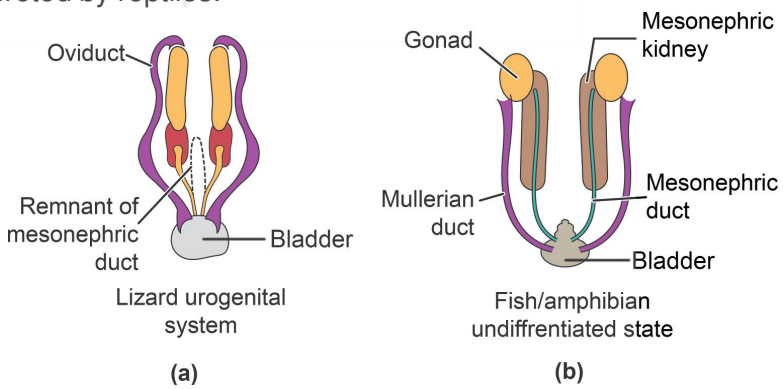


Fig.15.10: Kidneys of reptiles are: a) metanephric instead of being; b) mesonephric as seen in anamniotes.

13. Brain in all reptiles is moderately well-developed with expanded cerebrum (Fig. 15.11). 12 pairs of cranial nerves are present.

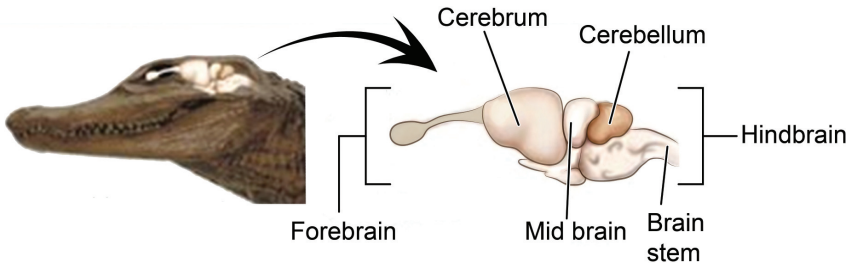


Fig.15.11: Reptilian brain showing a well-developed cerebrum.

14. Eyes of some reptiles have colour vision. Snakes and lizards have highly developed chemoreception (physiological response of a sense organ to a chemical stimulus) by using olfactory epithelia and Jacobson's organ as chemoreceptors. Some snakes have heat-sensitive pit organs for locating their prey (Fig.15.12a). The median or parietal eye which is a photosensory organ is present in some reptiles and is located near the middle of the top of the head (Fig. 15.12 b).

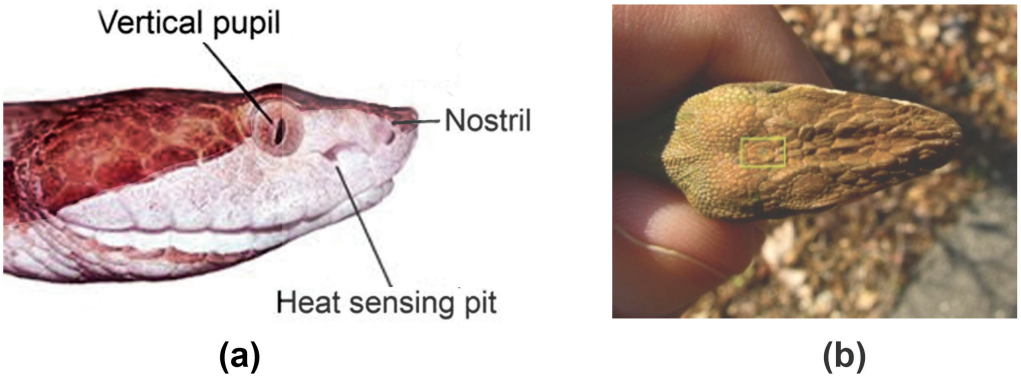


Fig.15.12: Snakes and lizards have highly developed chemoreception: a) heat- sensitive pit organ of a snake; b) parietal eye of an anole lizard.

15. In most reptiles, paired tympanum of external ears have evolved independently from amphibians and have been secondarily lost in some. Middle ear has a single bone called columella (Fig. 15.13).

16. Eggs are large with much yolk and are covered by leathery or calcareous (limy) shells. Eggs are usually laid and incubated outside (oviparous) or retained within the body for development (viviparous) Aminiotic embryes are nourished by yolk cell or placenta (ovoviviparity). Extra-embryonic membranes (amnion, chorion, yolk sac and allantois) are present during development of the embryos .

17. Sexes are usually separate but some lizards reproduce by parthenogenesis. Fertilization is internal usually by means of copulatory organs of males which are rarely absent. Male copulatory organ in case of crocodilians and chelonians (testudines) are a penis consisting of a phallus or in case of snakes and lizards a hemipenes (Fig. 15.14 a and b).Sex determination is by chromosomes or by the environment.

18. Young ones on hatching (or on being born) resemble adults. Metamorphosis is absent in reptiles. Parental care is absent in reptiles except in crocodilians.

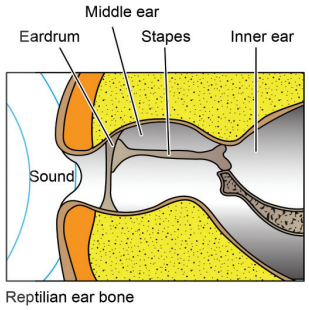


Fig. 15.13: Cross section of reptilian ear showing the tympanic-membrane (external ear), middle ear with collumella bone and the inner ear.

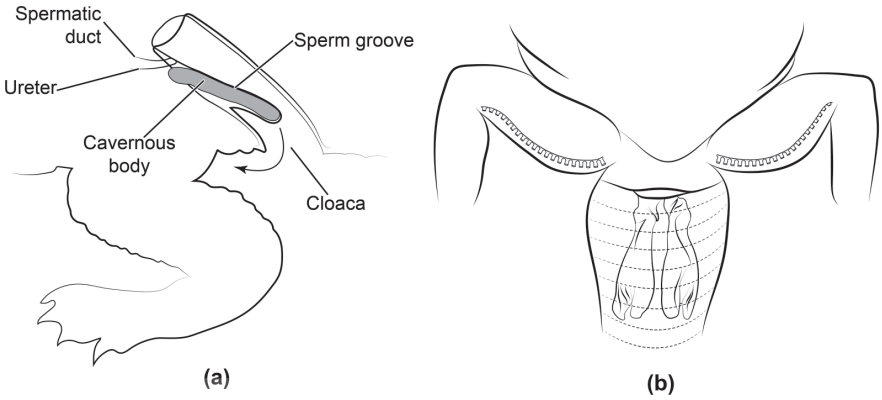


Fig. 15.14: Male reproductive organs of reptiles: a) copulatory organs of crocodilians and chelonians is a penis which consist of a phallus of erectile tissue; and b) copulatory organs of snakes and lizards consist of a pair of hemipenes which are everted from the tail base through the anal vent.

SAQ 2

Choose the correct word from parenthesis:

a) Reptiles are (ectothermic/ endothermic) and maintain a relatively high body temperature.

b) Teeth when present in reptiles are (polyphyodont/monophyodont)and are usually homodont

c) In reptiles (urea/uric acid) is the main nitrogenous waste that is excreted.

d) Young reptiles hatch as (gill/lung) breathing juveniles.

e) Gizzard is present only in (crocodilians/turtles)

15.4 CLASSIFICATION OF REPTILES

The traditional classification of amniotes has recently undergone important changes due to the use of cladistic methods of classification. **Cladistics** or phylogenetic classification places organisms in hierarchical monophyletic groups. This means that organisms that have a common evolutionary ancestor or ancestral group are placed together on basis of uniquely shared derived characteristics, called synapomorphies. As shown in Fig.15.15, the amniotic lineage is monophyletic which means that reptiles, bird and mammals all share a common ancestor. The traditional classification of Class Reptilia includes only turtles, lizards, tuataras, crocodilians and snakes and several extinct groups such as dinosaurs, pterosaurs, plesiosaurs and 'mammal' like reptiles and excludes birds which are placed in Class Aves, which is contrary to the current modern classification of reptiles.

15.4.1 Cladistic Classification of Reptiles

According to modern or cladistic classification, biologists have placed both birds and reptiles (excluding mammal like reptiles), in the same Class, namely Reptilia as they have the same origin and possess several common features

that unite them for example: i) type of skull, ii) ankle characteristics and iii) presence of a special type of keratin called beta keratin. Fig. 15.15 shows the phylogenetic tree of amniotes in which you can clearly see the shared ancestry of birds that belong to the Class Aves with the traditionally defined Class Reptilia that contains turtles, tuatras, snakes, lizards crocodiles and dinosaurs. Cladists consider the reptilian group that consist of dinosaurs, and crocodilians as a sister group of birds since both these groups are considered to be recent descendants from a common ancestor.Cladidsts thus group both reptiles and bird together in the Superorder Archosauria (which also includes the extinct dinosaurs and pterosaurs) of the class Reptilia.

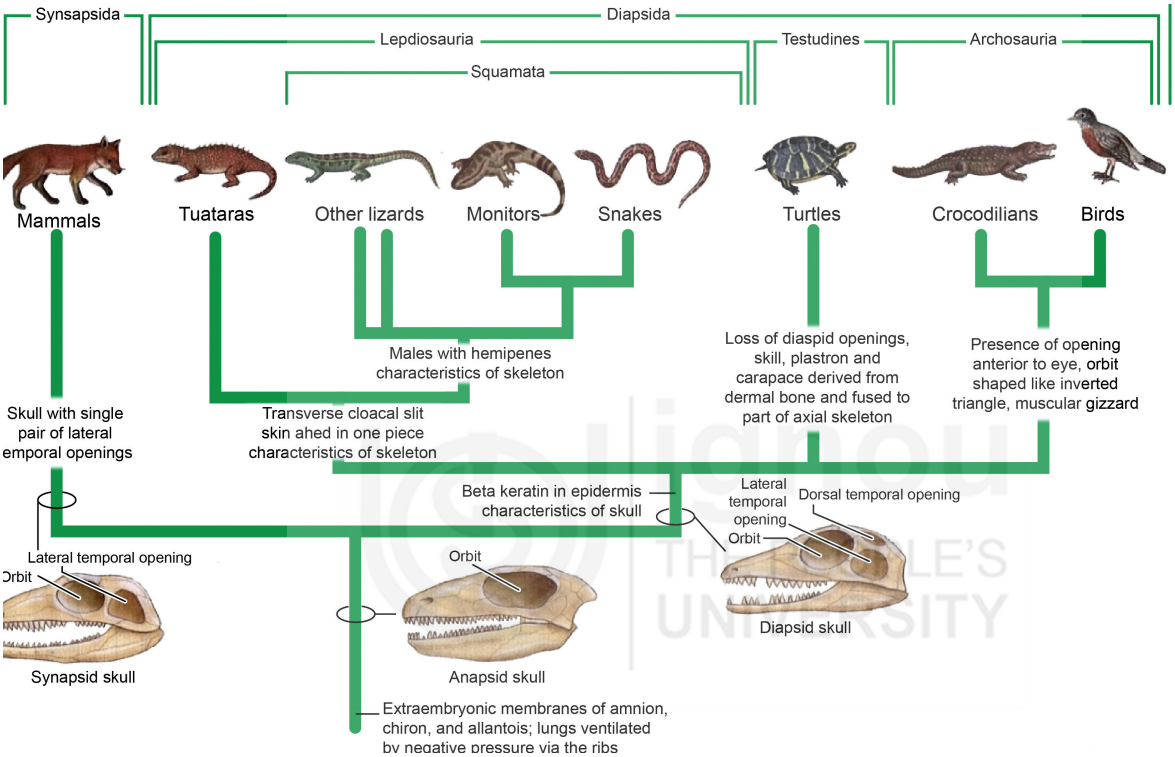


Fig. 15.15: Cladogram of living Amniotes showing the monophyletic groups. Figure modified from Hickman.

However, traditional taxonomists disagree and think that while crocodilians remain within the general reptilian adaptive zone and grade, the birds however, represent a novel adaptative zone and grade of organisation. According to their view the morphological and ecological novelty of birds should be recognised by maintaining the traditional classification that puts crocodilians in the Class Reptilia and birds in the class Aves. Traditional taxonomists argue that even though the Class Reptilia is a paraphyletic (different origin) group as determined by cladistic studies however, it should only include those amniotes which are neither birds nor mammals and share a common ancestry with reptiles.

15.4.2 Traditional Classification of Reptiles

In the present unit we have followed the traditional taxonomic classification and have included only those amniotes in the Class Reptilia which are neither birds nor mammals. We have also used the term reptiles instead of the present practice by some zoologists who use the term “nonavian reptiles”.

However, we want you to be aware that the classification of reptiles is subject to considerable revision.

All extant reptiles and bird have a diapsid skull and are placed in Subclass Diapsida which has four morphologically distinct superorders and one order (Fig.15.5) as described below:

1. **Superorder Lepidosauria:** Lepidosaurs are the largest group of reptiles (non-avian reptiles). Members of this superorder are characterised by sprawling posture. Bipedal specialisation is absent in them. The diapsid skull is usually modified by loss of one or both temporal arches. Lepidosaurs, unlike other tetrapods have a transverse cloacal slit instead of a longitudinal cloacal slit. Skin is shed in one piece. Lepidosaurs include 2 orders of living reptiles – Order Sphenodonta consisting of 1 species of Tuataras, and Order Squamata comprising about 5500 species of lizards and more than 3300 species of snakes.
2. **Superorder Archosauria:** This superorder contains the advanced diapsids. Gizzard is present in this Super order. The ventricle of the heart is fully divided. Parental care of young is present. Members of this super order include the living archosaurs namely, crocodilians placed in Order Crocodilia and birds and their extinct relatives namely, dinosaurs and pterosauras all of which are placed in Order Ornithisuchia. Many members like dinosaurs and birds belonging to this group are bipedal. You will be studying about birds (aves) in Unit 16 entitled “Aves”.
3. **Super order Sauropterygia** includes several extinct, aquatic sauropterygians like the long necked plesiosaurs.
4. **Superorder Ichthyosauria** is represented by extinct, ichthyosaurs that were aquatic, dolphin-like forms.

   Order Testudines includes all turtles both extant and fossil forms. The relationship of turtles to other diapsids is not clear but they seem to show affinity to lepidosaurs and archosaurians.

15.4.3 The Four Extant Reptilian Orders

The earth at present does not harbor as many reptiles as it once did. Out of the dozen or more main lines of reptiles that have been known to exist in reptile history, biologists have classified 11 orders of which only four are surviving today.

The four extant orders comprise of about 10,000 species and are clearly a successful group of reptiles, occupying a large variety of terrestrial and aquatic habitats. The most successful among these are lizards and snakes. The four extant orders that we will describe in the forthcoming sections are:

1. Order Testudines (Chelonia)
2. Order Sphenodonta
3. Order Squamata
4. Order Crocodilia

Let us now study the characteristic features of each order in more detail in this unit.

15.5 ORDER TESTUDINES

Turtles and Tortoises belong to the order Testudines (Chelonia) and are mostly aquatic though some are also terrestrial. Fossil records of turtles appear in the Triassic period, about 220 million years ago (mya) and the present day turtles have not changed much. There are approximately 225 species having the following general characters:

15.5.1 Characterstic Features of Testudines

1. Testudines vary in size from a few centimeters like the speckled padloper tortoise which is the smallest turtle, measuring less than 8 cm in length and weighing about 140 g, to large forms like the marine leatherback turtles that may be 2 meters in length and can reach a weight of over 900 kg (Refer again to Fig. 15.5).
2. The body or trunk of the turtles is short and broad and is enclosed in a protective bony shell. The dorsal portion of the shell is called **carapace** and the flatter ventral part is called the plastron (Fig. 15.16).

The terms "turtle", "tortoise" and "terrapin", are applied differently to different members of the order. The term tortoise is often used for land turtles, especially the large forms. British use of the term differs: tortoise is an inclusive term while turtle is used only for aquatic members. In North American usage, they are all correctly called turtles.

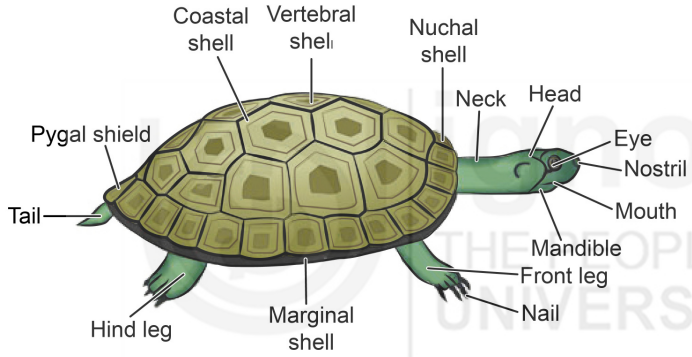


Fig. 15.16: External features of a turtles showing its plastron and carapace.

3. The carapace of the shell includes five rows of bony plates which internally enclose the fused vertebrae, laterally expanded ribs and bones in the dermis. Plastron is developed from the expanded and ossified dermal bones of the pectoral girdle (Fig.15.17 a). Keratin covers the shell on the outer side. As the turtles grow and age, new layers of keratin are laid down beneath the old ones. The shell of the turtle offers them protection. In many turtles the head and appendages can be drawn inside the shell for protection (Fig. 15.17 b).

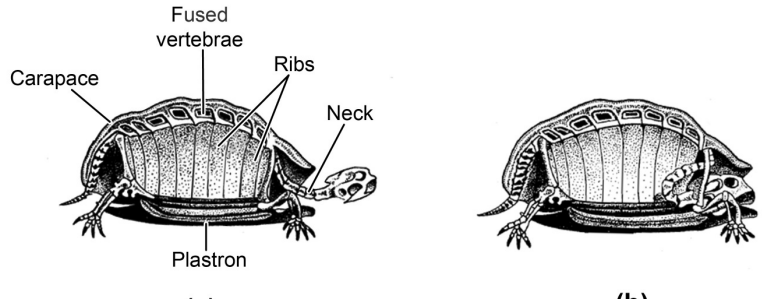


Fig. 15.17: The skeleton and shell of a turtle showing : a) the fusion of vertebrae and ribs with the carapace; and b) Most but not all turtles can bend their long and flexible neck into an S-shaped loop and then withdraw their head into their shell for protection.

Turtles at present are also an endangered lot because of the edibility of their meat and eggs and use of their shells for ornaments. Their vulnerable life history, changes in their environment and destruction of their habitats also contribute to their endangered status.

4. Turtle brain is small and never exceeds 1% of body weight however, it is larger than that of an amphibian. The turtle brain shows well developed cerebral hemispheres. Turtles are able to learn a maze nearly as quickly as a rat.
5. Tesudines have sharp vision and colour perception. Their eyes consist mainly of cones many of which contain oil droplets of various colours.
6. Turtles have a middle and an internal ear, but lack an external ear and so their sound perception is poor. Therefore, most turtles are mute although many tortoises during mating utter grunting or roaring sounds. The poor hearing sense of turtles is compensated by a good sense of smell and sharp vision.
7. Testudines include both i) herbivorous and ii) carnivorous forms. The earliest turtles possessed teeth and a reduced shell and but were otherwise very much like the modern turtles. Jaws of modern turtles are unique as they lack teeth and instead have tough, keratinized plates for gripping and chewing food. The tongue of testudines is not extensible.
8. Since the vertebrae of turtles are fused with the carapace, they therefore, compensate for an inflexible trunk by having a long flexible neck that facilitates feeding (Refer again to Fig. 15.17 b).
9. The limbs of testudines are stout but otherwise typically reptilian, with five digits in each. In terrestrial tortoises feet are stumpy while amphibious turtles normally have feet that are webbed and often have long claws. In the marine turtle they are transformed into paddles (Fig. 15.18). A unique feature of testudines among the vertebrates is that the limbs and limb girdles in testudines are located inside the ribs.

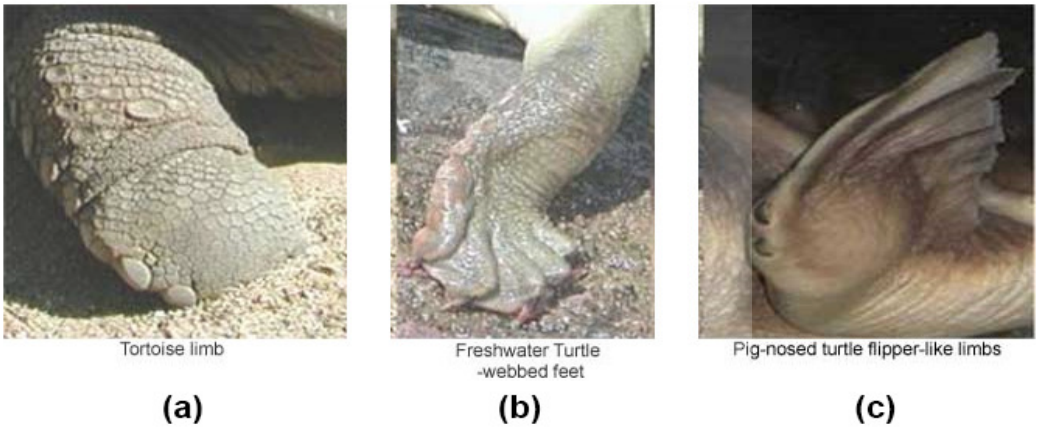


Fig.15.18: Different types of limbs found in turtles : a) Limb of a terrestrial turtle showing feet which are not webbed; b) Limb of a freshwater, aquatic turtle showing a webbed feet; and c) a flipper kind of limb of an aquatic turtle.

10. Tesudines due to their rigid shell, being fused with the ribs cannot expand their chest to breathe by changing the diameter of the rib cage as is done by the other amniotes. Lung ventilation in turtles is accomplished by using certain abdominal and pectoral muscles as a diaphragm. In order to draw in air the turtles, contract their limb flank muscles so that the volume of

the body cavity increases and pressure inside the shell and lungs decreases, so that air is drawn into the lungs. Exhalation is also an active process in which the shoulder girdle of turtle is drawn back into the shell, resulting in the compression of the viscera (organs). This forces the air out of the lungs. Lung ventilation is also helped by limb movement during walking. Many aquatic species gain oxygen supply through the vascular lining of their mouth and cloaca while pumping water in and out of their vascularized mouth cavity or cloaca. This allows them to remain submerged in the water for long periods when inactive. When active they need to breathe through the lung more frequently

11. Turtles have metanephric paired kidneys. Urine of turtles is fluid and consists mainly of uric acid.
12. Fertilization in turtles is internal. Turtles do not lay their eggs under water, although many species live in or around water. All turtles, even the marine forms bury their shelled, amniotic eggs in the ground. Females come ashore to lay eggs and usually take great care in making their nest but once the eggs are laid and covered, the female deserts them.
13. In some turtle families, in all crocodilians and some lizards the sex of the hatchlings is determined by the nest temperature. Males are produced if temperature is low during incubation while females are produced when temperature is high during incubation. Reptiles in which sex determination is temperature dependent lack sex chromosomes.

SAQ 3

Fill in the blanks with correct words in the following statements:

a) The dorsal portion of the turtle shell is called ……and the flatter ventral part is called the…….. .

b) Fertilization in turtles is…….. .

c) Reptiles in which sex determination is ……dependent lack sex chromosomes.

d) Jaws of modern turtles ……teeth.

e) The vertebrae of turtles are fused with the…… .

15.6 ORDER SPHENODONTA

Order Sphenodonta (Rhyncocephalia) consists of the tuataras which belong to a single surviving genus *Sphenodon* that is found only in New Zealand. The name tuatara is derived from the Maori(Mori) language, and means “peaks on the back” or “spiny back.” as the tuataras have a crest on their back (Fig.15.19) Tuataras have been referred to as living fossils which means that they have remained mostly unchanged throughout their entire history, of approximately 200 million years. However, this is now considered to be incorrect as recent taxonomic studies on Sphenodonta have shown that this group has undergone a variety of changes throughout the Mesozoic period.

Earlier it was thought that there were two living species of tuataras:1) *Sphenodon punctatus* (Northern tuatara) which has been protected by law by the New Zealand Government since 1895 and 2) *Sphenodon guntheri* (Brothers Island tuatara) which is confined to North Brother Island in Cook Strait. However a recent study published in 2010 on variations in mitochondrial DNA of both the species, concluded that both the species, are the same and should be known as *Sphenodon punctatus.*

15.6.1 Characterstic Features of Sphenodonta

Tuataras are the most primitive of the surviving lepidosaurs. The characteristic features of tuataras are:

1. Adult tuataras (Fig. 15.19) are terrestrial and nocturnal and live in burrows often shared with petrels (birds). The tuataras colour ranges from olive green to brown to orange-red. Tuataras can change colour over their lifetime. They shed their skin at least once every year, usually 3 or 4 times as juveniles.
2. The tuataras are medium-sized reptiles and resemble lizards. They have a strong tail. Adults are about 60 centimeters long from head to tail tip and weigh between 300 g to 1.3 kg. Both male and female tuataras have a crest of spiky scales, called spines, down the center of their back and tail. The spiny crest on their back is made of triangular soft folds of skin.
3. Tuataras have a primitive, diapsid skull with two pairs of temporal opening bounded by complete arches. Such type of a skull is not found in lizards but was present in the early Permian reptiles that were ancestors to the modern lizards.
4. The jaw of *Sphenodon* is inflexible as its upper jaw is firmly attached to the skull and the quadrate bone is immovable. The two jaws of the tuatara are joined by a ligament which allows it to chew the food with backward-forward movements. The tip of the upper jaw of the tuatara is beaklike and has two rows of teeth while the lower jaw has a single row of teeth. When the mouth is closed the single row of teeth of the lower jaw fit perfectly into the groove between the two rows of teeth in the upper jaw. This type of teeth arrangement is not seen in any other reptile. The teeth of the tuatara are small and are of acrodont type, (teeth are not in sockets but are fused directly with the upper part of the jaws) and so are not separate structures but sharp projections of the bone. Teeth of tuataras are not replaced when lost or broken.
5. Tuataras (sphenodonts) have a pair of normal, lateral eyes and also a single third eye on the top of their head called the parietal eye. Amongst all extant tetrapods, the parietal eye is most pronounced in tuatara. The parietal eye has its own lens, cornea, retina with rod-like structures and a degenerated nerve connection to the brain, suggesting it evolved from a real eye. The parietal eye is only visible in hatchlings. The function of this eye is not known, but it is thought that it may be useful in absorbing ultraviolet rays to manufacture vitamin D and also to determine light/dark cycles, and help with thermoregulation.
6. Tuataras have the most primitive hearing organs among the amniotes. They do not have external ears or eardrums, though they can respond to sound frequency in the range of 100-800 Hz.
7. Locomotion is by lateral undulations of the trunk and tail while moving.
8. Tuataras display sexual dimorphism, as the males are larger than females. The spiny crest on the back of males is bigger than in females and can be stiffened for display. However male copulatory organ is absent

in these animals. Tuataras reproduce very slowly, sometimes taking ten to twenty years to reach sexual maturity. White and soft-shelled eggs are laid by the female in covered, nesting burrows. Eggs incubate in the burrow for 12 to 15 months before hatching. The tuataras possibly have the longest incubation period as compared to any other reptile.

9. The gender of the tuatara is determined by the temperature of the nest where the eggs are incubated. It has been found that a difference of just one degree centigrade can change the young in a clutch of eggs from all females to all males. Eggs incubated at 21^{O}C have an equal chance of producing either males or females. At 22^{O}C about 80% of the eggs will produce males while at 20^{O}C, 80% are likely to produce females. At 18^{O}C all the hatchlings will be females.

10. Tuataras probably have the slowest growth rates of any reptile, continuing to grow larger for the first 35 years of their lives. The average life span is about 60 years, however, they can live to be over 100 years old. A male captured in 2012 is recorded to have been 114 years old.

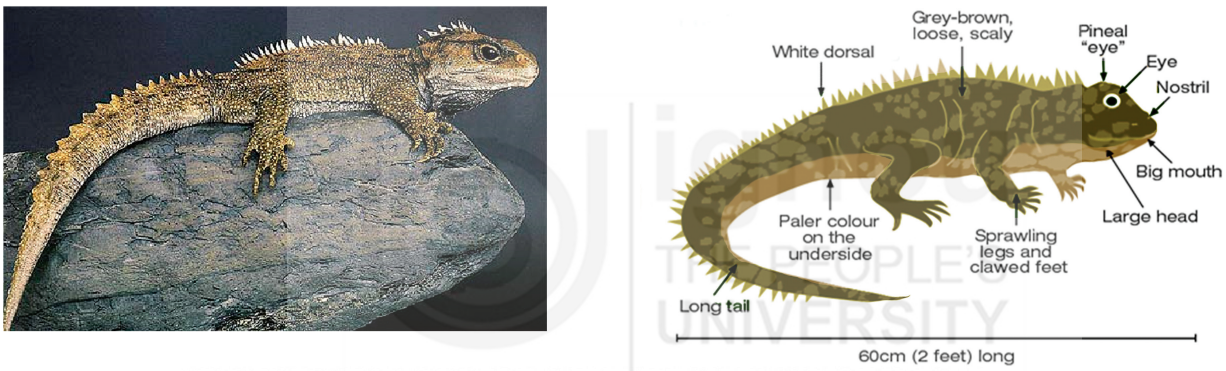


Fig.15.19: *Sphenodon punctatus* are commonly called tuataras and are the only living representative species of Order Sphenodonta and are found only in New Zealand:(a) A photograph of tuatra and (b) A labelled diagram of tuatara.

(http://www.factzoo.com/sites/all/img/reptiles/tuatara-perched-rock.jpg)

SAQ 4

Choose the appropriate words from the alternatives provided in the following statements.

a) *Sphenodon* is the most primitive surviving (archosaur/lepidosaur).

b) *Sphenodon* has a skull which is of (primitive diapsid/anapsid type).

c) In male *Sphenodon* a copulatory organ is (present/absent).

d) In *Sphenodon* teeth are (absent/present).

15.7 ORDER SQUAMATA

Lizards and snakes belong to the Order Squamata. Both these are the most successful of modern reptiles and together constitute, nearly 6000 species.

Box 15.2: Symbol of the medical profession

The medical profession as you may have noticed is symbolised by two snakes entwined around a staff called the caduceus (an Ancient Greek or Roman Herald's wand) carried by the messenger god Hermes or Mercury.

The squamates are diverse products of diapsid evolution, and make up approximately 95% of all known living reptiles (non avian reptiles). Lizards appeared according to fossil records in the Jurassic Period. Snakes appeared during the late Jurassic period and are believed to have evolved from a group of lizards whose descendents include the monitor lizards and Gila monster..

The familiar lizards, snakes and worm lizards though superficially different are similar enough in basic structure to be placed in a single Order Squamata.

15.7.1 Characterstic Features of Squamates

The most significant characters of squamates are:

i) Determinate growth (growth that stops when a genetically pre-determined structure has formed completely) which also occurs in birds and mammals but does not take place in crocodilians and turtles as they continue to grow throughout their lives, although, the growth rates of adults are much slower than those of juveniles.

ii) The typical lizards exhibit a number of primitive reptilian features. Members of Order Squamata as a group show interesting specialisations that are absent in *Sphenedon*.

iii) In majority of squamates, especially in snakes, the skull is highly kinetic, with a freely movable quadrate bone in the jaw, which allows the bones of the upper jaw to move freely. You will study about the kinetic skull of snakes in more detail in the forthcoming Sub-section 15.7.1.

iv) Paired copulatory organs of a unique type are present in the males (Refer again to Fig. 15.14).

v) There is a widespread tendency towards limb reduction, which appears to have taken place independently in extant snakes and in members of about half of the families of lizards.

vi) Among the living avian reptiles viviparity is limited only to squamates. Viviparity in this order has evolved about 100 separate times. In this group the developing young obtain nutrition from yolk sacs and this type of development is termed as lecithotrophy or ovoviviparity.

Order Squamata is divided into two Suborders namely:

i) **Suborder-Serpentes (Ophidia):** This includes snakes.

ii) **Suborder-Lacertilia, (Sauria)**, which consists of lizards and *Amphisbaena* (worm lizards).

15.7.2 Characteristic Features of Suborder Serpentes (Ophidia)

Snakes are considered odd creatures and are feared and loathed by many people but revered and worshipped in many cultures as symbols of power, healing and rejuvenation. Two specialisations that characterise snakes are

i) extreme elongation of the body and the accompanying displacement and rearrangement of internal organs; and ii) specialisation for eating larger sized prey (Fig.15. 20 a).

Snakes are found in temperate and tropical regions and are completely absent in New Zealand. In India there are a large number of both non-venonous (non-poisonous) and venomous (poisonous) snakes.

1. Snakes have elongate bodies as you have learnt in this unit. Most snakes are entirely limbless and lack sternum, and both pectoral and the pelvic girdles. Boa constrictors and python however, (Refer again to Fig. 15.8) are exceptions and retain spur like rudiments of hind legs that are used in courtship. Snakes may have more than 200 vertebrae and attached pair of ribs (Refer again to Fig. 15.7). The vertebrae are shorter and wider than those of other tetrapods and so allow quick, lateral undulations of the snake's exceptionally long trunk and tail through grass and over rough terrain. The snake has several slender, segmental body muscles that connect vertebrae to vertebrae; vertebrae to ribs; ribs to ribs, ribs to skin; skin to skin. Many muscles extend from one body segment to the next but other connect by tendons between segments far removed from one another. This arrangement makes possible the graceful sinuous movement of a snake. Locomotion for snakes is an obvious problem, since they are limbless. It is accomplished in two ways : i) by sideward muscular undulations of the body and ii) by movement of transverse ventral scales.

2. The snake tongue is narrow, flexible and ribbon like with a forked tip. The tongue can protrude through a notch in the upper jaw when the mouth is closed (Fig. 15.20 a and b).

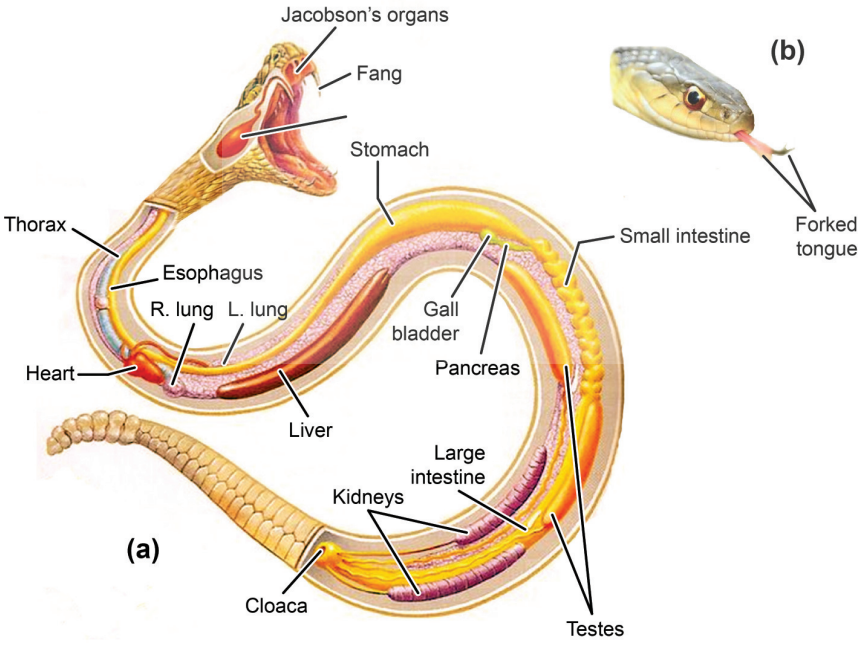


Fig.15.20: Morphology of a snake showing: a) elongated,compressed body and the placement of its internal organs; b) head of snake showing forked tongue that can protrude even when the mouth is closed.

3. The body of snakes similar to lizards is covered entirely with a tough, impervious scaly skin (Fig.15.21 a and b). The type, shape, size and location of the head scales and also the trunk scales are used to distinguish between non-venomous and venomous snakes about which you will study in detail in Sub-section in 15.7.3.

4. The scales of snakes may be smooth as in king cobra or keeled as in rattle snakes, garter snakes and others(Fig.15.21 a and b).The skin of snakes is not elastic and so when it needs to stretch, as it must after an enormous lunch, it does so in an unusual manner. The hard scales are normally set together, sometimes overlapping like shingles on a roof, with the skin folded inward between the scales (Refer again to Fig.15.6). When the snakes swallow a large object, the skin folds are pulled out straight, leaving the scales separated like islands on the skin.

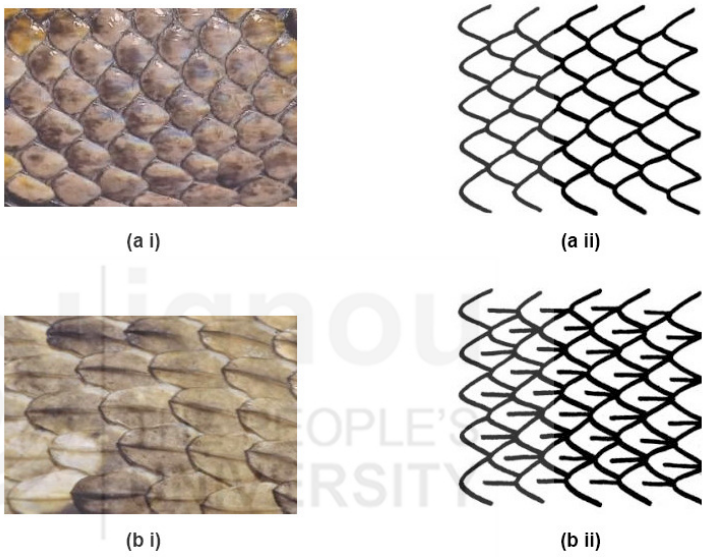


Fig.15.21: Snake body showing scales : a) smooth scales (i) photo (ii) diagram; b) keeled scales (i) photo (ii) diagram

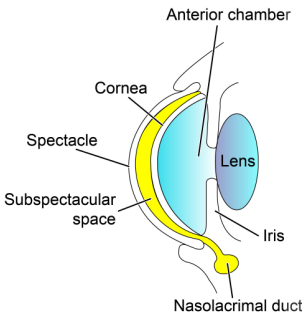


Fig.15.22: Cross section of a snake eye.

5. Most snakes have relatively poor vision, with the exception of some of the arboreal snakes that have excellent binocular vision. Eyes of snakes and some lizards have immovable eyelids. The cornea of the eye is permanently protected by a clear, transparent fused scale, termed as a spectacle (Fig. 21.1).The spectacle together with a lack of eye ball mobility, give the snakes their cold, unblinking stare that most of us find so unnerving. Between the spectacle and cornea there is a subspectacle space in which a tear film is present. Tears drain into the mouth through the nasolacyrimal duct system. Nasolachyrimal ducts are absent in testudines and so tears from their eyes spill over their lid margins.

6. Snakes lack external ears or tympanic membrane but have a pair of middle ears and a pair of internal ears. In snakes as well as in all reptiles each middle ear consists of a single bone called columella. Snakes can hear sound within a limited range of low sound frequencies (100 to 700 Hz) and are quite sensitive to vibrations travelling through the ground. Sound waves are transmitted via the quadrate bone in the jaw to the internal ear. Snakes also have a highly developed sense of touch with tactile receptors distributed throughout the length of their body.

7. Most snakes, however, use chemical senses rather than vision and hearing to hunt their prey. For this, snakes possess in addition to the usual olfactory areas in the nose, (which are not well-developed) a pair of pit-like chemosensory organs in the roof of the mouth called the **Jacobson's organs** (vomeronasal organs). Each of the Jacobson's organ has a duct opening, far forward on the palate. These organs are lined with a richly innervated chemosensory epithelium. The sensitive, forked tongue of the snake (and many lizards) picks up the odour particles from food, mates, predators and perhaps rivals and conveys these smells to the roof of the mouth. Tongue is then drawn past the Jacobson's organs or the tip of the forked tongue is directly inserted into the organs. Information is then transmitted to the brain where the scent is identified. The Jacobson's organ occurs in many other terrestrial vertebrates. It is particularly well-developed in snakes, which needs it to follow prey trails and for sex recognition (Fig. 15.23 a).

   Snakes such as pythons and boas referred to as "Boids'' and the pit vipers too have special heat-sensitive **pit organs** on their heads, located between their nostrils and eyes (Fig. 15.23 b) which respond to radiant or heat energy (long wave infrared 5000 to 15000 nm) and are especially sensitive to heat emitted by the warm bodied animals of their prey whom they can track and effectively strike even in total darkness.

8. The digestive tract in snakes is basically a straight tube from mouth to vent (anal opening). Virtually all other internal organs are elongated and the left lung is usually vestigial (Refer again to Fig. 15.20).

9. Hemipenis (plural: hemipenes) as in lizards are present in males (Refer again to Fig. 15.14 b).

10. Most snakes are oviparous that lay shelled elliptical eggs; others are ovoviviparous and a very few are viviparous, where a primitive placenta forms for the exchange of materials between embryonic and maternal blood streams.

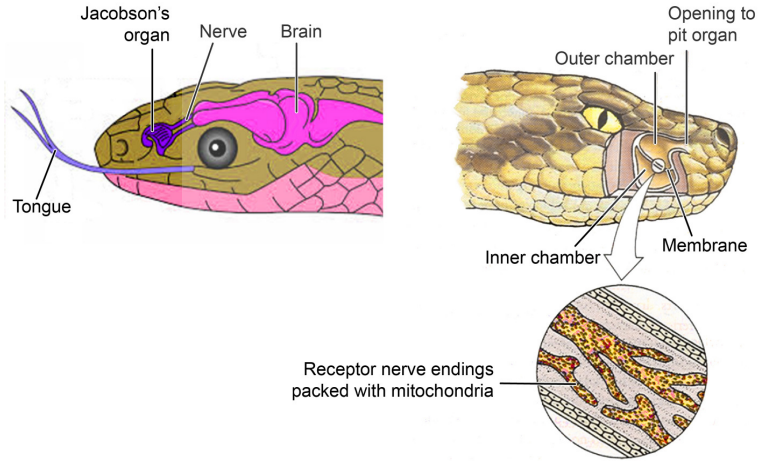


Fig. 15.23: Head of snakes showing: a) Jacobson's organ; b) Pit organ of a rattle snake (pit viper) with a cutaway showing location of a deep membrane that divides the pit into inner and outer chambers. Heat sensitive nerve endings are concentrated in the membrane.

11. Most snakes eat their prey live, they neither chew nor tear their food but swallow it whole. Snakes like pythons and boas, which constrict and kill their prey often, eat much larger preys. Venomous snakes inject venom in order to kill the prey before swallowing it.

15.7.3 Kinetic Skull of Snakes: Mechanism of Biting and Eating

Although snake species have different methods of finding and catching prey, all snakes eat in basically the same way. Most snakes capture their prey by grasping and swallowing them whole as you have read earlier. This is because of their amazingly kinetic skull and expandable jaws that enables them to prey on animals of much larger size than their mouths.

1. Features in Snakes for Swallowing Larger Sized Prey

The bones of jaws and skull in a kinetic skull are looslly joined with each other by elastic ligaments and may move apart due to the ligaments in order to ingest preys that are much larger than the snake's head. Furthermore, the skull bones move upon one another as all of them are loosely attached. This ensures that each bone is capable of moving independently. The swallowing of larger animals is possible due the following features of the kinetic skull (Fig. 15.24 a and b):

i) In snakes the bones of the upper jaw and lower jaws in the skull are movable due to being joined by ligaments.

ii) The two halves of the upper jaws are joined together anteriorly only by flexible ligament tissue in the form of muscle and skin that allow the jaws to spread far apart.

iii) In the same way the two halves of the lower jaw (mandibles) are also connected anteriorly by a flexible ligament tissue in the form of muscle and skin, that allow the jaws to spread far apart.

iv) Each half of the upper and the lower jaws can move independently of one another. Thus these flexible jaws while swallowing the prey advance alternately over it by a type of walking movement.

v) The loose and flexible attachment of the quadrate bone connects the upper jaw with the lower jaw posteriorly,

vi) Slender, backward pointing teeth present on the jaws and palate of both non venomous and venomous snakes prevent the food from slipping forward, once swallowing has begun.

vii) Absence of sternum (breast bone) and presence of ribs, which are ventrally free of any bony articulation, allows the body wall to be dilated.

viii) Presence of soft elastic skin between scales on the back and sides of body allow further dilation of the body wall.

ix) Walls of oesophagus and stomach are thin and easily stretchable.

x) The glottis of the trachea is placed far forward, between the jaws and just beneath the sheath for the slender tongue. This allows the snake to

respire even while swallowing food. In addition to this the glottis during swallowing may be projected forward in order to further aid in breathing (Fig.15.25).

xi) In some venomous snakes during the strike, the structural elements of the skull bones and the movement of skull bones function like a lever system to erect the fangs.

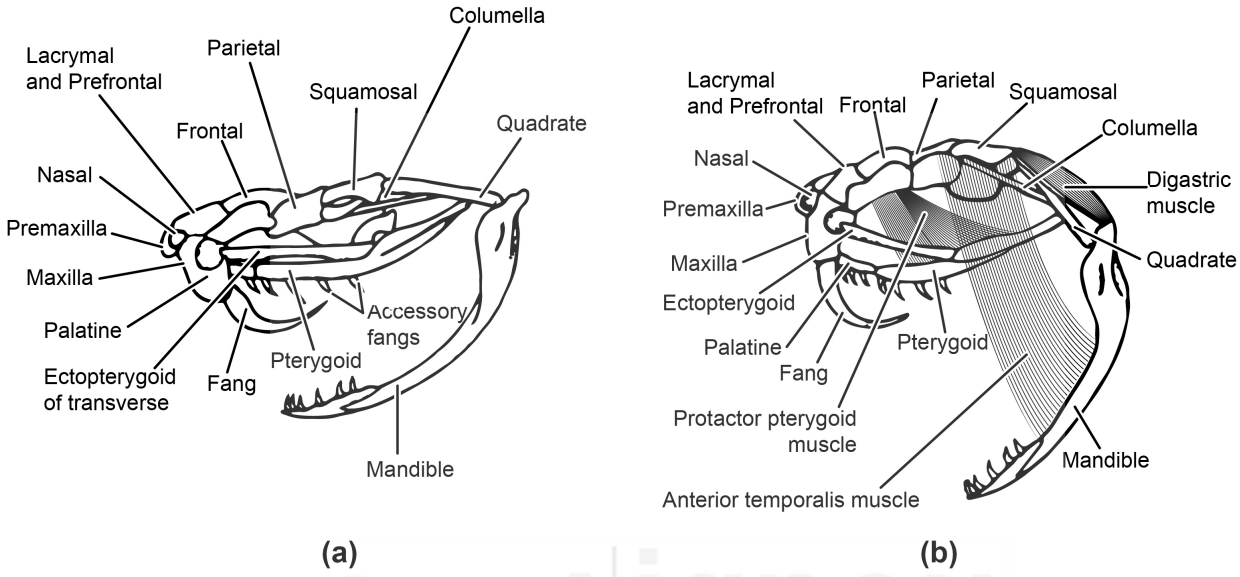


Fig. 15.24: The skull of all snakes is extremely kinetic and each side of the extremely kinetic skull has several movable bones which permit extraordinary movements of the jaw during feeding. The halves of the lower jaw are united by flexible soft tissues that permit wide separation and independent movement of each side. Lateral view of a skull of a venomous snake (viper) showing the biting mechanism: a) Mouth closed; b) Mouth open when striking.

2. Venomous Apparatus of Snakes:

The ability of venomous snakes to inject venom whether mild or extremely toxic, into the prey is through paired **fangs** that are located on the maxillary bone present with one fangs on either side of each half of the upper jaw. The fangs are supplied with venom by their **venom glands** (Fig. 15.25). The paired venom glands of the venomous snakes are exocrine glands (glands that

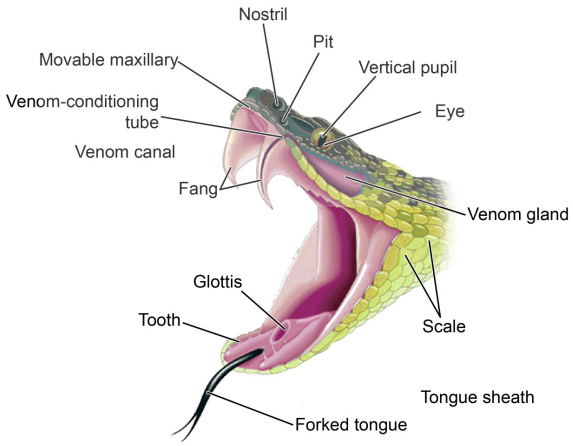


Fig. 15.25: Head of the venomous rattle snake, belonging to the family Viperidae showing the paired fangs with their associated venomous apparatus. Note the connection of the venom gland and the fangs via the venom duct.The glottis extends forwards while the snake is swallowing the prey.

produce and secrete substances onto an epithelial surface by way of a duct) in nature and are situated one on either side of the upper jaw in venomous snakes. Each venom gland is sac-like and is provided with a narrow duct at its anterior end. The gland is held in position by associated ligaments.

The fangs in venomous snakes act like hypodermic needles through which the venom (poison) is injected into the prey. The fangs are basically of two types:

a) Closed type as seen in vipers. In this type of fangs the poison groove forms a tunnel having two openings one at the base and one near the apex (refer again to Fig. 15.25); and

b) Open type as found in cobras in which the poison groove is of open type.

3. Biting and swallowing

The mechanism of biting in snakes is a complicated process and the sequences of biting can be described in the following steps:

Once a snake is ready to eat, it opens its mouth wide due to contraction of digastrics muscles. After the prey is captured the opposite sides of the upper and lower jaw are alternately thrust forward and retracted so that one side of the jaw pulls in the prey while the other side moves forward for the next bite. This action appears as if the jaws of the snake are "walking" over the prey. The snake drenches the prey with saliva and the backward-curving teeth grip it and prevent its escape and eventually help force the food into its oesophagus. The snake after this uses its muscles to simultaneously crush the food and push it deeper into the digestive tract, where it is broken down for nutrients. Because a snake must keep breathing during the slow process of swallowing, its tracheal opening (glottis) is thrust forward between the two mandibles of the lower jaw (Refer again to Fig. 15.25).

Vipers and rattle snakes, belonging to family Viperidae, possess hollow fangs on the maxillary bone at the anterior margin of the upper jaw (Refer again to Fig.15.24 and 15.25).These fangs are connected to venom glands that inject venom when the members of family viperidae bite. The fangs of the vipers are hinged on the maxillary bone of the upper jaw so that when the snake's mouth is closed, the fangs fold back and lie along the upper jaw. When the viper opens its mouth the maxillary bone rotates and causes the fangs to swing down and become erect.

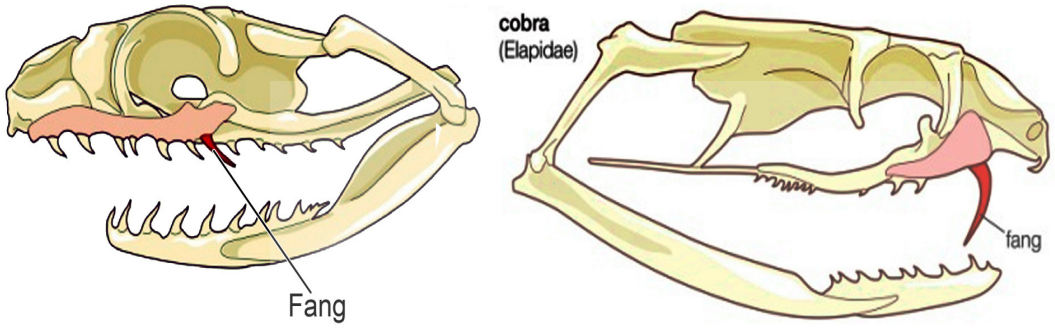
In case of the venomous, rear fanged snakes such as boomslang snake, which belongs to family colubride the fangs (Fig.15.26 a) are present at the rear end of the upper jaw and are grooved. In colubrid snakes that are venomous, when the snake bites the prey, the venom moves along the groove of the fang into the prey in order to quieten it during swallowing it.

In venomous snakes like cobras, coral reef snakes and sea snakes which belong to family Elapsidae the fangs (Fig.15.26 b) are always in an erect position and are rigidly attached to the upper jaw. When the mouth of these snakes is closed each fang fits into a pocket in the outer gum of the lower jaw. These erect and rigidly attached fangs may be either hollow or grooved. The

contraction of muscles associated with the venom gland injects venom into the fangs when the snake bites its prey. Some cobras can spit venom at their prey.

4. Closing of the mouth

The snake closes its mouth by the contraction of muscles. The time taken to open the mouth is longer than the time taken to close it.



Rear-fanged snake

(a) (b)

Fig. 15.26: The position of fangs in skulls of venomous snakes belonging to families a) Colubridae; b) Elapsidae.

15.7.4 Identification of Venomous and Non-Venomous Snakes

Venomous snakes can be easily distinguished from the non-venomous ones but it is extremely dangerous to try to identify live snakes on your own. Fig. 15.27 shows a venomous and a non-venomous snake that occur in India.

(a) (b)

Fig.15.27: a) Cobra (*Naja naja*), a venomous snakes that is found in India and is easily recognised by most Indians; and b) A new species of a non-venomous snake, named the Khaire's black shield tail (*Melanophidium khairei*) that has been discovered in India in 2016.

The identification of snakes is useful in case of a snake bite. It helps to provide first aid and then get proper medical aid. Before we explain to you, how to identify the various kinds of venomous snakes we would like you to become familiar with the types and names of the various scales that cover the head of snakes as shown in Fig. 15.28.

Names and location of head scales of snakes used for identification

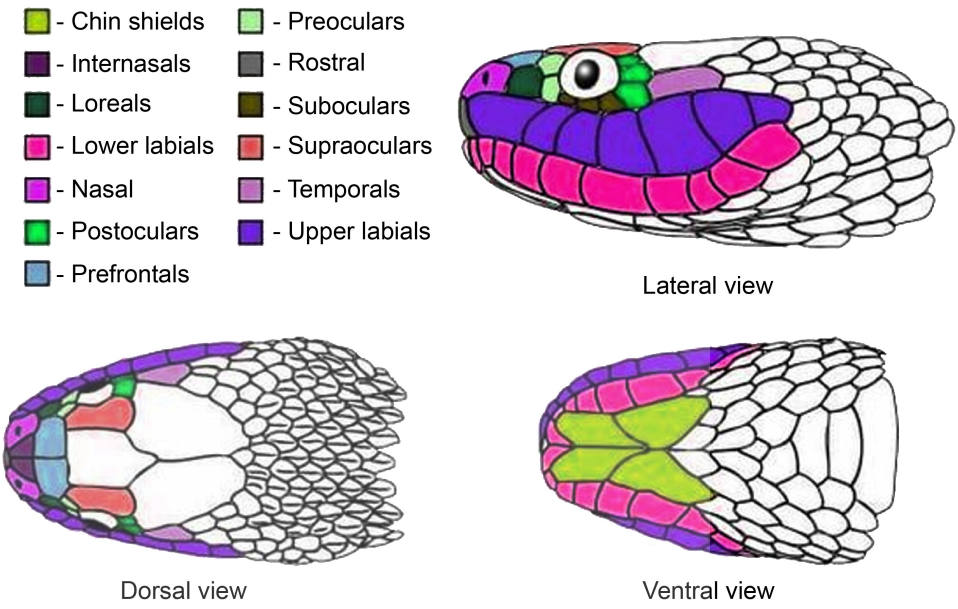


Fig. 15.28: Head of snake showing the various types of scales that are studied to differentiate between venomous and non-venomous snakes.

15.7.5 Identification Key of Venomous and Non-Venomous Snakes

Now let us learn to distinguish between venomous and non-venomous snakes with the help of Figs. 15.28 and 15.29 which are used as "a key", for identifying venomous and non-venomous snakes.

Let us begin by first examining the tail of the snake:

1. If the tail is laterally flattened and it is a sea snake then it is venomous, as all sea snakes in which tail is laterally flattened are venomous.

2. If on the other hand the tail is long, rounded cylindrical and whip-like the snake may be or may not be poisonous. In such cases examine the arrangement of scales on the ventral surface (belly) of the snake, (i) If the belly is covered by small, ventral scales or the ventral scales are somewhat broad as shown in the Fig. 15.29 then it is a non-venomous snake. **But** (ii) if the ventral scales are large, transverse plates that extend fully across the ventral side of the belly as shown in the Fig. 15.29, then it may or may not be venomous. For further identification now examine the dorsal surface of the head of the snake.

3. If the head is covered by small dorsal scales then it is a viper and all viper species are poisonous: i) If there is a loreal pit between the nostril and eye, then it is a pit viper which is venomous ii) If the sub-caudals (scales after the anal region) are in double rows and there is a loreal pit, than it is a Russel's viper and it is venomous;

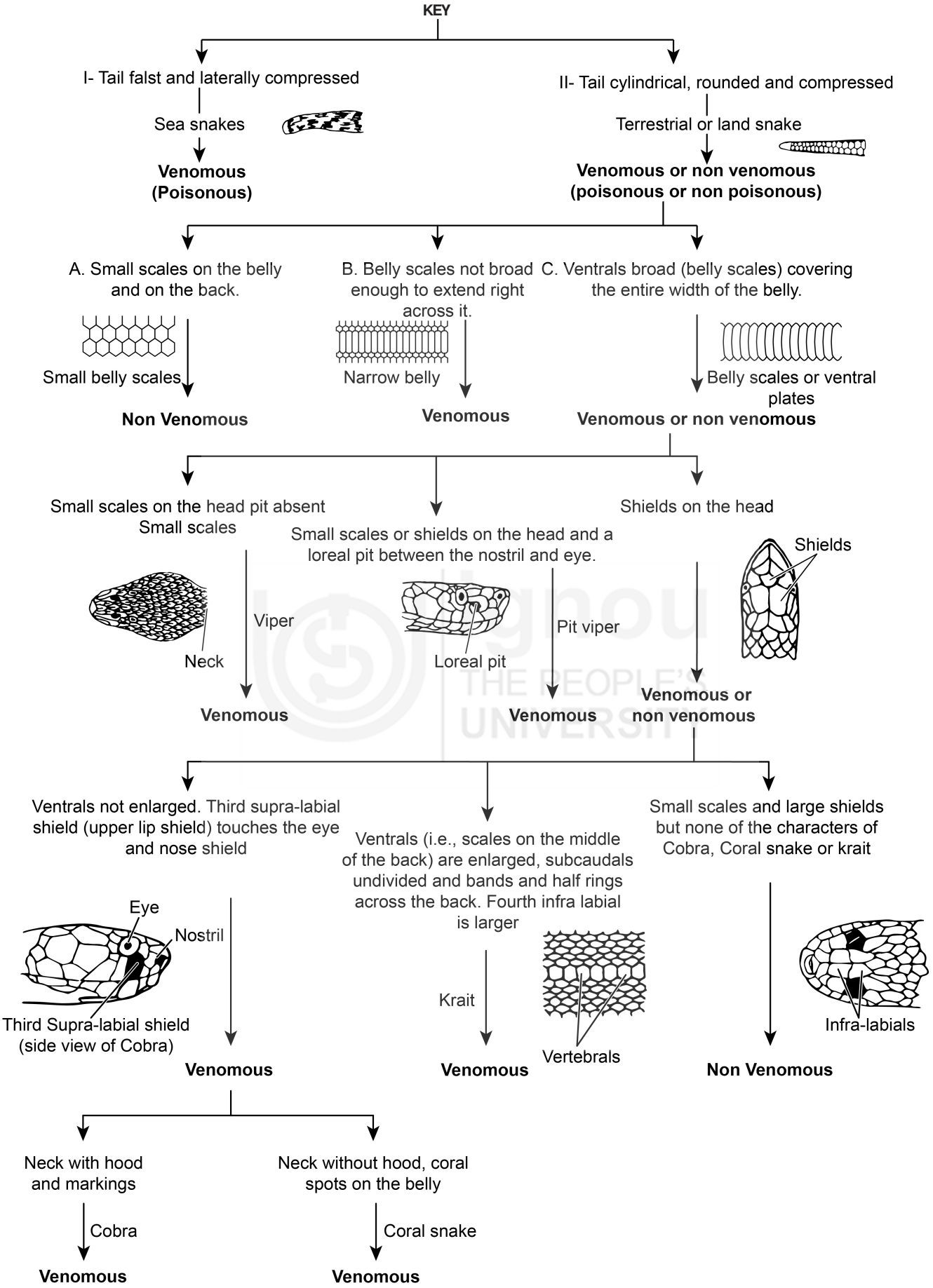


Fig. 15.29: Key for identification of venomous and non- venomous snakes.

4. Supposing the head is covered by both small and broad shield-like scales (shields) then it may or may not be venomous; In such cases examine the arrangement of scales along the margins of the jaws. Scales arranged along the margin of the upper jaw are called supralabials and those along the lower jaw are called Infralabials. (Fig.15.28 and 15.29). If the third supralabial anteriorly touches the scale that bears the nasal aperture and posteriorly touches the eye margin, then it is venomous and is a cobra, a king cobra or coral snake.

5. If the upper side of the head has both small scales and large shields but there is no loreal pit and the third supra-labial shield does not touch the eye then examine the back of the snake and ventral side of lower jaw. (i) If the middle row of scales on the back called vertebrals are larger than others and (ii) If ventral side of the lower jaw has a fourth infralabial shield which is larger than the others then it is a krait, and these are venomous.

6. If the snake has small scales and large shields on head but does not have characters of cobra, krait or coral snake, then it is non-venomous

SAQ 5

In the following statements pick out the suitable word from the alternatives that are provided in parenthesis.

a) In snakes, spur like rudiments of hind legs are only present in the (boas/cobras).

b) In snakes, during swallowing the glottis may be projected (backwards/forwards).

c) The arboreal snakes possess (poor /good) vision.

d) Most snakes in order to hunt their prey use (sight/chemical) sense.

e) In snakes the sternum is (absent/present).

f) The body scales of cobra are (smooth/keeled).

A large number of lizards are also found in India like the legless lizards, skinks, common house and garden lizards, horned toad and chaemeleons.Apart from these, other interesting lizards found in India are the monitor lizard *(Varanus sp),*though the largest monitors referred to as Komodo dragons are found only in Indonesia Some of these lizards are interesting because of their peculiar adaptations. Fig. 15.30 shows a few interesting lizards that occur in India and around the world.

15.7.5 Characteristic Features of Suborder Lacertilia (Lizards)

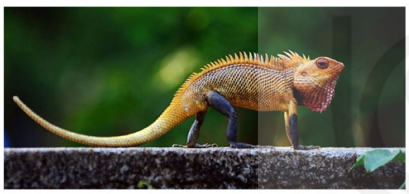
1. Modern Lizards are an extremely diversified group and include terrestrial, burrowing, aquatic, and arboreal members that are found throughout the temperate and tropical regions of the world. Most lizards are carnivorous, feeding on insects and other small prey. The gecko, that is a small and agile lizard has sticky toe pads that allows it to walk vertically or upside down. Another familiar lizard is the chameleon that is arboreal. Some larger species such as monitor lizards include the largest lizard “the Komodo dragon (*Varanus species*)” which preys upon vertebrates. Iguanas and some skinks are among the few vegetarian lizards. Gila monster (*Heloderma* species) is the only venomous lizard. Fig. 15.30 shows some lizards adapted for various modes of life.

(a.i) *Hemidactylus frenatus :* common house gecko

(a.ii) Legless lizard *(Sepsophis punctatus)*

(a.iii) The Desert horned lizard: (*Phrynosoma* spp)

(a.iv) Chameleon : (*Chameleo*) has a prehensile tail and a very long tongue



(a.v) Carnivorous Garden lizard (*Calotes versicolor*) (Photo by Mullook Kaaran)

(b.i) Komodo dragons (Varanus komodoensis) can easily hunt prey as big as goats.

(b.ii) Marine iguana (*Amblyrhynchus cristatus*) swimming in the waters of galapagos islands.

(b.iii) Gila (pronounced hee-luh) monster (*Heloderma suspectum*) is a venomous lizard and is native to the United States (Photo by Chuck Brown.)

Fig.15.30: Different types of lizards: a) Some interesting lizards found in India: i) house gecko; ii) legless lizard; iii) desert horned toad which is actually a lizard; and iv) chameleon with its long tongue and prehensile tail; v) Garden lizard; b) Some unique lizards that occur outside India: (i) The Komodo dragon (monitor) which are the largest living lizards as they are 3 meters or more in length. These Komodo dragons are now restricted to certain Indonesian islands and feed on small deer, wild pigs and goats. Smaller, different species of the monitor lizards also occur in India; ii) the marine iguana which is the only marine lizard that feeds on algae and can remain submerged under water for 30 minutes; and iii) Gila monster the only venomous lizard in the world.

2. Lizards similar to snakes as mentioned before have a kinetic skull. The specialized mobility of the skull enables the lizards to seize and manipulate prey. This type of skull also increases the effective closing force of the jaw musculature in lizards. However the kinesis of skulls in case of lizards is less than that of snakes. This is mainly due to the structure of the lower jaw of lizards since unlike snakes even in limbless lizard forms the two halves of the lower jaw are firmly united at the mandibular symphyasis. This limits the lizards from swallowing oversized prey, despite their kinetic skull. The jaws of lizards are provided with teeth, usually short and alike but differentiated in some.

3. In lizards the tongue may be only slightly mobile or freely extensible. In chameleons it can be shot several inches beyond the snout to capture insects on its sticky, mucous coated tip (Fig.15.30 a.v).

Hearing plays an important role in geckos. The male geckos are strongly vocal in order to specify territory and discourage other males from approaching and so they must, of course hear their own vocalisations. Other species of lizards vocalise to indicate defensive behaviour.

4. Most lizards have four limbs, though in many, limbs may be reduced or lacking as in a large number of limbless lizards ("glass snake" - legless lizards). Generally all limbless forms live in soil, through which they move by wriggling from side to side. In some fast running lizards tail is long and acts as a counterbalance but in sluggish forms it may be short and stumpy. In chameleons the tail is prehensile which allows them to anchor firmly on tree branches.

5. The lizard skin is flexible and is loosely attached to the body. It contains many scales that are arranged in longitudinal or transverse or diagonal rows. In most lizards the scales of the back and sides overlap behind, like shingles in a roof. The ventral surface is generally covered by small scales. One characteristic feature of lizards is their camouflage ability due to being able to change their colour rapidly so as to blend in with their background. Chameleons are an interesting example. However, not all lizards have this ability.

6. Unlike snakes, most lizards possess movable upper and lower eyelids (Fig.15.31) and many retain the parietal eye. Lizards have sharp daylight vision (retina is rich in rods and cones), although, the nocturnal gecko of one group has only rods in the retina which enables it to see extremely well in the dark. The eyes in chameleons are unusual as they can be swiveled forwards to provide binocular vision with excellent depth perception

7. Most lizards have an external ear that snakes lack (Fig.15.31) and this has evolved independently from the turtles. As with other reptiles hearing does not play an important role in the life of most lizards, except for male geckos that are strongly vocal.

8. Many lizards live in the hot and arid regions, being suitably adapted for desert life. Their scaly skin lacks glands which minimises water loss. Furthermore, they produce semisolid urine with a high content of crystalline uric acid.

9. Males have two hemipenes at the base of the tail. At copulation, one or both hemipenes are everted but usually one is used. Snakes also have hemipenis, a characteristic uniting the two groups.

10. Several lizards can regenerate their tail if it is cut. This is particularly seen in species like the skinks in which the tail vertebrae are incompletely ossified in a zone midway across the vertebra which functions as a breaking point. If tail is seized by the predator the vertebrae of the lizard separates (autotomises) at any one of the breaking points present in the tail. The autotomised, moving tail part distracts the predator and allows the lizard to escape. In time a new tail regenerates which however, is supported only by a cartilaginous rod and not by vertebrae which does not regenerate.

Fig. 15.31: Identifying differences in the head of: a) legless lizard in which both external ear openings and eyelids are present; and b) a snake in which both eyelids and external ear openings are absent.

11. *Amphisbaenia* is also referred to as worm lizard (Fig.15.32) though it is not a worm, but a lizard which is highly adapted for a burrowing life. The name *Amphisbaenia,* refers to the ability of these lizards to be able to move backward, nearly as effectively as forward. Amphisbaenians like earthworms live mainly a subterranean life, burrowing after worms and small earthworms. At present about 140 species of amphisbaenians are extensively distributed in South America and tropical Africa. Worm lizards have elongate, cylindrical bodies of nearly uniform diameter. The skin of amphisbaenians is soft and is divided into numerous, independently moving rings which can grip the soil, creating a movement similar to that created by earthworms. They use their conical or spade shaped, very strong skull and tail to push through the soil. They have rudimentary eyes that are usually hidden underneath the skin. They have no external ear openings. The worm lizards lack tympanic membrane but can detect ground vibrations by the lower jaw due to an extension of the stapes of the lower jaw. Most amphisbaenians lack any trace of limbs except for one genus with short front legs.

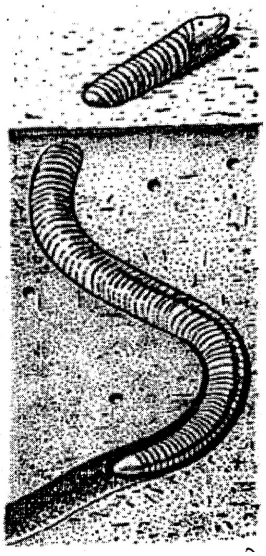


Fig. 15.32: *Amphisbaenia* is called a worm lizard. Worm lizards are burrowing forms with a solidly constructed skull which is used as a digging tool.

SAQ 6

In the following statements fill the blanks with suitable words:

a) The copulatory organ in male lizards is called…… .

b) In worm lizards the tympanic membrane is…… .

c) The worm lizards feed on worms and…… .

d) Most lizards possess……eyelids.

e) The largest living lizards are the …….. ……. .

15.8 ORDER CROCODILIA

Order Crocodilia is the scientific name for groups of reptiles that include many species of alligators, crocodiles, caimans and gharials (gavials). Modern crocodilians are the largest living reptiles and have remained virtually unchanged for some 200 million years. They differ very little in structural details from the primitive crocodiles of the early Mesozoic period that began their radiation in the late Cretaceous period.

15.8.1 Characteristic Features of Crocodilians

The characteristic features of order Crocodilia are given below (Fig.15.33):

1. Ancestral crocodilian species were terrestrial but modern ones have become specialised for an amphibious mode of life. All Crocodilians are predatory and carnivorous.
2. The skin of crocodilians is thick, with bony plates underlying the horny scales on the back and ventral sides of the body.
3. All Crocodilians have robust, elongate, well reinforced skull forming a snout. The shape and length of the snout vary considerably with diet.

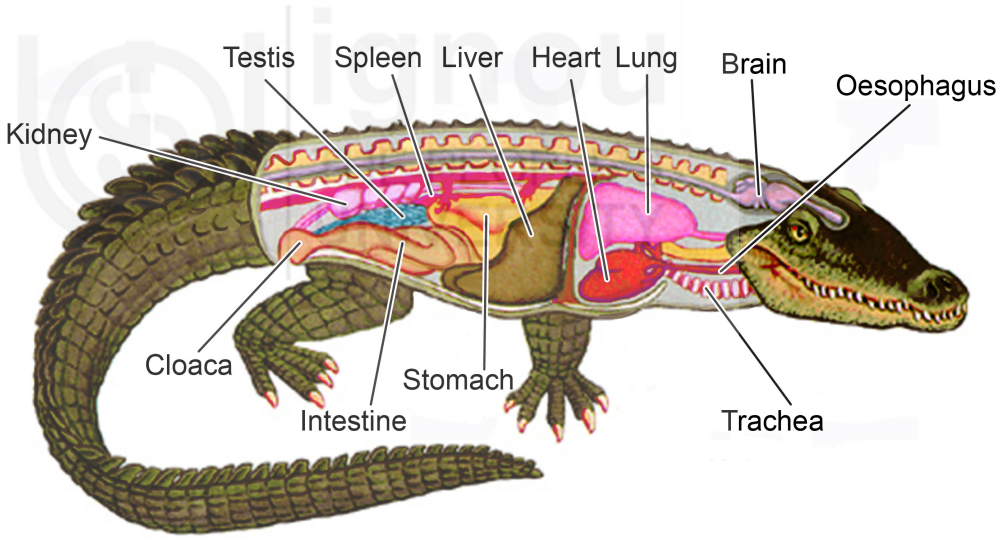


Fig.15.33: Features of a crocodile: a) External features; b) Internal anatomy.

4. The Jaws of crocodilians have a massive musculature which is arranged to provide a wide gape and enable rapid, powerful closure of the jaws. Crocodilians have sharp teeth that are set in sockets, a type of dentition called thecodont (Fig. 15.34 a). Such teeth were typical of all archosaurs as well as of the earliest birds.
5. Another adaptation found in crocodilians and found in no other vertebrate except mammals is the presence of a secondary palate (Fig.15.34 b). This feature enables the crocodilians to breathe even when their mouth is filled with water or food or both.
6. In crocodilians the eye, ear and nose openings are in a straight line and are situated on the top of the head, so, that they protrude above water and

allow the animal to be submerged as it stalks its prey. The tympanic membrane is exposed but protected by a fold of skin Valves close the ear and nose when under water.

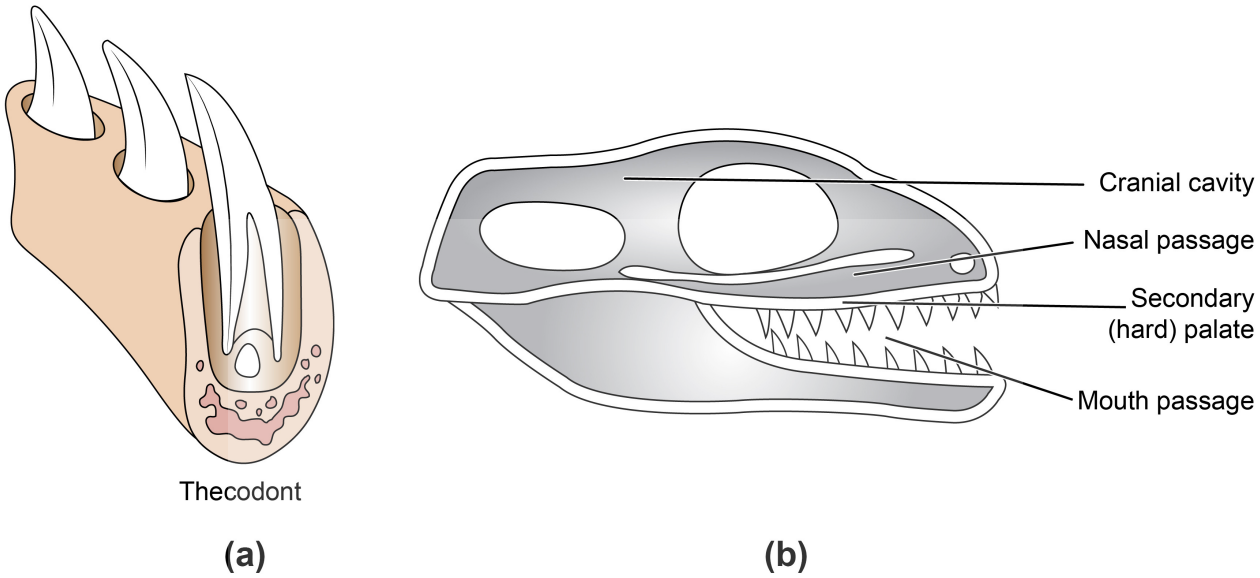


Fig. 15.34: a) The teeth of crocodilians which are of thecodont type as they are set in the sockets of the jaws ; b) A saggital section of reptilian skull showing its teeth and secondary palate that separates the nasal and mouth cavities.

7. Crocodilians along with birds and mammals have a four chambered heart with completely divided atria and ventricles.

8. Crocodilians have two pairs of short legs in which the fore feet have five toes and the hind feet have four toes. The hind feet are also webbed. Their tail is laterally compressed and so functions as is a very effective organ for swimming.

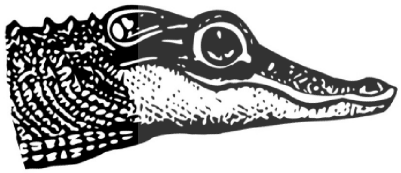
9. The anal opening of crocodilians similar to that of Tesudines is a longitudinal slit.

10. Crocodilians are oviparous. A female usually lays 20 to 50 eggs hidden in nest and guards them. Unlike other non avian reptiles, crocodilians provide extensive parental care. The mother hears the sounds made by babies in the eggs and assists them to escape from the nest.

11. Modern crocodilians (Fig. 15.35) are divided into three families: i) Alligatoridae that include the alligators and caimans, mostly a New World group (exception being the Chinese alligator). Alligators and caimans (or caymans) are freshwater forms; ii) Crocodylidae which comprise, the crocodiles that are widely distributed and include the salt water crocodiles, one of the largest living reptiles and the; iii) Gavialidae that contains the gavialis which are also referred to as gharials and is represented by a single species that occurs in India and Myanmar.

Crocodile
(a)

Alligator
(b)



Caiman
(c)

Gavial(Gharial)
(d)

Fig. 15.35: The modified snouts of four species of crocodilians reflect their different feeding habits: a) crocodiles; and b) alligators can be easily distinguished if you carefully observe their heads. The snout of alligator is comparatively broader and rounder and the teeth fit inside jaws, while in crocodile the fourth teeth on the lower jaw protrudes outside; c) The caiman which is very similar to the alligator is difficult to tell apart. It is more aggressive than the alligator; d) The gavials or gharials are quite distinct from crocodiles and alligators, as they can easily be recognised by along narrow snout, and sharp teeth. Males have a protuberance at the end of snout.

SAQ 7

a) Fill in the blanks with the appropriate words in the following statements:

i) In all crocodilians, dentition is…….. .

ii) Crocodilians can breathe even when the mouth is filled with water or food or both because of the presence of a secondary…… .

iii) The……limbs of crocodilians webbed.

b) Match the name of the animal given on the left in Column A with its order on the right in Column B.

Animal A		Order B
i)	Turtle	a) Crocodilia
ii)	Lizard	b) Squamata
iii)	Tuatara	c) Testudines
iv)	Caiman	d) Sphenodonta

15.9 SUMMARY

- Amniotes diverged from a group of early tetrapods and diverged into groups or clades that occupied a wide range of aquatic and terrestrial habitats.
- The success of amniotes developing into the first true terrestrial vertebrates is attributed to several adaptations including the evolution of the shelled, amniotic egg which with its four extra embryonic membranes- i) the amnion; ii) allantois; iii) chorion; and iv) yolk sac. These extra embryonic membrane allowed the development of embryos in the terrestrial environment.
- Before the end of the Paleozoic era, the amniotes underwent an extensive radiation that could be distinguished by skull structure into three groups 1) the anapsids which lack temporal fenestrae; 2) the diapsids which have two pairs of temporal fenestrae. Early diapsids gave rise to all birds and reptiles (also now named as non avian reptiles). Turtles are now considered to be diapsids; and 3) the synapsids, which have one pair of temporal fenestrae. Mammals evolved from early synapsids
- Reptiles are better adapted to terrestrial life than the amphibians. Their dry, nearly glandless skin, covered with keratinized scales limits water loss from the body. Gas exchange during respiration in reptiles occurs only through lungs. Jaws are more powerful. Circulatory system is more advanced than amphibians, and heart is nearly completely divided into four chambers.
- Excretory system is also more advanced in reptiles and in order to minimise water loss from their body, nitrogen from metabolic wastes is excreted mainly as uric acid rather than as ammonia or urea.
- Fertilization is internal and the amniotic egg is laid either on the land or retained within the uterus till the young ones hatch. A few species of lizards and snakes are viviparous.
- Like amphibians however reptiles are ectothermic, but most of them can maintain a high and nearly constant body temperature during periods of activity by behaviourally regulating their exposure to sun.
- Extant members of reptile belong to only four orders: (1) Testudines, (2) Sphenodonta, (3) Squamata, (4) Crocodilia.
- The turtles (order Testudine) with their distinctive body shell are a small group of long living, terrestrial or semiaquatic, being either fresh water aquatic or marine species. They have an anapsid looking skull which is believed to have evolved secondarily from a diapsid skull. Turtles lack teeth. All are oviparous and all including the marine forms bury their egg on land.
- The tuatara of New Zealand Order Sphenodonta is a relict species and the sole survivor of a group that otherwise disappeared 100 million year ago. It bears several primitive characters that are almost identical to those of the Mesozoic fossil reptiles.

- Snakes and lizards that now also include amphisibaenians are placed in Order Squamata. Order squamata is subdivided into two Suborders : 1. Serpentes (ophidio) including snakes and 2. Lacertlia including Lizards. Squamates have a modified diapsid skull. Jaws of all snakes and several lizards are highly flexible and can open very wide. Such types of skulls are referred to as, "kinetic skulls". 1) **Suborder Serpentes** consist of snakes which are entirely limbless and are characterised by elongate bodies, highly kinetic skull which enables them to swallow whole prey that may be much larger that their own body diameter. Most snakes rely on chemical sense, especially, Jacobson's organ, to hunt prey rather than on the weakly-developed visual and auditory senses. Many snakes are venomous and can be distinguished externally from the non-venomous snakes by their head shape, placement of scales on the head and rest of the body, shape of tail. 2) **Sub order Lacertilia** consists of lizards including the amphisbaenians. They are a diverse and successful group. Lizards are distinguished from snakes by having typically two pairs of legs (however, some species of lizards are legless), united lower jaw halves, movable eyelids, external ears and absence of fangs. The worm lizards (amphisbaenians) are a small group of legless, burrowing lizards with both eyes and ears hidden beneath the skin.
- The crocodiles, alligators, gharials and caiman belong to Order Crocodilia. They are the only living reptilian representatives of the archosaurian lineage which gave rise to the extinct dinosaurs and the living birds. Crocodilians have several adaptations for a carnivorous, semi aquatic life, including a massive skull with powerful jaws, a secondary palate and four chambered heart. Among the reptiles they exhibit the most advanced parental care.

15.10 TERMINAL QUESTIONS

1. What are the three main reptile lines that evolved from the amniotes during the Mesozoic era and from which lineage did the present day reptiles evolve? How would you distinguish among the anapsid, diapsid and synapsid types of skull.
2. Describe the distinguishing features of turtles of Order Testudines.
3. How are tuataras different from lizards?
4. Describe two anatomical features of lizards (including legless members) that distinguish them from snakes.
5. How do crocodiles and alligators differ from each other?

15.11 ANSWERS

Self-Assessment Questions

1. a) F; b) F; c) T; d) F; e) T
2. a) Ectothermic; b) polyphyodont; c) uric acid; d) lung; e) crocodilians

3. a) carapace and plastron; b) internal; c) temperature; d) lack; e) carapace
4. a) lepidosaur; b) diapsid; c) absent; d) present
5. a) boas; b) forward; c) good; d) chemical; e) absent; f) smooth
6. a) hemepenis; b) absent; c) earthworms; d) moveable; e) Komodo dragon.
7. a) i) thecodont; ii) palate; iii) hind

   b) i) c; ii) b; iii) d; iv) a

Terminal Questions

1. Refer to Subsection 15.2.1
2. Refer to Subsection 15.5.1
3. Refer to Subsection 15.6.1, and Subsection 15.7.4
4. Refer to Subsections 15.7.6 and Fig. 15.31
5. Refer to Subsection 15.8.1

UNIT 16

AVES

Structure

16.1 INTRODUCTION

You have already read in the previous unit (Unit 15) of the BZYT-101 course about the Amniota group which includes reptiles, aves and mammals, members of which have evolved strategies that allowed them to lay eggs or to produce young ones on land instead of in water. This allowed members of these classes to become totally adapted to a terrestrial mode of life and to be able to breathe air through lungs. In Unit 15 you also learnt about the distinguishing features of Class Reptilia and how its members have evolved. Furthermore, you have also been familiarised with the classification of reptiles, and the salient features of the four extant orders: Sphenodonta (Rhynchocephalia) Testudines (Chelonia), Squamata and Crocodilia and their adaptations to terrestrial life.

In the present unit you will study about birds which belong to the Class Aves. You will learn about the evolution, classification and salient characters of birds and the distinguishing features of the various orders of Class Aves. You will

also become familiar with the various adaptations in birds that enable them to fly. This unit will also help you to understand the role of various factors in flight of birds.

Objectives

After studying this unit, you should be able to:

- describe briefly the evolution and affinities of birds belonging to Class Aves;
- give the distinguishing characteristic features of birds;
- give the classification of extant birds upto the level of order;
- describe in brief the features of various extant orders of birds of class Aves;
- explain and describe the adaptations of birds particularly in relation to flight; and
- explain the role of various factors that makes bird flight possible.

16.2 ANCESTRY AND EVOLUTION OF BIRDS

Birds belong to the Class Aves (from the Latin word Avez which means birds) and are easily recognisable from the other vertebrates due to the presence of feathers.

Birds especially the males have a colourful plumage. Most birds have a melodious voice. Birds are homoeothermic like mammals, but share as you know from Unit 15 many of the reptilian characters.

Birds are the only vertebrates capable of intense and sustained flight. However they cannot live in the air all the time and have to come to land or to water in order to feed, roost and nest. Birds share with mammals the highest organ development in the Animal Kingdom. However, their entire anatomy is designed around flight and its perfection which thus restricts diversity in features and imparts great structural and functional uniformity to all of them. Like any other flying machine, birds have sacrificed everything for low weight and flying power.

The Class Aves in which birds are placed is "defined as the clade that contains the ancestor of Archaeopteryx and all of its descendents, including the living birds.

16.2.1 Archaeopteryx: A Link between Reptiles and Birds

Birds, first made their appearance during the Cretaceous period. The typical modern birds made their appearance by the Cenozoic Era. Not many bird fossils have been found, as bird bones are perforated with air cavities and so disintegrate easily and leave no remains. The earliest known bird fossil *Archaeopteryx lithographica* (ar-kee-opter-ix-lith-o-graf-e-ca, means ancient wing inscribed in stone), was found near Bavaria in Carboniferous deposits in the early 1960s. *Archaeopteryx* fossils are 150 million years old and so these fossil birds occurred in the Jurassic period (Fig. 16.1 a and b).

(a) (b)

Fig. 16.1: The *Archaeopteryx*, which is 150 million years old, is the ancestor of modern birds. It lived in the upper Jurassic period: a) cast of Fossil of a complete *Archaeopteryx*, including indentations of feathers on wings and tail; b) Model of *Archaeopteryx* on display at Geneva natural history museum.

The *Archaeopteryx,* a crow sized land bird had both reptilian and avian features and is recognised to be a link between reptiles and birds. Reptilian characters found in *Archaropteryx*: i) include jaws with homodont teeth, ii) reptile like tail with caudal vertebrae, iii) solid bones instead of hollow bones iv) weak sternum, v) scales being present on the body and vi) presence of reptile-like the pelvic girdle. The avian features in *Archaeopteryx* include: i) presence of feathers, ii) modification of forelimbs into wings, iii) tail with feathers, iv) presence of beak, v) skull bones being partially fused, vi) presence of sternum with keel and vii) presence of V shaped furcula (Fig. 16.2).

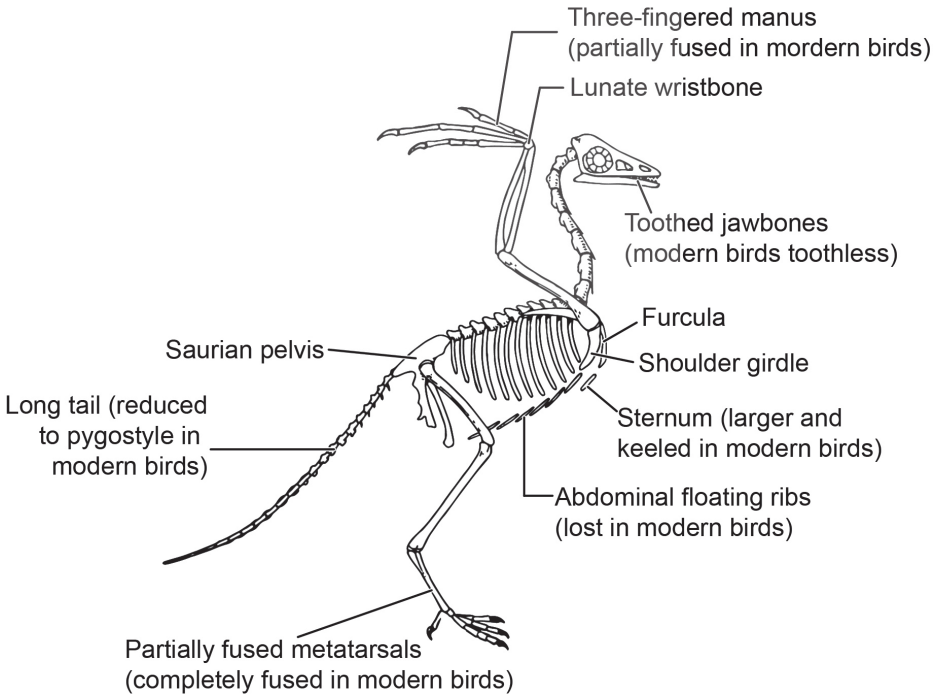


Fig.16.2: Skeleton of an *Archaeopteryx*.

Despite the fact that *Archeapteryx* had both reptilian and avian features, and however, it is considered to be almost identical to certain theropod dinosaurs with the exception of feathers, wing like structures of the hand and enlarged eye orbits. Most probably *Archaeopteryx* is not in direct lineage leading to modern birds but can be regarded as a sister group to modern birds (Fig. 16.3).

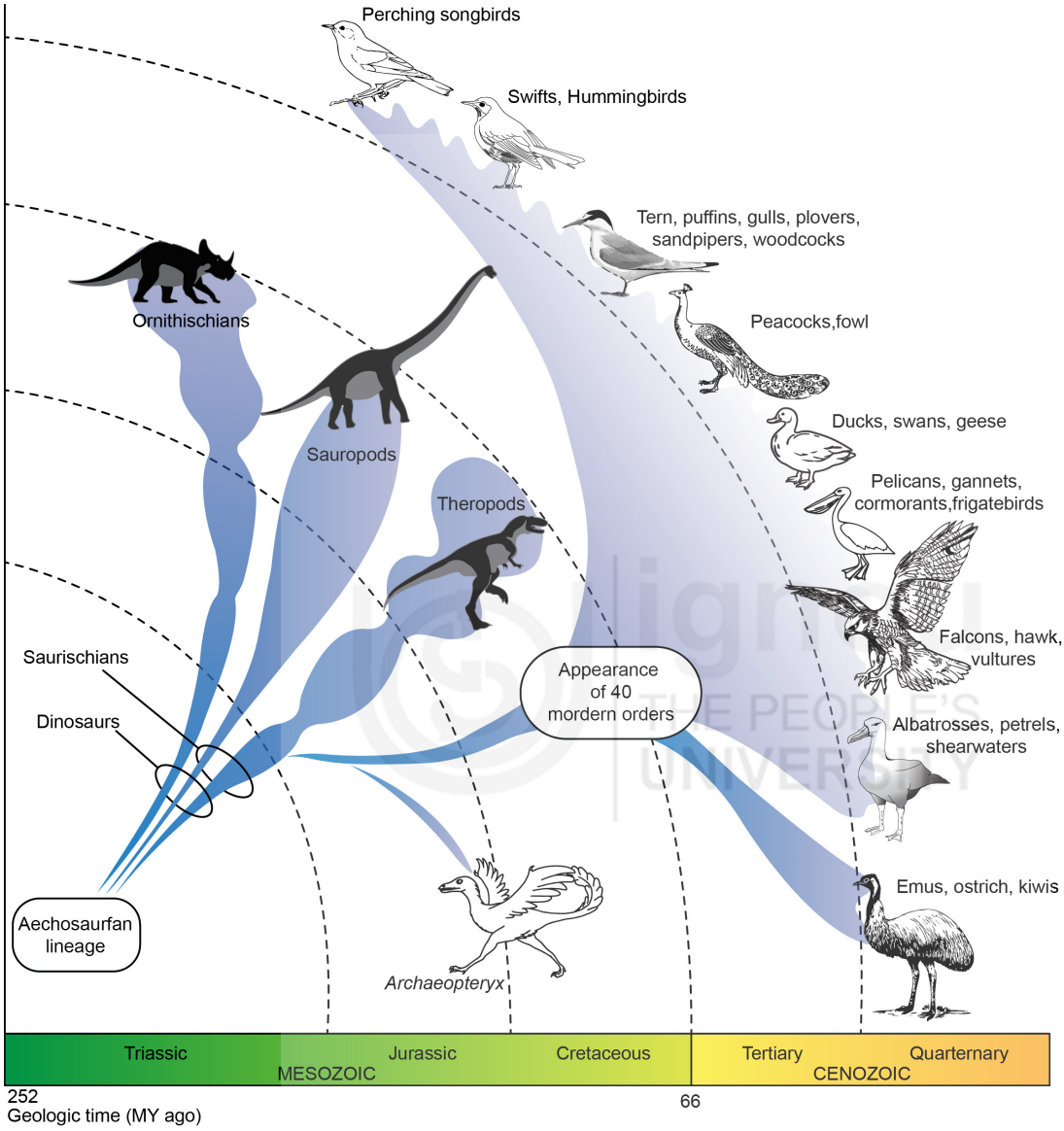


Fig. 16.3: ***Archaeopteryx*** **are considered as a sister group to modern bird. Birds show monophyletic origin in their evolution. It means birds evolved from a single ancestor. During their course of evolution and during the 60 million years of their existence, very few structural changes have taken place in birds. The few changes that have taken place in birds is thought to be due to the restrictions imposed by an aerial mode of life to which birds have adapted in various ways.**

16.2.2 Affinity of Reptiles, Aves and Mammals

Birds and reptiles share several morphological features. The skull of birds and reptiles articulate with the first neck vertebrae by a single occipital condyle (a small bony knob) unlike mammals which have two such occipital condyles.

Birds and reptiles both have a similar middle ear bone which is called the columella. The lower jaw of bird and reptiles have five bones while mammals have only one bone the dentary. Both birds and reptiles excrete their nitrogenous wastes as uric acid unlike mammals which excrete urea. As you have read in the previous unit both birds and reptiles lay large, shelled, yolked, fertilized eggs which enclose the developing embryo. These developing embryos are nourished by the yolk, present in the egg.

16.2.3 Evolution of Birds

Cladistic scientists, on the basis of phylogeny have recently classified birds with theropod dinosaurs. Both reptiles and aves have evolved from the archosaurian lineage and belong to the Saurischian clade (Fig. 16.4).

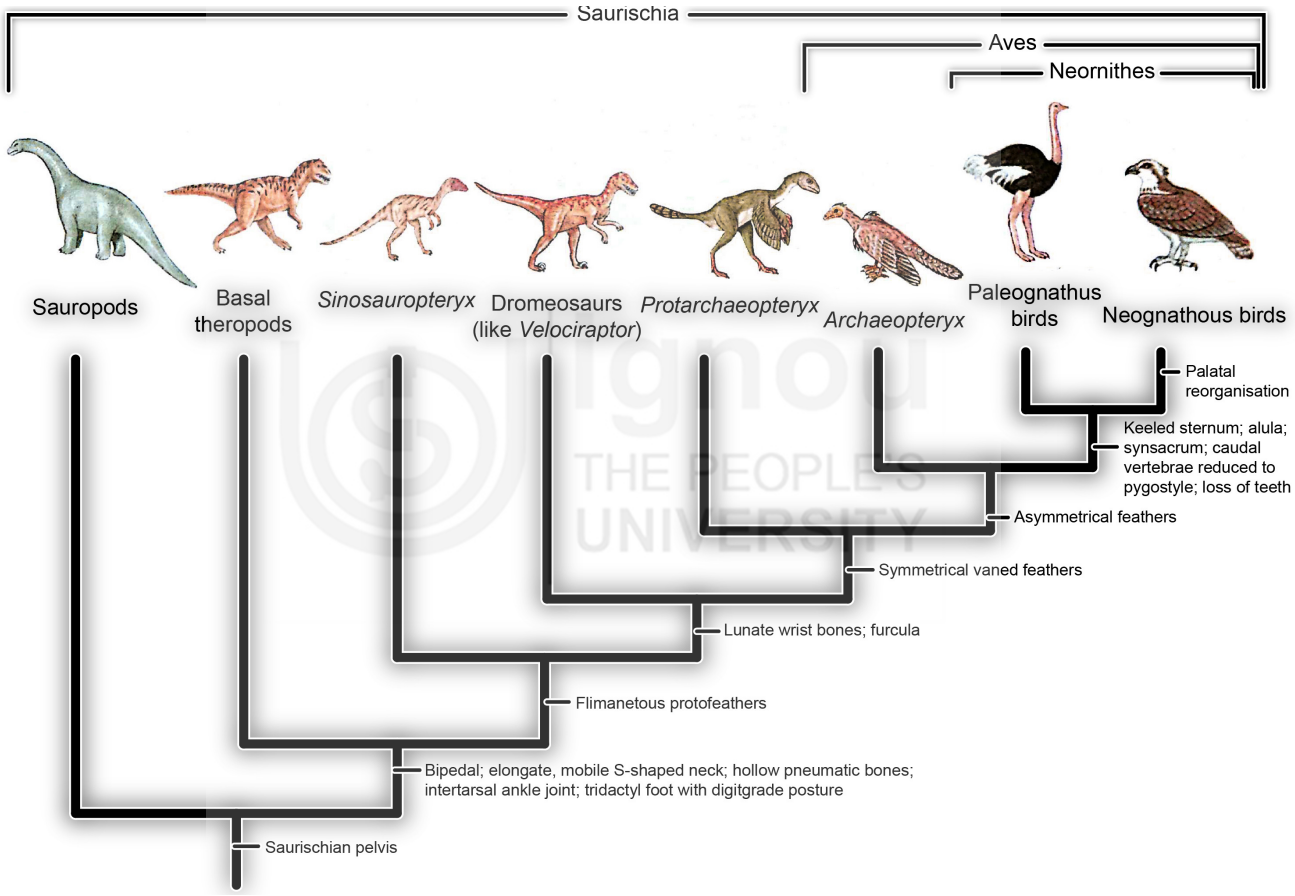


Fig. 16.4: Cladogram of clade Saurischia, showing the relationship of several taxa to modern birds. This figure shows a few shared derived characters that are mostly related to flighti, and have been used to construct the genealogy. The ornithischians are the sister group to the saurischians and all are members of the clade Archosauria.

16.3 CHARACTERISTIC FEATURES OF BIRDS

1. The body of Birds is covered with feathers (Fig. 16.5 a).
2. Birds have paired wings, which are used by most of them for flying.
3. Birds are endothermic vertebrates.
4. Body of the birds is usually spindle shaped, with four divisions: head, neck, trunk and tail. Neck is long, which makes it possible for the bird to

turn its head almost 180^{O}. Furthermore, it is S-shaped for balancing and gathering food (Fig. 16.5 a and b).

5. In birds the integument is thin and is composed of epidermis and dermis. Epidermis of skin is covered by epidermal feathers or leg scales. Body is covered with feathers while shanks and toes are sheathed with keratinized epidermal skin. Cutaneous or sweat glands are absent in birds but, the uropygial oil or preen glands are present in them at the root of the tail.

6. In contemporary bird species, the jaw is narrow and covered by a keratinized- sheath that forms the beak. Teeth are absent in birds.

7. Skeleton of birds is delicate looking, but is actually, strong and fully ossified. The bones of the birds are usually pneumatic (with air) with air cavities. In birds the skull bones are fused and the skull similar to reptiles has only one occipital condoyle.

8. Birds have a smaller number of bones than mammals or reptiles. This is because many of their bones are fused together. Birds have more neck (cervical) vertebrae than many other animals. In birds, the vertebrae after the neck and up to the tail are fused together and also with the pelvic girdle; fully or partially fused, lumber or caudal vertebrae to form a synsacram which imparts rigidity to the skeleton. The pelvic girdle also referred to, as pelvis is fused with numerous vertebrae to but is open (free) ventrally. The tail is not elongate and the posterior caudal vertebrate are fused together to form the pygostyle. Small ribs with strengthening processes called uncinate are present. The breastbone or sternum is one of the largest bones of the bird skeleton and is part of pectoral girdle. The sternum usually has a median keel-like projection called keel or carina to which the flight muscles attach. However, a keeled sternum is absent in flightless birds.

9. Birds have two pairs of limbs. The anterior pair corresponds to the forelimb of tetrapods and is modified to form a base for the attachment of feathers and so forms the wings. The posterior pair of limbs form the hindlimb of the bird and are variously adapted for perching, walking or swimming (with webs). Each posterior foot, usually has four toes.

10. Nervous system is well-developed in birds. The brain is well-developed with 12 pairs of cranial nerves. Eyes and visual centers in the brain are large and essential.

11. In birds pinna of ear is rudimentary. A single bone, called columella, similar to reptiles is present in the middle ear of the birds. The Inner ear contains a coiled cochlea. Length of cochlea is not very long.

12. The digestive system of a bird starts from the beak and leads to the mouth which opens into an oesophagus. The oesophagus has a crop at its distal end which helps in storing food. The crop opens into the stomach which is divided into (i) an anterior proventriculus and (ii) a posterior muscular gizzard. Gizzard opens into the small intestine which is provided with villi. Small intestine opens into the large intestine that

opens to the outside by a cloaca. Gizzard helps in the mastication of food and substitutes for the absence of teeth and for the weak jaw musculature of the bird.

13. Respiration in birds is by means of compact, spongy and only slightly expandible lungs which are connected to thin walled air sacs that extend among the visceral organs and skeleton of the bird. Lungs and air sacs form an unusual pattern of air passages and air sacs that produce an exceptionally efficient continous one-way passage of air across the respiratory surface.

14. Circulatory system consists of a four chambered heart with two atria and two separate ventricles so that the oxygen depleted blood and oxygen rich blood are completely separate. As a result birds have separate pulmonary and systemic circuits. A persistent right aortic arch is present. Red corpuscles are nucleated, oval and biconvex.

15. Excretory system consists of paired, metanephric kidneys and ureters that open into the cloaca. Bladder is absent. Uric acid is the main nitrogenous waste (urine) and is semisolid in order to conserve water.

16. In birds, sexes are separate. Males have paired testes. From each testis a vas deferens opens into the cloaca. Males of most birds lack a copulatory organ. The copulatory organ when present is in the form of penis and is found only in a few birds like ducks, geese and flightless birds (except for tinamous) and a few others. Fertilization in birds is internal and is either by penis when it is present or by means of cloacal contact between male and female. Females have only a left functional ovary and oviduct. Right ovary and oviduct atrophy during development.

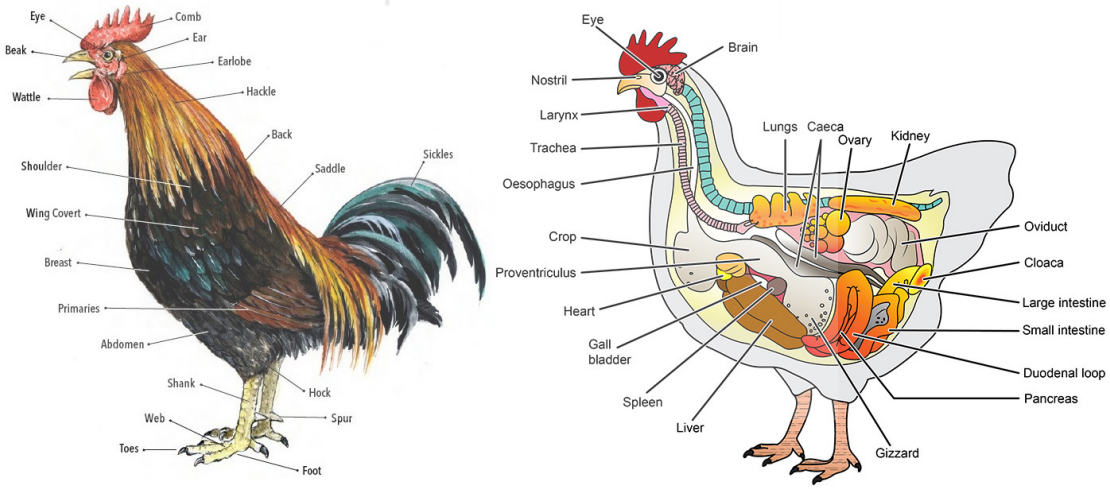


Fig. 16.5: General features of a bird: a) External features of a male domestic fowl (rooster: cock); b) internal anatomy of a female domestic fowl (hen) showing, its internal organs.

17. Birds lay eggs and so are oviparous. Eggs in birds are amniotic and cleidoic with, a large amount of yolk and covered by a hard, calcareous shell. During embryonic development, all the four foetal membranes (amnion, chorion, yolk sac and allantois) are present within the egg. Albuminous material and a hard calcareous shell are secreted around the

fertilized egg as it passes down the oviduct. Incubation of the eggs is outside the body. Parents incubate their eggs and exhibit extensive parental care of their hatchlings. Hatchlings may be active at hatching (precocial) or naked and featherless (altrical). Sex determination is by females (which have heterogametic sex chromosomes).

SAQ 1

Fill in the blanks with suitable words:

i) *Archaeopteryx* fossil bird is believed to be from the ……period.

ii) The *Archaeopteryx* fossil is recognised to be a link between ……..…… and ……. .

iii) The number of bones present in the lower jaw of reptiles and birds is …….. .

iv) The skull of birds and reptiles articulates with the first neck vertebrae by ……..condyle.

v) Birds have a …… origin as they have evolved from a single ancestor.

vi) A keeled sternum is …….in flightless birds.

vii) Red corpuscles of birds are ……..,biconvex and …….. .

16.4 CLASSIFICATION OF EXTANT BIRDS OF CLASS AVES

The Class Aves contains more than 10,400 species at present. These species are distributed among 40 orders of living birds. Before the study of Sibley and Alquist (1990) the birds of classification was primarily based on morphological similarity. However, Sibley and Alquist used DNA hybridization results for classifying birds. Recent attempts at working out the higher relationships of birds have been done mainly on basis of mitochondrial DNA (mtDNA) and nuclear DNA sequences. In the present unit: i)the classification of Aves,ii) the number and types of Orders and iii)the number of species of living bird, placed in various Orders is based largely on the "2012, International Ornithologist Union World Bird List". This list itself is based on the study of Sibley and Alquist and various other, more current, phylogenetic reconstructions.

Class Aves is divided into two Superorders: 1) Super order–Paleognathae and 2) Super order–Neognathe

16.4.1 Superorder Paleognathae

These are modern, large, flightless, toothless birds that have retained the ancestral archosaurian palate. These birds are also called ratites and consist of birds like the ostriches, rheas, cassowaries, emus, and kiwis. Ratites have a flat sternum (breast bone) as keel is absent on the sternum (unkeeled

sternum).Among the ratites or flightless birds, the tinamous bird are an exception as they have have a keeled sternum. The pectoral muscles which are the flight muscles are poorly developed in birds that belong to this Super order. Super order Paleognathae has five orders that are briefly described below:

ORDERS

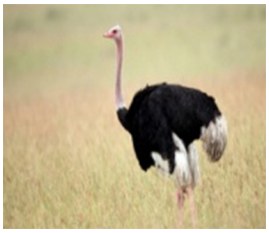


Fig. 16.6: Ostrich

Fig. 16.7 : Rhea bird

Fig. 16.8 : Emu

Fig. 16.9 : Kiwi

Fig. 16.10 : Tinamou bird

1. **Order Struthioniformes (stru-theeo-nee-formez):** consists of ostriches which are large, flightless birds with small wings that have numerous fluffy plumes. Ostriches have an unkeeled sternum. The head and neck of these birds are largely devoid of feathers. These birds also have large powerful legs with two toes of unequal size which are covered on the underside with pad like skin that enable them to travel rapidly over sandy ground. The ostrich, Struthio camelus (Fig.16.6) of this order is the largest living bird, which is 2.4 m tall and weighs135 kg. Order Struthioniformes consists of 2 species which are found in Africa.

2. **Order Rheiformes (ree-for-mez):** consists of Rhea bird which are large, flightless birds with unkeeled sternum like the ostriches (Fig.16.7).However, The head and neck of these birds are feathered and they have heavy legs with three toes. Order Rheiformes has two species which are found in the grasslands of South America.

3. **Order Casuariiformes (kasoo -er-eeformez):** includes cassowaries and emus which are large ,flightless birds with small wings and unkeeled sternum (Fig.16.8). These birds have long hair-like feathers which have a long after shaft. They have heavy legs with three toes. Cassowaries have four species which are found in the forests of northern Australia and New Guinea. The emu is the second largest living bird species, and is confined to Australia.

4. **Order Apterygiformes (ap-te-ree-jee-formez):** consists of kiwi birds (Fig.16.9), which are hen-sized, flightless birds with vestigial wings and unkeeled sternum. Kiwi birds have a long bill (beak) with nostrils. They have feet with four toes. Kiwi birds are nocturnal in habit. Order Apterygiformes consists of 5 species which are found in New Zealand.

5. **Order Tinamiformes (tin-amee-foremez):** includes tinamous birds (Fig.16.10), which are large, partridge-like, ground dwelling birds with weak powers of flight. Their sternum retains a keel. Order Tinamiformes has 47 species all of which are found in Central and South America.

16.4.2 Superorder Neognathe

All the other birds that can either fly a little bit or fly well, belong to this group. This Superorder consists of modern, toothless birds with flexible palate. Birds belonging to Superorder Neognathe are also called Carinates. Most members of this group possess a keeled sternum on which large, well-developed flight muscles are inserted. However, you should be aware that several neognathous birds are flightless and a few have a sternum in which the keel is

absent. *Nannopterum* harrisi a flightless cormorant belongs to the neognathe group of birds and lacks a keeled sternum.

1. **Order Anseriformes (an- seree-formez):** includes swans, geese and ducks (Fig.16.11), all of which have a long sternum with a low keel. Members of this order consist of short-legged, swimming and diving birds with webbed feet in which the foot web is restricted to the front toes. These birds have broad bill with flat and transverse horny ridges that are adapted for filtering food from water. Members of this order have an undercoat of dense down feathers. Order Anseriformes has 176 species which show worldwide distribution.

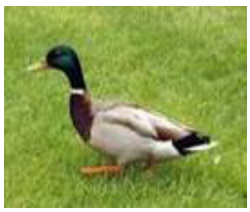


Fig. 16.11: Duck

2. **Order Galliformes (gallee-formez):** includes quail, grouse, pheasants, ptarmigan, turkeys, and domestic fowl (Fig.16.12).Birds of this order are ground dwelling, herbivores that nest on the ground. These birds have relatively short, concave wings and short, stout and strong beaks. Furthermore; they have heavy feet with short, strong claws, adapted for running and for scratching the ground. This order has 299 species which have worldwide distribution.

Fig. 16.12 : Domestic Fowl

3. **Order Sphenisciformes (sfee-nisee-for mez):** consists of penguins (Fig.16.13). Penguins have a keeled sternum. They are heavy bodied, flightless, oceanic birds with webbed feet. These web-footed birds have four anteriorly directed toes with a web between three of them Wings of penguins are paddle like structures and so instead of using their wings for flight, penguins use them for swimming and diving. The body of penguins is well-insulated with fat. Order Sphenisciformes has 18 species all of which are marine swimmers and are found in the southern seas from north Antarctica to the Galápagos Islands.

Fig. 16.13 : Penguin

4. **Order Gaviiformes (ga-vee-formez):** consists of loons (Fig.16.14) who are well adapted for swimming and diving. Members of this order have heavy bodies as they have heavy bones. They have short legs, located far back on the body, webbed feet and short tail. The beak in loons is strong, straight, sharply pointed and compressed. Order Gaviiformes has five species, all of which live exclusively on fish, supplemented with amphibians and crayfishes. They are found mainly in northern waters of North America and Eurasia.

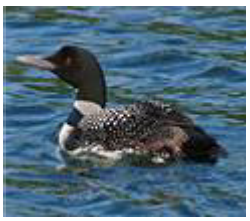


Fig. 16.14: A Loon

5. **Order Podicipediformes (podee-see-pedee-formez):** consists of grebes (Fig.16.15) which have short wings and soft and dense plumage. They have short legs which are located far back on the body. The legs have lobate-webbed toes with flattened nails. Tail is reduced in members of this order. This order has 23 species, all of which are very good divers. Grebes are most common in old ponds where they build their raftlike floating nests. Members of this order show worldwide distribution.

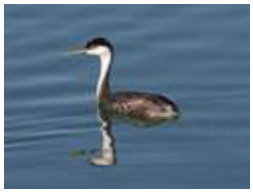


Fig. 16.15 : A Grebe

6. **Order Phoenicopteriformes (fonee-cop-teree-formez):** consists of flamingos (Fig.16.16) which are large, colourful, water wading birds that use the lamellae in their beaks to strain zooplanktons from the water. Order Phoenicopteriformes has 6 species and worldwide distribution in the tropical regions.

Fig. 16.16: Flamingos

Fig. 16.17: An Albatross

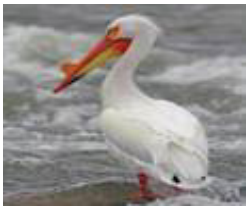


Fig. 16.18: A Pelican

Fig. 16.19: Tropic bird

Fig. 16.20: A Cormorant

Fig. 16.21: A Stork

Fig. 16.22 : A Vulture

Fig. 16.23 : A Falcon

Fig. 16.24: A Bustard

7. **Order Procellariiformes (pro-sell-laree-formez):** includes albatrosses (Fig.16.17), petrels, fulmars, and shearwaters, all of which are marine birds. Members of this order have hooked beaks, tubular nostrils, large nasal glands and long, narrow wings. They have webbed feet in which the fourth toe is vestigial. The wingspan of albatross is the largest among the flying birds, being more than 3.6 meters. Order Procellariiformes has 139 species all of which show worldwide distribution.

8. **Order Pelecaniformes (pel-ee-canee-formez):** includes pelicans (Fig.16.18), ibises, and herons which are mostly colonial (living in colonies) fish-eaters that inhabit coasts, lakes, wetlands, and streams. In members of this order nostrils are absent or rudimentary and all the members have a large gular pouch. These birds have four toes which are joined in a common web. Order Pelecaniformes has 118 species, which have worldwide distribution, especially in the tropical and subtropical regions.

9. **Order Phaethontiformes (fay-thontee-formez):** consists of tropic birds (Fig.16.19) which are large seabirds with predominantly a white plumage and elongated central tail feathers. They have a large head with short and thick neck and a large, powerful and slightly decurved bill. Members of this order have totipalmate feet (all four toes are connected by a web) Order Phaethontiformes has three species all of which are found in the tropical regions.

10. **Order Suliformes (sulee-formez):** includes frigate birds, gannets, bobbies, and cormorants (Fig.16.20) which are medium to large sized, diving seabirds that feed mostly on fishes. This order has 60 species all of which show worldwide distribution.

11. **Order Ciconiiformes (sikonee-formez):** includes storks (Fig.16.21) which are long-necked, long-legged, wading birds with broad feet that are usually not webbed. Members of this order have long and stout beaks .This order has 19 species which are found in the tropical regions of the world.

12. **Order Accipitriformes (as-sipee-tri-formez)**: consists of vultures and (Fig.16.22) eagles which are mostly diurnal birds of prey with keen vision and sharp, curved talons. This order includes 265 species, all of which have worldwide distribution.

13. **Order Falconiformes (falko-ni-formez):** consists of falcons (Fig.16.23) which are very fast birds of prey with strong, hooked beaks, sharp curved talons and large wings. Falcons primarily eat other birds. Order Falconiformes has 67 species all of which show worldwide distribution.

14. **Order Otidiformes (o-tidee-for mez):** consists of the bustards (Fig.16.24) that are large, long-legged, terrestrial birds, living in arid habitats. This order has 26 species that occur in Africa, Asia and Europe.

15. **Order Mesitornithiformes (mesee tor-nithi-formez):** consists of the mesite birds (Fig.16.25) that are small, terrestrial birds, inhabiting forests and brush lands which are areas of dense vegetation consisting of shrubs or small trees.This order has 3 species that are restricted to Madagascar.

Fig. 16.25: A Mesite bird

16. **Order Cariamiformes (carry-amee–formez):** consists of seriema birds (plural: seriemas) (Fig.16.26) which are small, long-legged, terrestrial birds, inhabiting grasslands and open forests. This order has 2 species that are restricted to South America.

Fig. 16.26: A Seriema bird

17. **Order Eurpygiformes (yur-pijee-formz):** consists of two kinds of birds, namely kagu (Fig.16.27) and sunbittern that belong to two separate genera. Each genus has one species .The two bird in this order inhabit tropical forests. The kagu bird is found in New Caledonia and the sun bittern in Central and South America.

Fig. 16.27: A Kagu bird

18. **Order Gruiformes (gruee-formez):** includes cranes (Fig.16.28), and coots. In these birds the part of the head between the eye and nostril (the lores) is feathered. In these birds the feet are not webbed though sometimes the toes are lobed. In some groups of this order the legs of the birds are elongate. Order Gruiformes has182 species which are mostly prairie and marsh breeders. Birds of this order have worldwide distribution.

Fig. 16.28: A Crane

19. **Order Charadriiformes (ka-ra-dree- formez):** consists of a diverse group of shorebirds that includes gulls, plovers, sandpipers, terns, woodcocks, snipes, skuas, skimmers, auks and puffins (Fig.16.29) and many others. The birds of this order are strong fliers and are usually colonial. Order Charadriiformes contains 385 species, all of which show worldwide distribution.

Fig. 16.29: A Puffin bird

20. **Order Pteroclifformes (ter-o-clee-formez):** includes seed-eating, gregarious, pigeon type birds, like the sand grouse (Fig.16.30). This order contains 23 species that are found in Africa, Asia, and Southern Europe.

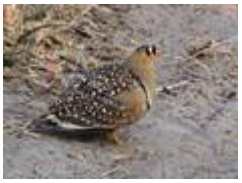


Fig. 16.30 : A Sand grouse

21. **Order Columbiformes (ko-lum-bee- formez):** includes pigeons (Fig.16.31) and doves, in which their dense feathers are loosely set in the skin. All birds of this order have short necks, short legs and a short, slender bill with fleshy pad at its base and overhanging slit-like nostrils. Digestive system of all the members of this order have a well-developed crop.The flightless dodo, *Rapbus cucullatus*, of the Mauritius Islands which became extinct in 1681 also belonged to this order. Order Columbiformes has 335 species all of which show worldwide distribution.

Fig. 16.31: A Pigeon

22. **Order Psittaciformes (sittaa-see-formez):** includes parrots (Fig.16.32) and parakeets, most of which have a brilliantly coloured plumage. Members of this order have a heavy beak with a hinged and movable upper beak and a fleshy tongue. Feet of these birds are adapted for grasping, as the fourth toe is capable of being turned back beside (reversible) the first toe. Order Psittaciformes has 388 species all of which show pantropical distribution.

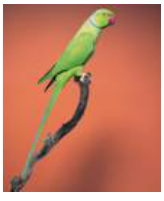


Fig. 16.32: A Parrot

Fig. 16.33: Hoatzin bird

Fig. 16.34:A Turaco bird

Fig. 16.35: A Roadrunner

Fig. 16.36: An Owl

Fig. 16.37: A Nighthawk

Fig. 16.38:A Humming bird

Fig. 16.39:A Mouse bird

23. **Order Opisthocomiformes (o-pistho-co-mee-formez):** consists of hoatzin birds which also known as stink bird, or Canje pheasant.Members of this order are herbivorous. These bird have a long neck, a small head and an unfeathered blue face with maroon eyes. Their head is topped by a spiky crest (Fig.16.33).This order has 1 species which is found in South America.

24. **Order Musophagiformes (mew-so-faa- jee-formez):** consists of Turaco birds (Fig.16.34) which are plantain (banana)-eaters. Members of this order consists of medium to large birds with brightly colored beaks, short and rounded wings and a conspicuous patch of crimson on the spread wing. Order Musophagiformes consists of 23 species which are restricted to dense forests or forest edges of Africa.

25. **Order Cuculiformes (ku-kulee-formez):** includes cuckoos and roadrunners (Fig.16.35). Members of this order consist of birds with a long tail. The fourth toe of the foot of these birds is capable of being turned back beside the first toe. The common cuckoo, *Cuculus canorus*, lays its eggs in the nests of smaller birds, which without realising rear the young cuckoos. However, the american cuckoo usually rears its own young ones. Order Cuculiformes consists of 149 species all of which show worldwide distribution.

26. **Order Strigiformes (strijee-formez):** consists of owls (Fig.16.36), all of which are nocturnal predators with large, forward-turned eyes, powerful hooked beaks and sharp curved talons (feet with claws).In these birds the face feathers are arranged as a facial disc around the large, eyes. Flight of these birds is very silent. Order Strigiformes has 229 species that show worldwide distribution.

27. **Order Caprimulgiformes (kap-ree-muljee-formez):** includes nightjars, nighthawks (Fig.16.37) and whipporwills all of which are insectivorous and have owl-like head and plumage. They have wide mouths that are fringed with bristle-like feathers in order to help them net insects. These birds have weak legs and small feet. Members of this order are night and twilight feeders. Order Caprimulgiformes consists of 119 species, all of which show worldwide distribution.

28. **Order Apodiformes (a-podee-formez):** includes swifts and hummingbirds (Fig.16.38). Members of this order are small, fast flying birds with long narrow wings, rapid wing beat and short legs. Most species of humming birds occur in the tropics, but there are 24 species in the United States, of which only one, the ruby-throated hummingbird, occurs in the eastern part of the country. Order Apodiformes has 461 species and the members have a worldwide distribution.

29. **Order Coliiformes (ko-lee-for- mez):** consists of mouse birds (Fig.16.39) which are small, crested birds with long tails. All

members have strong claws and reversible outer toes. Order Coliiformes consists of 6 species which are restricted to Southern Africa.

30. **Order Trogoniformes (tro-gonee-formez):** consists of trogon birds (Fig.16.40) which are richly coloured and long-tailed. Order Trogoniformes consists of 43 species which show pantropical distribution.

Fig. 16.40: A Trogon

31. **Order Leptosomiformes (lep-toe-somee-formez):** consists of the cuckoo roller birds (Fig.16.41).In these birds the eyes are set far back in the face. Members have a stout beak and small leg and feet. These birds have zygodactylous feet with two toes pointing forward and two toes pointing backwards. Order Leptosomiformes consists of a single species which inhabits the Madagascar forests.

Fig. 16.41: A Cuckoo roller bird

32. **Order Coraciiformes (ko-rasee-for mez):** includes kingfishers (Fig.16.42) and bee-eaters. Members of this order often have a brilliant, metallic plumage. All of them have a large head with a large, strong, and prominent beak and grasping feet. These birds nest in cavities. Order Coraciiformes has158 species, all of which have worldwide distribution.

Fig. 16.42:A Kingfisher

33. **Order Bucerotiformes (beau–sere-otee-fomez):** includes hoopoes (Fig.16.43) and hornbills, both of which have large, curved beaks. Most of the birds of this order nest in tree cavities. Order Bucerotiformes consists of 73 species that are found mostly in tropical Asia and Africa.

Fig. 16.43 : A pair of Hoopoe

34. **Order Piciformes (pisee-formez):** includes woodpeckers (Fig.16.44), toucans, and honeyguides which nest in cavities. These birds have highly specialised long and strong beaks. Members of this order have strong legs and feet which have two toes that extend forward and two that extend backwards. Order Piciformes has 437 species, all of which show worldwide distribution.

Fig. 16.44:A Woodpecker

35. **Order Passeriformes (pas-seree-formez):** is the largest order of perching birds as their feet are well adapted for perching on thin stems and twigs. This order consist of 120 families and 60% of all birds that are present today. Most members of this order are songbirds and have a highly developed syrinx (voice box).Songbirds such as thrushes, warblers, finches and sparrows, (Fig.16.45) and several other singing birds belong to this order. This order also contains birds such as swallows, magpies, crows, ravens and jays, which are not songbirds. The young ones, of this order are altricial (the young are born helpless). Order Passeriformes contains 6243 species, all of which show worldwide distribution.

Fig. 16.45: A Sparrow

SAQ 2

a) Match the common names of the birds given on the left 'Column A' with the Orders given in the right 'Column B' :

Column A	Column B
1. Pelican	i) Struthiformes
2. Ostrich	ii) Anseriformes
3. Swan	iii) Galliformes
4. Domestic fowl	iv) Sphenisciformes
5. Penguin	v) Pelecaniformes

16.5 ADAPTATIONS FOR FLIGHT: FORM AND FUNCTION

Birds show variations in their: 1) beaks and feet which are specialised for different modes of feeding and locomotion respectively; 2) in the structure of the intestinal tract of birds as the structure of the intestinal tract, depends on the dietary habits of the birds; 3) wing shape as the wing shape determines the type of flight. However, despite these variations the morphology of birds is more uniform as compared to other vertebrate. In all birds: i) the forelimbs are modified as wings, although not all birds are capable of flight; ii) hindlimbs are adapted for walking, swimming or perching; iii) a keratinized beak without teeth is present; and iv) fertilization is internal and the embryo develops within an egg, which is laid outside the body by the female.

In birds the uniformity in structure is believed to be due to the specialisation of birds for flight. Flight in birds is one of the most important features. However in addition to be able to fly, birds must feed themselves, convert food into metabolic energy, avoid predators, try to repair their own injuries, maintain a high, constant temperature and also reproduce.

Birds, for the purpose of flight have various, special adaptations which relate mainly to two things:1) less weight and 2) more power and energy . In this unit we will study some of the important features that have been adapted for flight as given below:

1. Body shape and size for flight.
2. Endothermy for high energy requirement during flight.
3. Efficient digestive and blood circulatory system for meeting the high-energy demands of flight.
4. Efficient respiratory system for meeting the high oxygen demands and for cooling the body during flight.
5. Adaptation of eye for extraordinary sight which is required during high-velocity flight.
6. Modification in skeleton in order to provide a light but rigid airframe.
7. Presence of wings and feathers for support and propulsion and flight.
8. Flight muscles should be well-developed.
9. Reduction in the size or number of organs in order to decrease body weight which helps in better flying.

16.5.1 Body Shape and Size

Birds have a spindle shaped body which ensures least wind resistance to flight. Flight also imposes a maximum body size on birds. It is for this reason that large birds like ostrich and emu are unable to fly. The smallest bird is Helen's hummingbird of Cuba and the largest living bird is the African ostrich which stands 2.13 meters tall and weighs upto 136.4 kg and so is too big to fly.

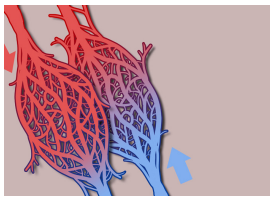


Fig:16.46 : *rete mirabile* in which the arteries that carry warm blood away from the heart are closely located near the veins that carry cold blood from the feet. A heat exchange occurs, and the feet become warm.

16.5.2 Endothermy

Birds require a lot of energy for flying and so have evolved true endothermy. They maintain body temperatures at relatively high levels of 40-43°C and their metabolic rate is many times that of reptiles. Heat is produced internally and its loss is controlled at the body surface. Insulation is provided by a subcutaneous layer of fat present under the skin and by the presence of feathers. Water which is a very good conductor of heat is prevented from penetrating the feathers by an oily secretion produced by the uropygial gland (Gr, oura = tail + puge = rump), located on the back, near the tail base. The oily secretion is spread on the feather surface. The feet of birds are scaly and sinewy and have very few nerves, which reduces the feeling of cold that the birds might feel through their feet. The scales of the feet are also specialised to minimise heat loss. In many birds however, heat loss by feet is further reduced by a vascular countercurrent mechanism that takes place in the rete mirabile (pronounced 'reyta mirah-biley' which means 'wonderful net'. This "rete mirabile' ' is a network (Fig. 16.46) of entwined fine arterial and venous vessels in which the arteries that supply warm blood downwards to the feet, break into, a maze of tiny blood vessels and surround the fine venous vessels of the feet that carry cold blood returning to the body. This, thus ensures that the heat flowing peripherally in the arterial blood is transferred to the cooler venous blood returning to the body so that the warmth is short circuited from the arteries to the vein and back into the body and heat is conserved.

In addition to this, birds birds in order to keep warm also take turns, lifting one foot and tucking it beneath their wings to warm it up, or crouching down covering their feet by their wings to warm them.

16.5.3 Skeleton

The skeleton (Fig. 16.47 a and b) of bird is modified in relation to flight, bipedal locomotion and laying of large eggs with hard shells. One of the major adaptation of modern bird that allows it to fly, is its light but sturdy skeleton (Fig.16.47), unlike the skeleton of *Archaeopteryx* which was solid with reptile-like bones, and so too heavy for flight (refer again to Fig. 16.2). The bones of modern birds are amazingly light, delicate, thin, hollow, pneumatic, being laced with air cavities due to extensions from the lungs into them. The skeleton however, is strengthened by internal struts present within the bone (Fig. 16.47 b). The skeleton of all birds weighs less in relation to their body weight as compared to the skeletons of mammals.

Skull

The skull of modern birds is highly specialised for flight and so it becomes difficult to see any trace of the original diapsid condition. Most birds have a light, kinetic skull in which a large number of skull bones are fused together (Fig. 16.47 a) due to which the weight of the bird's skull is reduced. Apart, from the fusion of skull bones, the weight of the bird skull is further reduced due to the absence of teeth in the jaws and the lack of heavy jaws and jaw muscles. The skull weight of birds as a result is usually only 1% of the bird's body weight. The anterior skull forms the jaws which extend forward into a keratinized (horny), toothless beak.

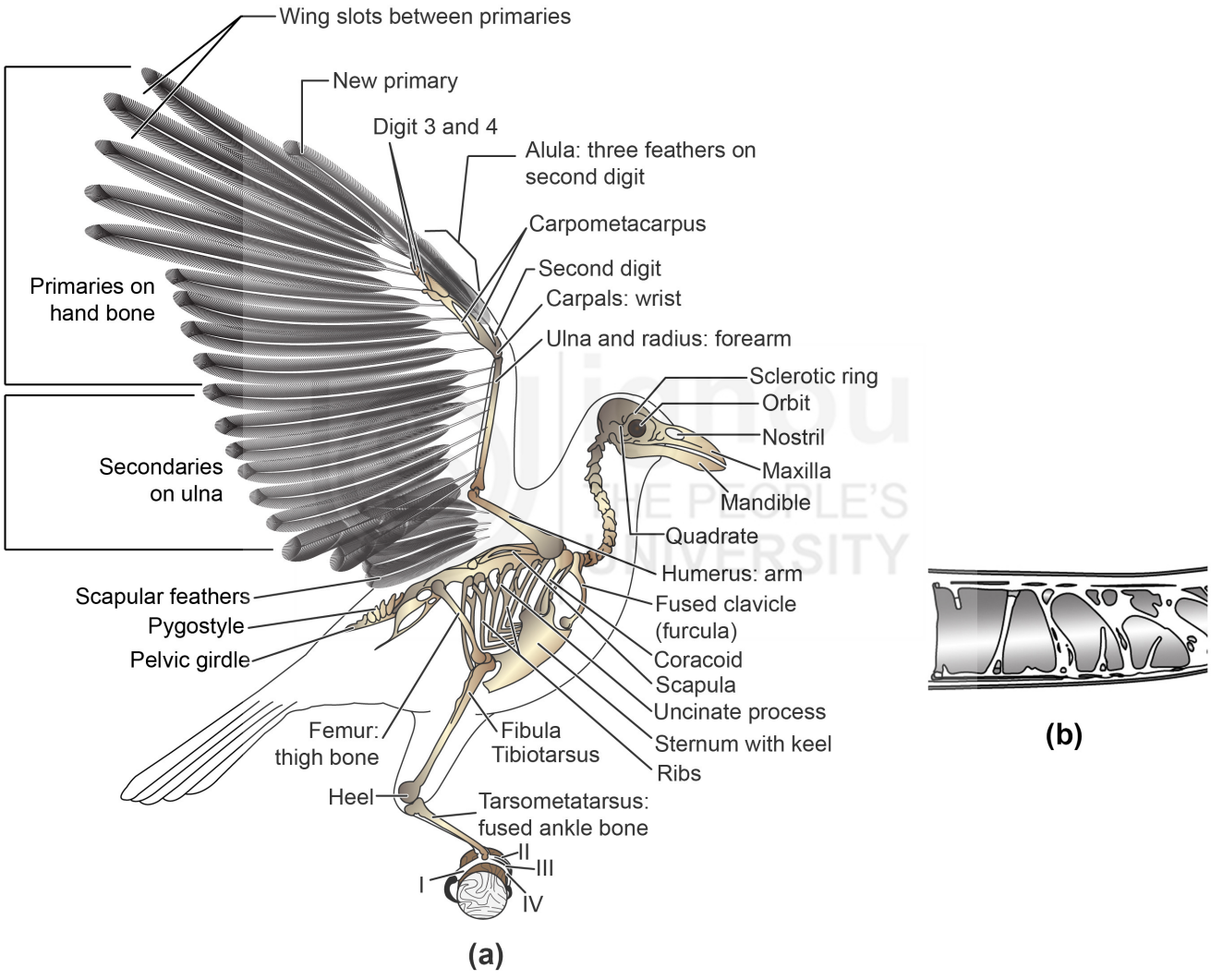


Fig. 16.47: a) Skeleton of a bird; and b) a Longitudinal section of a bone of bird showing, its internal, hollow structure with stiffening struts (support) and air spaces that replace bone marrow. Such pneumatized bones are remarkably light and strong.

The cranial region or brain case and the eye orbits of the skull of brids are large and so can accommodate an enlarged and bulging brain which is required for quick motor coordination and for the large, well-developed eyes needed for superior vision. The brain contained in the brain case continuous posteriorly as the spinal cord or column through a cavity called the foramen magnum present at the posterior end of the skull. The spinal cord is enclosed and protected by the vertebral column. The vertebral column consists of a

series of bones which are linked together to form the vertebral column, with the skull at one end and the tail at the other. An anterior sclerotic ring consisting of 10-18 overlapping bones (Fig. 16.48) function to contain and protect the large eye balls in the skull.

Cervical (Neck Vertebrae)

The single occipital condyle of the skull of the bird (Refer again to Fig.16.48 b) articulates with the atlas vertebrae which is the first neck vertebra of the vertebral column. The vertebral column of birds is highly specialised for flight. Its most distinctive feature is its rigidity. The neck of the bird is very long with more cervical (neck) vertebrae than that which occurs in many other animal group. Most birds have 13 to 25 flexible cervical (neck) vertebrae which are articulated in such a fashion so that the head and neck are very mobile, since freedom of movement of the head is very essential for flying.

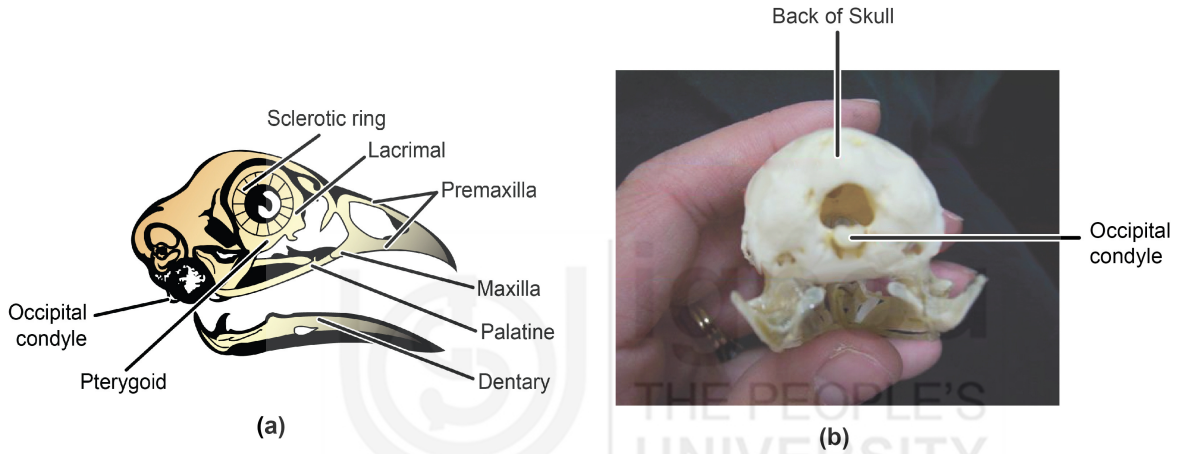


Fig. 16.48: a) Bird skull; and b) occipital condyle present at the posterior end of the bird skull. .

Vertebral Column (of Trunk Tail), Ribs and Girdles

i) Trunk and Tail Vertebral

The trunk region in birds in comparison to the neck is short as most of the vertebrae except the cervical vertebrae are fused together. The trunk vertebrae are fused together and include: 1) the last thoracic vertebra, 2) all lumbar vertebrae, 3) all sacral vertebrae and 4) the first few caudal vertebrae. All these fused vertebrae are also fused to the pelvic girdle (pelvis) in order to form a stiff but light synsacram which is present as a dorsal ridge of bone in the pelvic region of birds. Posterior to the synsacram about 6 to 7 caudal vertebrae are free, after which 4 to 7 caudal vertebrae are fused to form the pygostyle which forms the skeleton of the tail of the bird which is not very long. The pelvis though, fused to numerous vertebrae is however, free and open ventrally. The synsacram supports the weight of the bird's body on the hindlimbs, while walking or standing and also provides rigidity for flight.

ii) Ribs

The ribs of birds are ossified and thoracic ribs have posteriorly directed uncinate processes that overlap the next rib, thus providing a brace against each other for strengthening the rib cage and providing rigidity to the skeleton. The uncinate process if you will recall is also present in the reptiles which is

indicative of common ancestry between birds and reptiles. For imparting further rigidity to the skeleton these ribs are mostly fused with the thoracic vertebrae, pectoral girdle and the ossified sternum.

Pectoral girdle

In flying birds (Carinates) and in penguins which are strong swimmers, the sternum has a keel or carina for attachment of muscles which is absent in all ratites except the tinamou birds. The keel is a thin projection present on the median ventral side of the strerum. The pectoral girdle and forelimbs form the shoulders of the bird and are highly specialised, especially in flying birds, because of the extremely powerful primary flight muscles attached to them (Fig. 16.49). The pectoral girdle is a very stout, bony structure which on either side is connected with a broad sternum which is usually keeled to support the wings. The two parts of the pectoral girdle are similar and each part of the pectoral girdle consists of a scapula also called shoulder blade, coracoid and a clavicle. The coracoids are prominent in modern birds and function as a sturdy strut (bar) for support and for bracing the pectoral girdle against the sternum which prevents the medial collapse of the shoulders when the flight muscles are being used.

In most carinate birds the two clavicle bones fuse medially and ventrally with the interclavicle bone to form the furcula or wish bone. The Furculum serves as an additional site for the attachment of muscle flight muscles. In some ratite and carinate birds such as parrots and pigeons the clavicles are absent or rudimentary.

Shoulder of bird: wing bones

The skeleton of the anterior appendages or wings of birds (Fig. 16.48 and 16.49) are clearly a rearrangement of the basic vertebrate limb in which all the elements- humerus(upper arm), radius and ulna (forearm), wrist (carpals and metacarpals) and fingers (phalanges), similar to all amniotic vertabrates are present but become modified for flight due to fusion and loss of bones. The modified bones of the forelimbs of bird to which the wing feathers are attached are:1) the shoulder bones which consists of the scapula (shoulder blade); 2) coracoid (projecting part of the shoulder blade); 3) the humerus or the upper arm to which the pectoral muscles are mainly attached; 4) the bones of the lower arm also called forearm which is distal to the humerus consists of radius forming the outer side of the lower arm also called forearm and ulna forming the inner side of the forearm (lower arm). The upper arm articulates with the proximal end of the lower arm to form the elbow; 5) the distal end of the lower arm articulates with the wrist bones namely the carpals and metacarpals. The three distal carpal bones usually fuse with three metacarpal bones to form a rigid carpometacarpus of the wrist ; 6) digits fingers are present distal to the wrist and are usually three in number, and 7) the thumb (alula) supports the “bastard wing” which moves independently of the rest of the wing.

Pelvic Girdle

The pelvic girdle (Refer again to Fig. 16.47) consists of two separate halves lying on either side of the synsacram with which they are fused. Each half is

known as innominat bone and each half is composed of ilium which forms the top of the hip, ischium which forms the side of the hip and the pubis which forms the front of the hip. Innominate bones are of evolutionary significance as their structure allow the birds to lay eggs. At the junction of three bones namely, ilium, ischium and pubis a concavity, called the acetabulum (hip socket) is present which provides a surface for the articulation of the head of femur of the hindlimb.

Hindlimbs

The hindlimbs of birds resemble that of bipedal dinosaurs and have undergone less pronounced modifications than the wings, since they are mainly designed as were those of their reptilian ancestors for walking, perching and occasionally for swimming. In birds, each hind limb at its proximal end consists of : i) a single bone called femur which forms the thigh or upper region of the hind limb. The proximal or heard of each femur articulates with the acetabulum of the pelvic girdle present at its side; ii) the lower limb or shank of the hind limb articulates on its proximal end with the femur bone. The lower limb of the hind limb consist of two bones tibia and fibula, of which the fibula is much reduced in birds while the tibia is strong . iii) The tibia bone fuses at its distal end with the proximal row of tarsal bones and forms the tibia tarsus. (iv) the distal row of tarsal bones unite with the 2nd, 3rd and 4th metatarsal bones to form a single tarsmetatars bones complex. (v) Distal to the tarsometatarsus complex are phalanges or bones of the toes of the birds.

The fifth toe has been lost in all birds. The first toe is turned posteriorly in many species and is absent in some. It functions as a prop and enhances the grasping action of the foot when the bird perches. The efficiency of the leg in running on the ground and jumping at take off is increased by the elongation of the metatarsals and by the elevation of the heel off the ground. Fusion of certain limb and pelvic bones reduces the chance of dislocation and injury as the bird's legs function as shock absorbers when the bird lands. The pubes and the ischium of the two sides of the pelvic girdle are directed backwards and do not unite to form a midventral pelvic symphysis as they do in other terrestrial vertebrate. This allows more posterior percentage displacement of the viscera which together with the shortened limbs shifts the center of gravity of the body over the hind legs.

16.5.4 Muscular System

A bird has about 175 different muscles which mainly control the movement of neck, wings, tail and hind limbs.

Neck Muscles

The neck of bird has the most complex muscular system as the thin and stringy muscles of the neck are elaborately interwoven and subdivided, providing the bird neck with extraordinary flexibility.

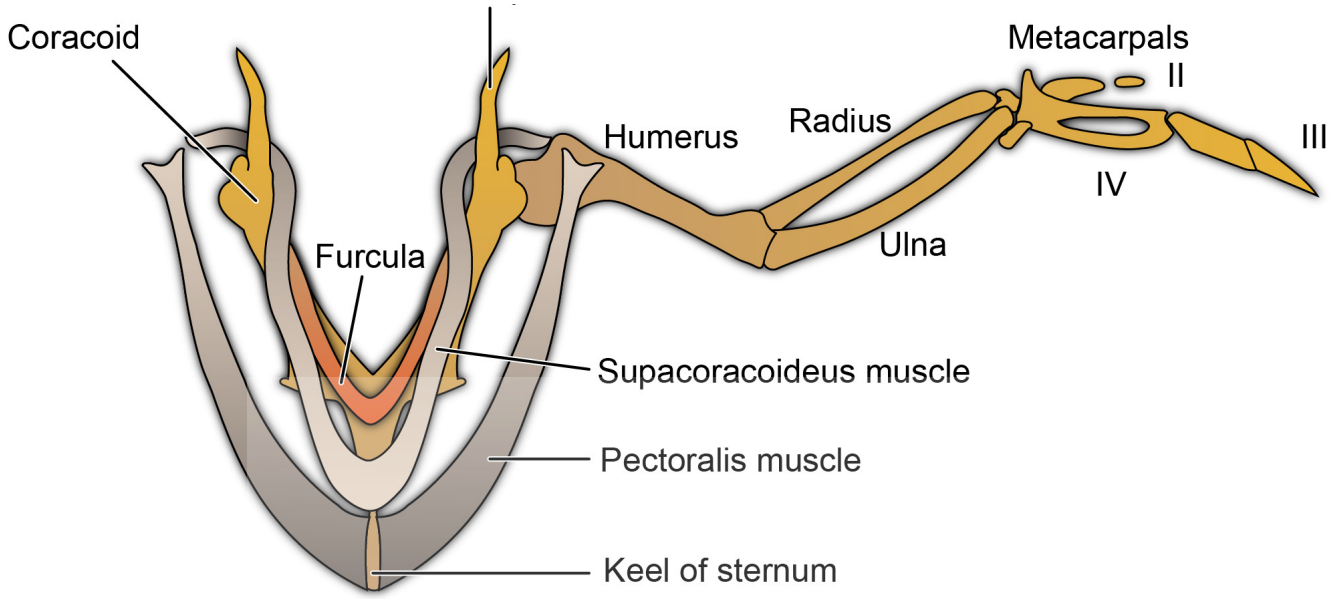


Fig. 16.49 : A diagrammatic cross section through the shoulder region showing the modified bones of the forelimbs of bird to which the wing feathers are attached. The cross section of sternum of a bird is also present in the figure and shows the attachment of flight muscles, which are arranged in a manner to keep the center of gravity low in the body.

Body Muscles

The muscles on the back or on the dorsal surface of the bird are considerably reduced. However, the flight muscles located below the wings are massive. The flight muscles attach to the sternum and clavicles and run towards the humerus bone. The location of the flight muscle prevents the bird from rolling out of control. The largest muscles in the bird are the pectoralis major, also referred to as pectorals or breast muscles. Pectoralis major make up about 15 to 25 % of a bird's full body weight and is responsible for the powerful downstroke of the wings of the bird as it depresses(lowers) the wing in flight. You might expect that the dorsally placed muscles would be responsible for the recovery stroke, but instead another, ventral muscle the supra coracoideus muscle is responsible for the recovery or the upstroke (raising) and so it is an antagonist to the pectoralis major. The supra coracoideus muscle is located on the sternum, dorsal to the pectoralis major and so it is positioned above the pectoralis on the breast. The supra coracoideus muscle is attached to the upper side of the humerus of the wing by a tendon. Both the pectoralis major and supra coracoideus muscles are anchored to the keel. These two muscles are exceptionally large in birds that are powerful fliers and together constitute upto 25-35% of their body weight (Refer again to Fig. 16.49).

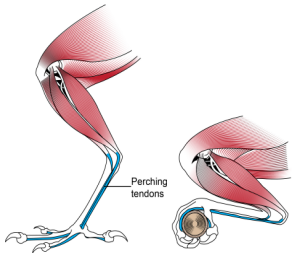


Fig.16.50: Hindlimb of bird showing, tendons that automatically tighten, closing toes around the perch.

Leg Muscles

In the legs of birds, the main muscle mass is located in the thigh, surrounding the femur and a smaller mass lies over the tibiotarsus (shank or drumstick). Strong but thin tendons extend downwards from the top the hind limbs through

sleeve like sheaths to the toes. As a result, the feet which are nearly devoid of muscles appear thin and delicate. This arrangement places the main muscle mass near the bird's center of gravity and at the same time allows great agility to the slender, light weight feet. The feet of birds are composed mostly of bone, tendon and tough scaly skin, and so are highly resistant to damage from freezing as discussed earlier. The perching mechanism of birds is also controlled by strongly developed muscles which are so modified that when a bird sits on a perch the toes automatically grip the perch by a toe locking mechanism that prevents the bird from falling even if it falls asleep while perching (Fig. 16.50).

Modern birds unlike the Archaeopteryx have a comparatively shorter tail. The tail of modern birds have a pincushion like muscle mound into which the tail feathers are rooted. The pincushion type of muscle mound, present in the tail contains as many as 1000 array of tiny muscles which control the tail feathers. The tail and its feathers in modern birds serve as a rudder during flight, as it helps in steering, lifting and counterbalancing the bird.

16.5.5 Skin

The skin of bird differs from that of mammal in being thin, loose and dry. There are no sweat glands as these would be of no use in a body covered densely with feathers. The only large cutaneous gland present is the uropygial gland which is used for preening (cleaning and arranging) the feathers, with the help of the beak and oily secretion of the uropygial gland.

16.5.6 Bird Feather

A feather is a dead structure which is extremely light in weight, yet is remarkably tough with high tensile strength. Feathers more than any other single feature characterise birds. Feathers similar to the scales of feet of birds have evolved from reptilian scales to which they are thus homologous. Both feathers and scales of feet of bird are epidermal outgrowths of the integument. Feathers develop from follicles in the skin which are epidermal invaginations of the skin. Only the inner pulp of feathers contain the dermal elements, such as blood vessels, which supply nutrients and pigments for the growing feather. As the feather matures its blood supply is cut off and the feather becomes a dead keratinized epidermal structure which is rooted in the feather follicle. The chemical composition of feather is remarkably simple and uniform. The feather consists of more than 90% of a particular type of beta keratin, which is a protein and as mentioned in Unit 15 is related to the keratin B that forms the scales of lepidosaurs.

The feathers of modem birds provide an external covering whose uses vary from heat insulation, to heat conservation, to flight, to protective colouration, to sexual display. Birds have between 1,000 and 25,000 feathers, depending upon the size of the bird. A humming bird has fewer feathers than a swan. You will study in greater detail about the structure of the feather and its different types in the next course.

Birds have several types of feathers which serve different functions. The different types of bird's feathers can be divided into 5 categories [Fig.16.51:b (i to v)]: i) Contour feather which is present in all birds and imparts them with a streamlined body. The contour feathers that extend

beyond the body and are used for flight are called flight feathers; ii) Semi plume feather; iii) Filoplume feather; iv) down feather; and v) Bristle feather. All these types of feathers are not present in all birds as the presence of the types of feathers present in the birds depends on the type of bird. Fig.16.51a shows the type of feather found in *Archaepteryx* while Fig. 16.51 b shows the types of feathers that are found in modern birds.

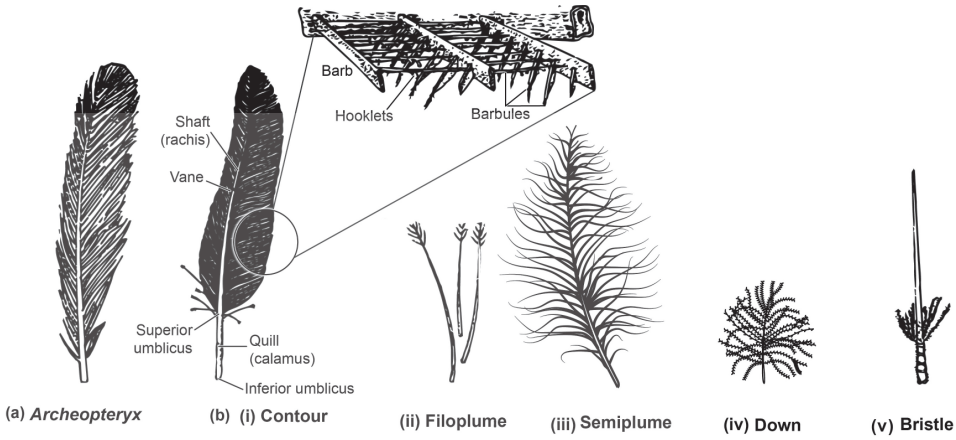


Fig.16.51: a) A feather of *Archaepteryx* (b) Types of bird feathers of modern birds: i) A contour feather (flight feather), inset enlargement showing minute hooks on the branches that interlock together, to form a continuous surface of vane; ii) Filoplume feather; iii) down feather; iv) bristle feather and; v) Semiplume feather.

The various bones of the forelimb of birds form a base for attachment of feathers which cover the skin of forelimbs bones and as a forms the wing structure (Refer again to sub-section 16.5.3).

The flight feathers of the wing (Fig.16.52 a and b) are called remiges and include: 1) primaries which are attached to various bones of the hand and wrist and fingers; 2) secondaries or cubitals which are attached to the ulna and 3) and humerals or tertiaries that are supported by the humerus bone . Contour feathers of the tail are called retrices.

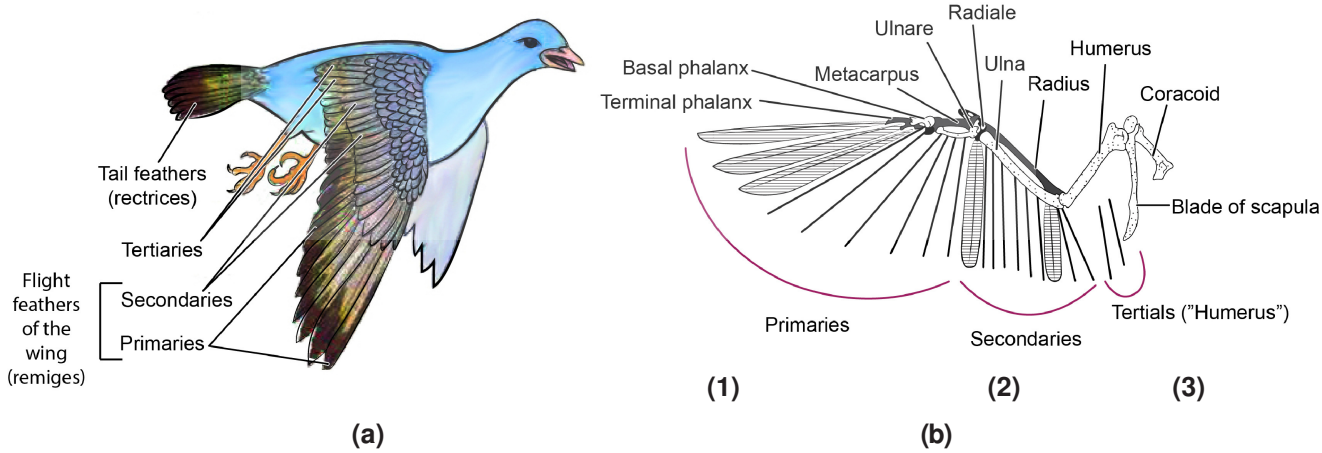


Fig. 16.52 Placement of feather in a bird showing: a) The arrangement of various kinds of feathers covering a bird's body; and b) The terminology used for the feathers of a bird, which are given according to the bones of forelimb to which they are attached i) large wing feathers which are involved in flight and are called remiges and include: 1) primaries which are supported by various bones of the hand and wrist; 2) secondaries or cubitals which are supported by the ulna; and 3) and tertials or humerals that are supported by the humerus. Contour feathers of the tail are called retrices.

16.5.7 Nervous and Sensory Systems

The nervous and sensory systems of the birds are developed for the complex problems of aerial life.

Brain

The brain of a bird has well-developed cerebral hemispheres (cerebrum), cerebellum and midbrain (Fig.16.53). The large cerebrum results from enlargement of the deeply situated mass forming the core of grey matter, the corpus striatum. The corpus striatum is the main integrative center of the brain in birds and controls such activities as singing, flying, eating and all other complex, instinctive, reproductive activities. Intelligent birds such as parrots and crows have large cerebral hemispheres in comparison to less intelligent birds such as chickens and pigeons. The cerebellum is also an important co-coordinating center where muscle - position sense, equilibrium sense and visual cues are assembled and used to coordinate movement and balance. The optic lobes which are laterally bulging outgrowths of the midbrain form the visual association apparatus used for seeing. the visual association apparatus of birds is comparable to the visual cortex of mammals.

The capacity of avian ear to distinguish differences in sound intensities and its response to rapid fluctuations in pitch, far exceed that of humans.

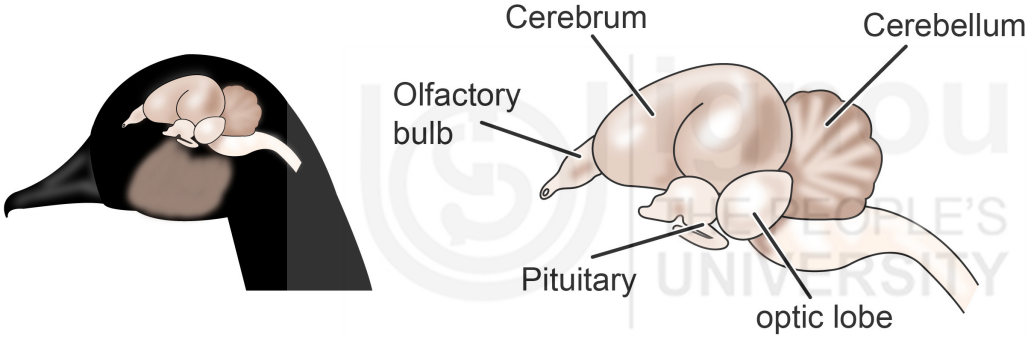


Fig.16.53: Head of bird (goose) showing: a) location of the brain in the bird; and b) labelled figure of brain of bird (goose) with its the main regions.

Olfactory Sense and Smell and Tongue and Taste

With the exception of flightless birds, ducks and vultures, the olfactory sense of smell and taste are poorly developed in most birds and so the olfactory organ and olfactory parts in the brain are reduced in them. This deficiency is however, well-compensated by good hearing and extraordinary vision.

Eyes and Vision

In birds, the placement of eyes in the head, is correlated to the bird's mode of life. Vegetarian birds that have to evade predators, have laterally placed eyes in order to obtain a wide view of the world, and so are able to see, behind themselves as well as in front. Predaceous (living by preying on other animals) birds such as owls and hawks have eyes directed to the front. The eyes of bitterns a bird species that searches for food in the marshes are directed downwards.

Sight is very important to flying animals and so the eyes of birds are relatively large, with binocular vision and wide field of view. A nictitating membrane is present in birds which is transparent or translucent and covers the eye ball during flight. A sclerotic ring of bony plates protects the eye ball and increases the distance between the lens and retina for sharp distant vision. The eyes of birds in gross structure (Fig. 16.54) resemble that of other vertebrates, but are relatively larger, less spherical and almost immobile. Birds, instead of turning their eye, turn their head to scan the visual field. Colour vision is well-developed. Rods for dim light vision and cones for colour vision are more densely packed in the light sensitive retina of the birds than in mammalian retina, making visual acuity which is the ability to distinguish objects as they become smaller and closer together, in birds several times greater than that of humans. Cones predominate in day birds and rods in nocturnal birds. A slightly depressed area of the retina, called the fovea is present and is particularly abundont in cones. The fovea magnifies the central part of the visual field and is the area of greatest acuity and is present and is well developed in birds of prey which need to focus accurately on the prey. Many species, including hummingbirds and albatrosses, have two foveas in each eye. The ability to detect polarised light is also common in birds. A unique feature of the avian eye is the presence of pecten which is belived to provide nourishment to the eye. The pecten a highly vascularised organ, attached to the retina near the optic nerve and jutting out into the vitreous humour of the eye (Fig. 16.54).

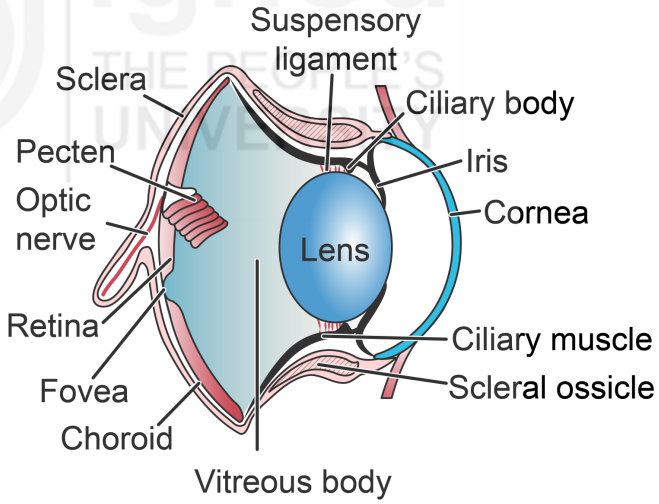


Fig. 16.54 : The eye of a bird of prey. The avian eye has all the structural component of the mammalian eye as well as a peculiar pleated structure the pecten, which is believed to provide nourishment to the retin. It also occurs in the reptilian eye.

Ear and Hearing

The avian ear has three regions (Fig. 16.55 a) : i) the external ear which is a sound conducting canal and extends up to the ear drum; ii) the middle ear that contains a rod like columella which transmits vibrations; and iii) the inner ear in which a cochlea is present but which is much shorter than that of mammals. The bird despite the short cochlea can hear approximately the same range of frequencies as humans.

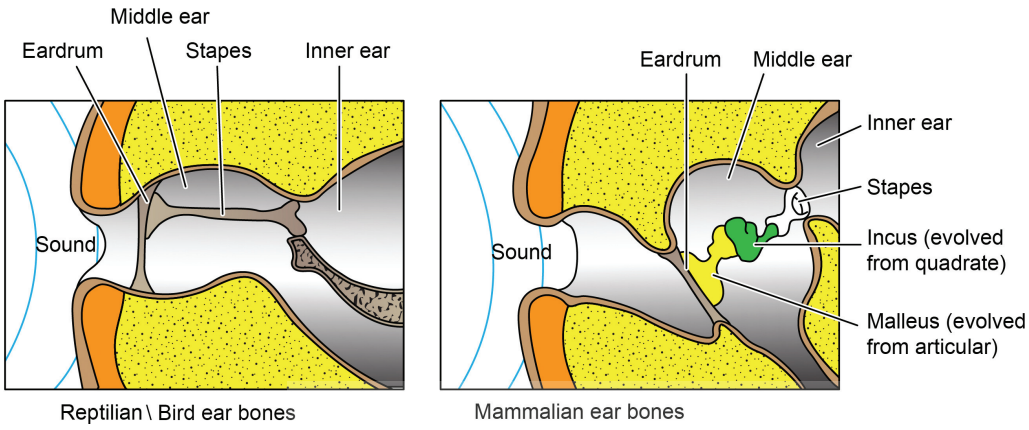


Fig.16.55: Generalised figure of the middle ear: a) a bird/lizard with a single ossicle called the columella or the stapes which spans the middle ear cavity; and b) of a mammalian middle ear with three ossicles in a chain-stapes (S), malleus (M), and incus (I) within the middle ear cavity.

SAQ 3

Choose the correct word from parenthesis:

i) Birds have evolved true (ectothermy/endothermy) and maintain a relatively high body temperature.

ii) The skeleton of all birds weigh (less/more) in relation to their body weight as compared to skeleton of mammals.

iii) The efficiency of the bird's legs in running on the ground and jumping at take off is increased by the (shortening/elongation) of the metatarsals.

iv) Predaceous birds such as owls ad hawks have eyes that are directed (to the front/downwards).

v) Secondaries or cubital feathers are supported by the (ulna/humerus) bone.

vi) The feather of birds consists of more than 90% of a particular type of (alpha/beta) keratin, which is a protein.

16.5.8 Digestive System

Birds, due to their aerial mode of life have a high metabolic rate in order to generate energy and so must have an energy rich or calorie rich diet. Birds also consume more food in proportion to their size than most animals. For example, a warbler might eat 80 percent of its body weight in a day. As a group, birds are voracious feeders and eat all types of food in large quantities. Birds may be carnivorous or herbivorous or both in which case they are termed as omnivore. Birds which have a wide eating range are termed as euryphagous or 'wide eating' species as they eat whatever is seasonally abundant. Others are specialised eaters, eating limited type of foods and so are referred to as stenophagous or "narrow eating" species.

The preference for specialised food by stenophagous bird, acts as limiting factor for them as the reduction or destruction of the types of food they eat (due various reasons like diseases, adverse climate etc.) may decrease their chances of survival.

Beaks

Beaks of birds are highly specialised according to the type of food they eat. The shape of the beak in birds range from the generalised types such as the strong, pointed beaks of crows, to grotesque, highly specialised ones as in flamingoes, horn bills and toucans. Fig. 16.56, shows the beaks of various birds that are adapted for the particular type of food they eat.

It is essential for birds due to their high energy requirements to rapidly digest the food eaten by them in an efficient digestive system. For example, a shrike bird can digest a mouse in three hours, and a thrush digests berries in just 30 minutes.

In pigeons, doves and some parrots, the crop not only stores food but also produces milk by the breakdown of the epithelial cells of the lining. This 'bird milk' is regurgitated by both female and male into the mouth of the young chicks (bird babies or squabs). Bird milk is found to have a much higher fat content than cow's milk.

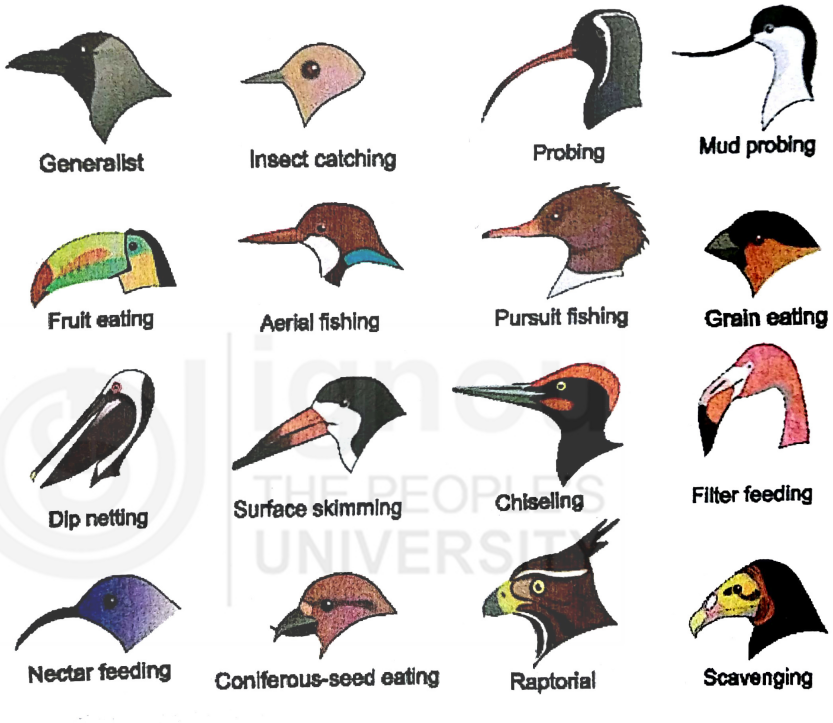


Fig. 16.56: Different beak types adapted for different modes of feeding.

Alimentary system

The digestive system of birds is well-developed (Fig. 16.57). Since birds lack teeth, and the jaw bones and jaw muscles are not able to chew food and so the food ingested by the beak of the birds enters the mouth cavity without being chewed. Poorly developed, paired, salivary glands are present in the mouth and serve primarily to secrete mucous in order to lubricate both the food eaten and the slender, horn-covered tongue. The tongue of birds has few taste buds, although all birds can taste to some extent.

The unchewed food from the mouth passes into a short pharynx and then into a straight and relatively long muscular and elastic oesophagus. In many birds such as pigeons, and similar seed and grain-eating species the oesophagus at the distal end becomes enlarged to form a chamber called crop which serves as a temporary storage of food in which the food is moistened and softened with water.

The food from the crop which is located at the distal end of the oesophagus passes into stomach which consists of two parts: i) the first proximal glandular part called the proventriculus which is the true stomach since it is the glandular part where digestion primarily begins. The proventriculus secretes hydrochloric acid and gastric digestive enzymes, such as pepsin, both of which start to break down the food present in the proventriculus. The digestion of food in the proventriculus is much more extensive as compared to the breakdown of the food due to the secretions of the salivary glands and ii) the distal mastigatory part the muscular gizzard, which is the highly modified part of the stomach with thick muscular walls that are internally lined with horny plates and modified glands. These modified glands secrete the horny plates. The gizzard serves as millstones (grinding stones) to assist in grinding food, thus, performing a function similar to that of teeth and jaws. The partially digested and ground food from the gizzard passes through the pyloric sphincter into the small intestine which on the basis of structure and function is divisible into the three following areas (i) proximal duodenum ii) Jejunum and iii) ileum.The bile juice and enzyme that are manufactured in the liver and pancreas respectively are secreted into the duodenum where the digestion process continues with the help of bile juice and enzymes, further breaking down the food. The internal lining of the small intestine has villi for absorption of the digested food. The small intestine leads to the large intestine which at its distal leads to the rectum. The rectum opens into a cloaca which is the terminal part of the digestive canal from which the excretory matter of the bird passes outside the body.

Paired genital ducts and ureters also open into the cloaca. In birds the cloaca is a large tripartite chamber, divisible into three compartments (1)anterior coprodaeum into which the rectum opens (2) a short middle urodaeum in which the paired ureters of the kidney and the paired genital ducts open (3) the large proctodeum which is used during copulation and develops a penis in several amniotes. All the excretory and secretary products from the body are removed by the cloacal aperture which opens at the surface of the body. A pair of small, blind pouches called caeca, which may be well-developed in some species are present at the junction of the small and large intestine. The dorsal wall of proctodeum of cloaca of young birds bears the “bursa of Fabricius” which is important in the immune response of the birds and disappears when the chicks attain sexual maturity.

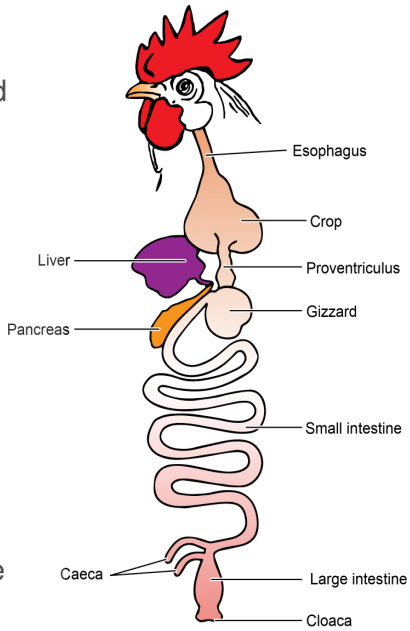


Fig. 16.57: Generalised alimentary and excretory system of a bird (pigeon).

SAQ 4

Give one to three words for each of the following statements:

i) Birds that eat only limited type of food are called …….. .

ii) The enlarged lower end of oesophagus present in some birds that serves as a temporary storage for food is called …… .

iii) The muscular portion of stomach in birds, lined with horny plates that serves for grinding food is called …….. .

iv) The organ on the dorsal wall of cloaca of young birds which is important in immune responses is called……...

16.5.9 Circulatory System

The general plan of blood circulation in birds (Fig. 16.58 a) is quite similar to that of mammals. Heart is large, four-chambered with strong ventricular walls. The heart is completely divided into the right and left sides, preventing the oxygen-depleted blood mixing with the oxygen-rich blood (Fig.16.58 b).

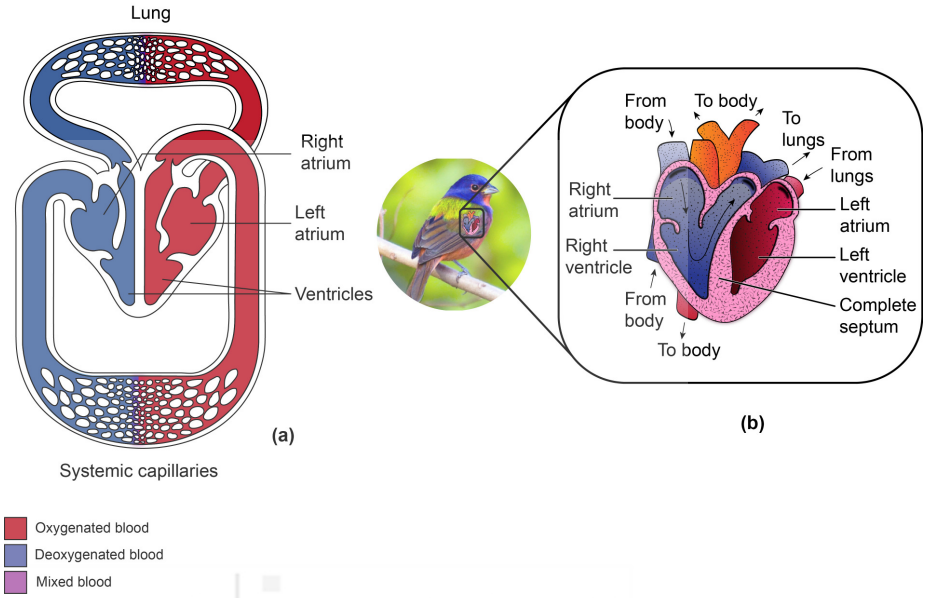


Fig. 16.58: a) Circulatory system of bird; b) Ventral view of avian heart.

In birds, similar to mammals there is complete separation of the respiratory and the systemic circulation. The circulatory system of birds is very efficient and as in mammals the heart beat is extremely rapid. There is an inverse relationship between heart rate and body weight. For example, at rest a turkey has a heart rate of approximately 93 beats per minute while a chicken which is comparatively smaller has a heart rate of 250 beats per minute. Blood pressure in birds is roughly equivalent to that in mammals of similar size. The blood of birds has high glucose levels, which is almost twice the level that is present in the mammals.

Red blood corpuscle of birds differs from that of mammals in being slightly larger, oval and nucleated. The mobile amoeboid blood cells (phagocytes) of the blood are unusually active and efficient in birds both in the repair of wounds and in destroying microbes.

16.5.10 Respiratory System

The respiratory system of birds is one of the major systems of the body. It has a number of very important functions that include: 1) providing of oxygen to the lungs and consequently to the body; 2) removal of carbon dioxide; 3) removal of excess heat (thermoregulation) and 4) a role in vocal communication.

The bird respiratory system is a complex one and differs radically from that of reptiles and mammals as it is well-adapted to meet the metabolic requirements of flight. It is proportionately larger and much more efficient than in any other animal group, since flight is a more demanding activity than walking or running.

The structure of the avian respiratory system (Fig.16.59 a and b) is different from that of other vertebrates. Birds have relatively small lungs. They also have nine air sacs which are connected with the lungs and play an important role in respiration but are not directly involved in the exchange of gases. Fig.16.59 a and b. show the respiratory system of a bird with its associated air sacs. The air sacs permit a unidirectional flow of air through the lungs. Unidirectional flow means that air moves only in one direction through the bird lungs and so this air is largely 'fresh' having, a higher oxygen content. As a result more oxygen is available in the lungs of a bird for its diffusion into the blood.

The nine interconnected air sacs (Fig. 16.59) which lie in various organs of the bird are as follows:

1. A single median interclavicular air sac from which a diverticulum or axillary air sac is given off on each side. This unpaired intraclavicular air sac is connected with both lungs.
2. Paired cervical air sacs which are placed at the root of the neck.
3. Paired anterior thoracic air sacs which are present in the front of the posterior thoracic air sac.
4. Paired caudal air sacs also called posterior thoracic air sacs are present behind the anterior thoracic air sacs that are found closely applied to the side wall of the body and
5. Paired abdominal air sacs. Each pair lies on each side of the body among the coils of the intestine.

In birds all the air sacs extend into the bones, and so replace a large amount of bone marrow which makes these bones pneumatic (filled with air) and light and so helps in reducing the body weight of the bird which is essential in flight. The air sacs act like bellows and are inflated and deflated by flight muscles with each stroke of the wing.

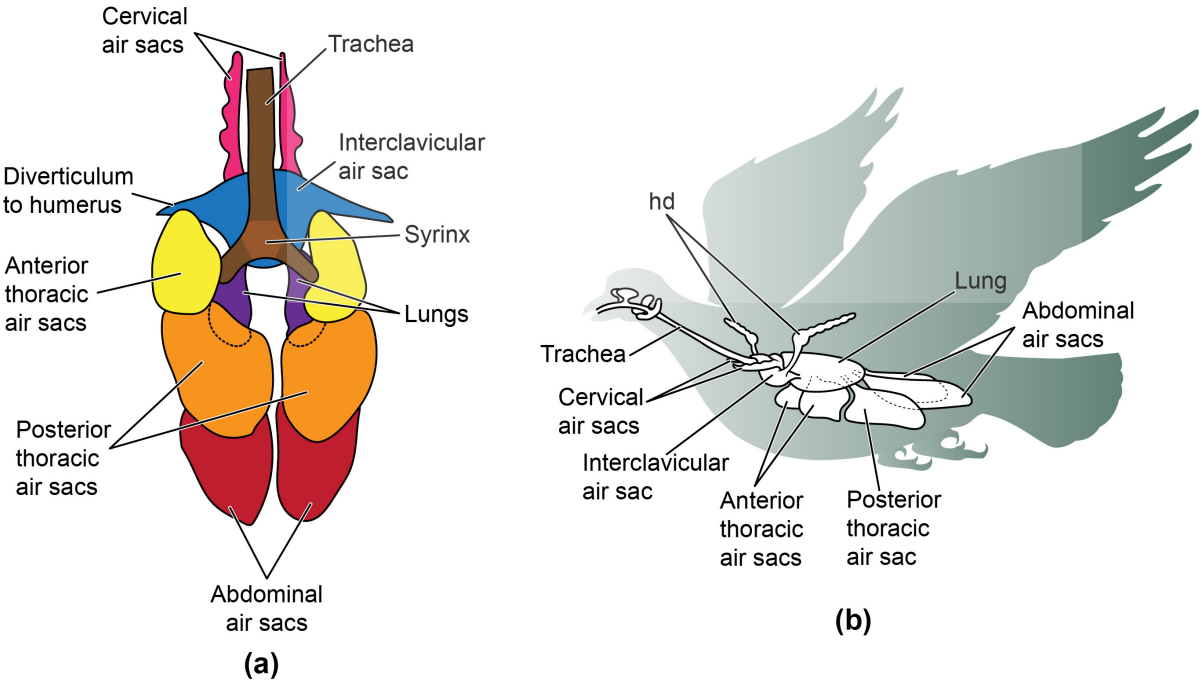


Fig. 16.59: a) The nine air sacs connected to the lungs; b) Respiratory system of birds.

In birds air enters into the mouth through nostrils and leads into the long, flexible trachea through a slit like glottis which is present in the floor of the pharynx. It then continues to the trachea and then to the syrinx which is the 'voice box' or the organ for sound generation and is well developed especially in songbirds. After the syrinx the air flows into the two branches of the trachea as the trachea is divided after the syrinx into two branches called the primary right and left bronchus (plu: bronchi). Air from each bronchus flows into the lung present on its side. The lungs are small, paired, spongy organs with little elasticity.

The paired primary bronchi do not immediately branch within the lung into sac-like alveoli as in mammals instead each brochus runs through the lung giving off lateral or secondary bronchi called mesobronchi to the lung substance. Branchng off from the mesobronchi are smaller tubes called dorsobronchi and ventrobronchi. The dorsobronchi and ventrobronchi, in turn, lead into the still smaller parabronchi. The Parabronchi are not blind endings, but join other parabronchi which in turn lead back to the secondary and primary bronchi to form anastomosis that eventually leads into the air sacs. Thus, the bronchial system of birds is continuous and the air moves into them accordingly (Fig. 16.60).

The primary bronchi after branching within the lungs continue posteriorly beyond the lungs into the paired abdominal air sacs.

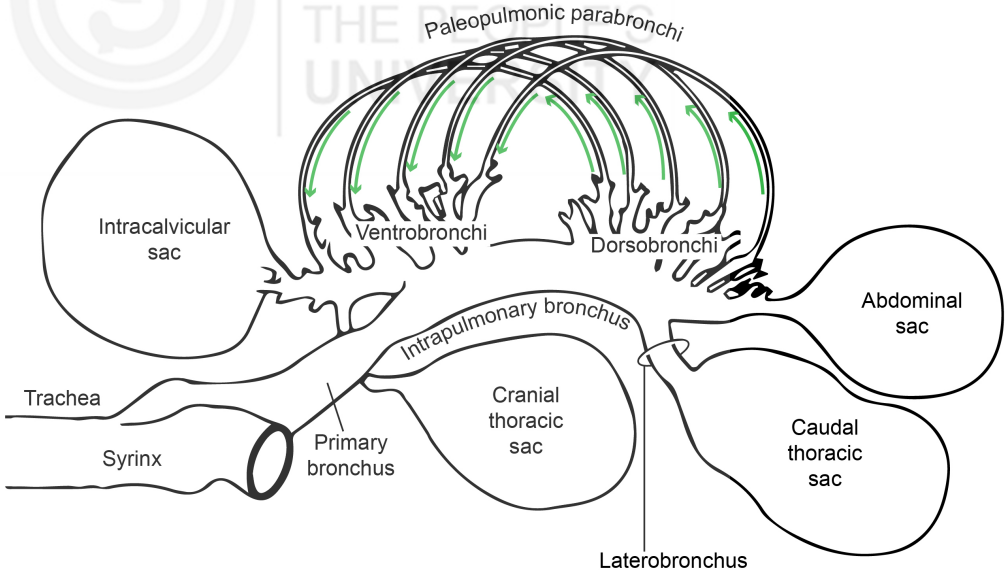


Fig. 16.60 : Respiration pathway: a) Schematic representation of the lungs and air sacs of a bird and the pathway of gas flow through the pulmonary system during inspiration.

16.5.11 Excretory System

In common with amniotes, birds have paired, relatively large, metanephric kidneys (Fig 16.60 a and b). Urine from the kidneys passes by way of ureters, one from each kidney to the cloaca. The urinary bladder has been lost in birds, possibly as an adaptation towards weight reduction.

The number of kidney tubules is large in birds due to the high rate of metabolism, yet water has to be conserved. That is why only some and not all tubules have Loops of Henle that allow water to be resorbed from tubules. Birds compared to mammals cannot produce a concentrated urine and so similar to reptiles from which they have evolved, they secrete their nitrogenous wastes as uric acid instead of urea, which is an adaptation that originated with the evolution of cleidoic egg. Due to uric acid's low solubility in water, a bird can excrete 1 gram of uric acid in only 1.5 to 3 ml. of water, as compared to a mammal which may need about 60 ml of water to secrete 1 gm of urea. Thus birds conserve most of their body water by excreting 75–90% of their nitrogen wastes as uric acid which is discharged as a white crystalline paste, mixed with faeces.

Birds despite having less efficient kidneys as compared to mammals with regard to their concentrative ability are able to concentrate and excrete uric acid which is nearly 3000 times more concentrated than its concentration found in blood.

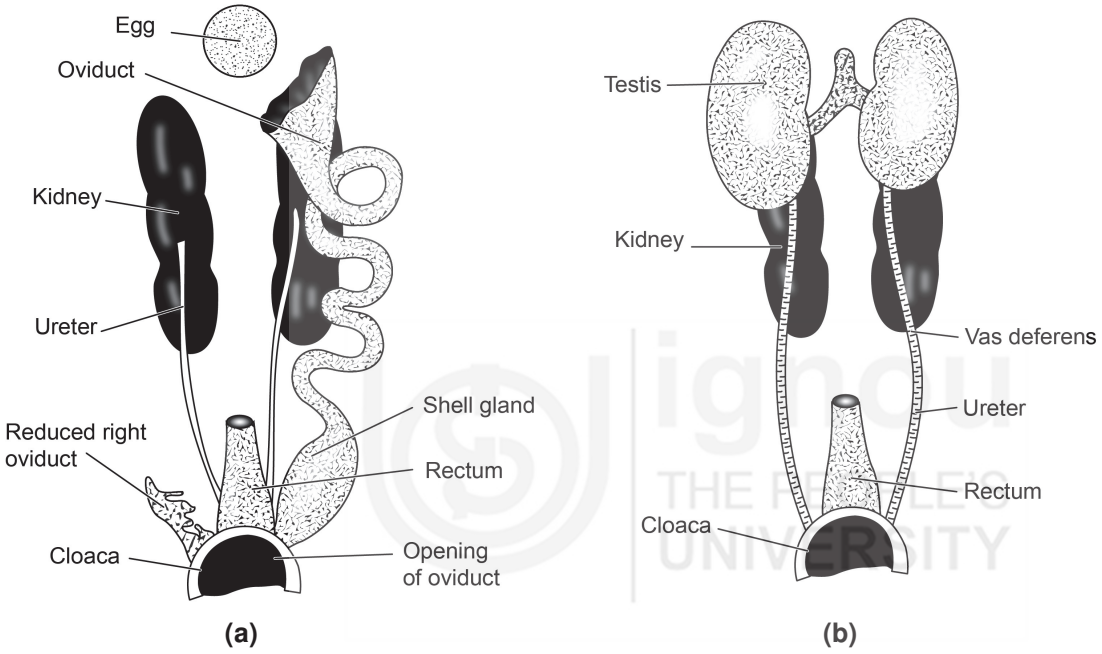


Fig. 16.61: Urogenital system of a bird (pigeon) showing both the excretory and reproductive system in: a) female; b) male.

16.5.12 Reproductive System

All birds are oviparous, and produce cleidoic eggs which undergo internal fertilization. Most of the female birds have only the left ovary and oviduct (Fig.16.61a). The right pair dwindles to a vestigial structure, probably as an adaption for the weight reduction in flying. The left ovary is small but enlarges greatly during reproductive season as eggs accumulate yolk (Fig. 16.62). In males the paired testes and accessory ducts are similar to other amniotic vertebrates.

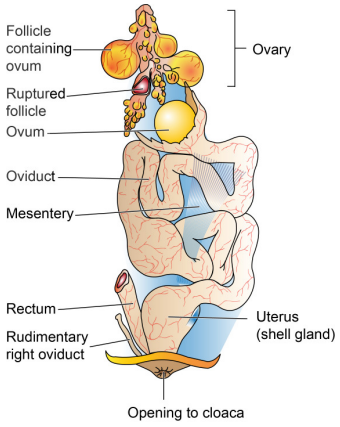


Fig. 16.62: Reproductive system of a female bird showing developing ova.

16.6 VARIOUS FACTORS INVOLVED IN BIRD FLIGHT

Flight has played a key role in the evolution and adaptation of birds and in their classification. In order to fly a bird needs to become airborne and move forward. Bird flight is a balance between two sets of forces, weight and lift

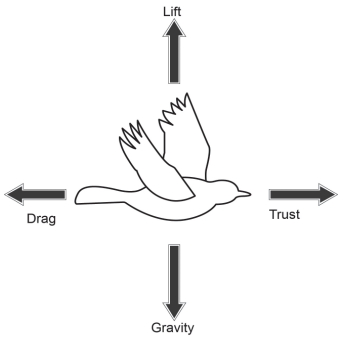


Fig. 16.63: Showing the balance of forces during bird flight.

and drag and thrust (Fig.16.63). Weight is a force produced as a result of gravity and it deters flight. In order to overcome gravity and become airborne the bird must generate lift forces greater than its, own body's weight and in order to move forward it must generate enough thrust to overcome the resistive forces of drag. Drag is a force which is opposite to the direction of motion.

16.6.1 Drag and Thrust

There are three major drag forces that impede a bird's aerial flight and include: 1) Frictional drag which is caused by the friction of air and the body surface of the bird; 2) drag which is caused due to the front area of the bird; and 3) Lift- induced drag which occurs due to air vortices (mass of spinning air) that develop at the wing tips and pulls things into its center. These three drag forces are reduced or overcome by the streamlined body of the bird and the use of wings that generate force for lifting the bird and moving it forward against drag (Refer again to Fig. 16.63).

16.6.2 Weight and Lift

The wings of birds are adapted for different types of flight. However, irrespective of whether a bird glides, soars or has a flapping flight, the mechanism of flying are similar. The natural shape of the wing of a bird resembles that of an airfoil and so is not flat. In cross section the bird wing is seen to be slightly concave below and convex (cambered) above (Fig.16.61 a and b).

The inner part of the wing which is closer to the body of the bird has less vertical motion than the part of the wing which is at a distance and forms the outer wing, and acts as an airfoil which generates lift, and ensures that air slips smoothly over the wing in such a way so that lift is generated with minimal drag.

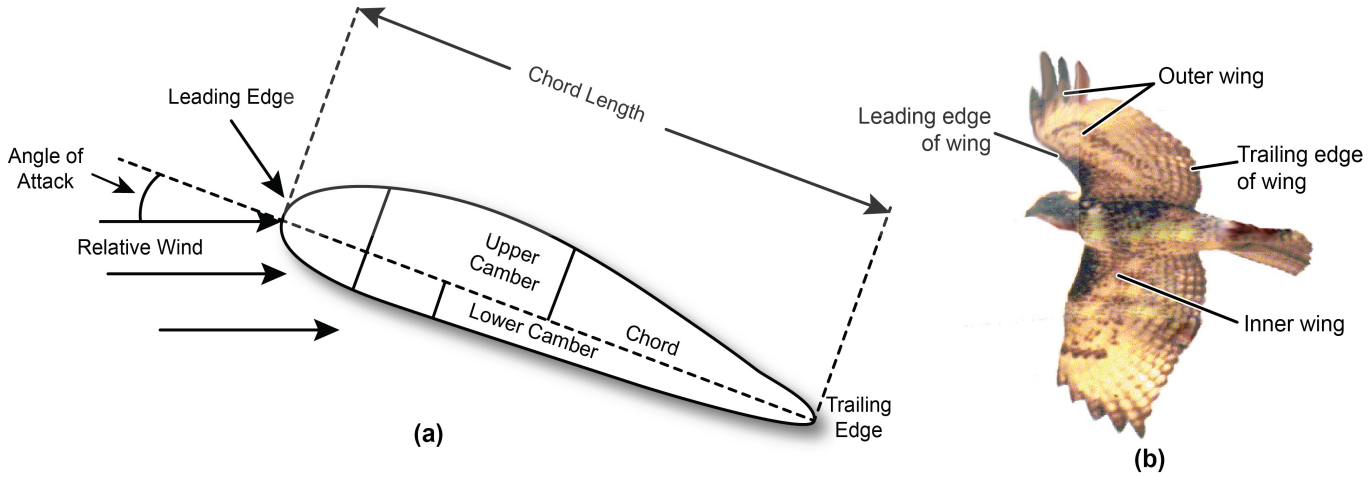


Fig. 16.64: Part of a bird's wing : a) schematic labelled diagram of a wing; and b) actual figure of a wing.

SAQ 5

Tick the following sentences as True or False.

i) Birds have relatively small lungs plus nine air sacs that play an important role in respiration. T/F

ii) In birds, not all nephric tubules have the loop of Henle. T/F

iii) Most of the female birds have only the right ovary and oviduct. T/F

iv) The left testes and ureters are lost in males of most birds. T/F

v) In birds, fertilization is internal. T/F

vi) In cross section the wing is seen to be slightly convex below and concave above. T/F

16.7 SUMMARY

- At present the Class Aves contains more than 10,400 species. These species are distributed among 40 orders of living birds and a few fossil orders.
- Birds are egg laying, endothermic vertebrates covered with feathers, with the forelimbs modified into wings. Phylogenetically birds are closest to the theropods a group of dinosaurs of the Mesozoic era which had several bird-like feature. The oldest known fossil bird *Archaeopteryx* believed to be from the Jurassic period of the Mesozoic era had a mosaic of reptilian and bird-like characteristics. Most probably *Archaepteryx* is not in direct lineage leading to modern birds but can be regarded as a sister group to modern bird.
- Adaptation for flight is the key theme in bird evolution and is of two main types: reduction of body weight and those factors promoting more power for flight. The main identifying feature of birds is the presence of feathers which are epidermal outgrowths and are derivatives of the reptilian scales. They are light, yet strong, water repellent and highly insulative. Body weight is reduced by elimination of some bones, fusion of others (to provide rigidity for flight) and the presence of hollow, air-filled spaces in many bones. The heavy jaw with teeth of the reptiles are replaced in birds by a toothless, light horny beak that serves both as mouth and hand for them, and is adapted variously for diverse feeding habit.
- Adaptations that provide power for flight include endothermy, high metabolic rate and high body temperature, coupled with an energy rich diet, and an extremely efficient circulatory system with a four chambered heart. The efficient circulatory system ensures by the double circulation the complete separation and circulation of oxygenated and de oxygenated blood, along with an effective and an efficient respiratory system, comprising of lungs and air sacs, all of which are arranged in such a manner so as to allow the passage of air only in one direction across the respiratory surfaces, thus maintaining a high level of oxygen at the gas

exchange surfaces. Powerful flight and thigh muscles are arranged to place muscle weight near the bird's center of gravity.

- Birds have keen eye sight, good hearing and superb coordination for flight.
- Most birds have poorly developed sense of smell.
- Digestive system is extremely efficient, digesting food very rapidly.
- Water is conserved by the metanephric kidneys, which eliminate the nitrogenous metabolic wastes as uric acid. Birds lack a urinary bladder.
- Bird wings form airfoils that provide lift.
- Flightlessness in birds is unusual but has evolved independently in several bird orders. However, both flightless and flying birds have evolved from flying ancestors.

16.8 TERMINAL QUESTIONS

1. Where was the *Archaeopteryx* discovered? Give reasons for the *Archaeopteryx* being considered the connecting link between reptiles and birds.
2. Birds are divided into two Superorders: Paleognathae and Neognathae. Explain the difference between the two Superorders.
3. The special adaptations of birds all contribute to two factors essential for flight namely, more power and less weight. Explain how each of the following contributes to one or the other or both:

   i) Endothermy, ii) Respiratory system, iii) Skeleton system and

   iv) Excretory system.
4. Explain the role of drag and thrust in bird flight.

16.9 ANSWERS

Self-Assessment Questions

1. i) Jurassic; ii) birds/Aves and reptiles; iii) five; d) occipital; iv) monophyletic;

   v) absent; vi) oval and nucleated.
2. 1. v; 2. i; 3. ii; 4. iii; 5. iv.
3. i) Endothermy; ii) less; iii) elongation; iv) to the front; v) ulna; vi) beta
4. i) called stenophagous or "narrow eating"; ii) crop; iii) gizzard; iv) bursa of Fabricius
5. i) True; ii) True; iii) False ; iv) False ; v) True; vi) True; vii) False

Terminal Questions

1. Refer to Subsection 16.2.1.

2. Refer to Subsections 16.4.1 and 16.4.2.

3. Refer to: i) Sub-section 16.5.2; ii) 16.5.10; iii) Sub-section 16.5.3; iv) Subsection 16.5.11.

4. Refer to Section 16.1.

UNIT 17

MAMMALS

Structure

17.1 INTRODUCTION

In the previous two units you have studied about tetrapod amniotic vertebrates namely, reptiles and birds that lay on land, shelled, fertilized, amniotic eggs containing their developing embryos, an adaptation they have acquired in order to minimise water loss. This thus allows the reptiles and aves to raise their offsprings without being dependent on a watery environment. In the present unit, you will study about another group of amniotic vertebrates called "mammals" which unlike reptiles and birds do not lay shelled eggs, containing developing embryos. Instead most mammals of except for the mammalian monotremes (which lay shelled eggs), have acquired an adaptation that makes their developing embryos less vulnerable to both predators and the environment. As a result this adaptation, in the mammals, the fertilized egg is retained inside the uterus of the mother where it develops within a fluid –filled, amniotic sac Once the development of the embryo is complete the mother give birth to a fully developed young one.

Most mammals Apart from giving birth to young ones mammals are uniquely different in several features from other amniotic vertebrate. Mammals are the only group of vertebrates which have mammary glands that secrete milk to nourish their young ones. The brain of mammals is more developed than all

other classes of vertebrates. All mammals have a large neocortex (the newer portion of the cerebral cortex which occupies 76% of the brain volume. This neocortex serves as the center of higher mental functions. All mammals have a single bone in their lower jaw and their respiration is aided by a special feature called the diaphragm. The middle ear of mammals has three bones instead of the single bone that occurs in reptiles and aves. The mammals have hair in some form on their bodies, unlike reptiles that have scales covering the body and birds that have feathers. However, similar to birds, the mammals are endothermic that is they are able to maintain a high metabolic rate.

In the present unit we will be studying the characteristic features and form and function of mammals. We will also study those features found in mammals that are unique to them when compared to other amniotic vertebrates.

Objectives

After studying through this unit, you will be able to:

- list and describe the derived features of mammals which are unique to them;
- explain how the derived features of mammals differ from features of other amniotes;
- list and describe the general characters of mammals which are similar to other amniotes; and
- explain how the various features of mammals have enabled them to live on land, air and water.

17.2 SALIENT FEATURES OF MAMMALS

We think of mammals as the most dominant group of vertebrates on earth, however, at present there are only about 5000 extant species, which is much less than the species of birds and ray finned fishes. Though mammals are a very diverse group, in terms of size (ranging from shrews to elephants and whales), shape, form and function however, they have a number of derived and general characteristics that allow them to be grouped into a distinct Class called Mammalia. In the present unit you will be studying about the derived and general features of mammals so that you are able to distinguish them from members of other class of amniote vertebrates namely, Reptilia and Aves. Studying the form and function of mammals in this unit will also aid you to understand the next unit which deals with the evolutionary progress of mammals and their classification upto the level of order.

Mammals are placed in the Class Mammalia and have evolved several features which are unique to them and a number of features that are similar to the other classes of vertebrates. Mammals can be defined as **"endothermic vertebrates which possess mammae or teats for suckling the young"**. Another major feature in mammals is the possession of hairs by which mammals can be distinguished from other groups of vertebrates. Though some caterpillars of insects and hairy crabs of crustaceans possess hair like

structures however, these are not true hairs. The Class Mammalia consists of (i) monotremes also called prototherians which are oviparous as they lay eggs and (2) Therians that give birth to young ones and so are viviparous.

In the present section we will list and briefly give the defining and general features of mammals which are as follows:

DERIVED FEATURES OF CLASS MAMMALIA

1. All Mammals exhibit bilateral symmetry.
2. Mammals are the only animals which have mammary glands that are modified sweat glands. Mammary glands are present in both males and females but are more specialised and developed in female mammals for producing milk to nourish their young ones. Nipples or teats are present in the breast of all mammals except in monotreme where they are absent.
3. Only mammals have sweat glands which secrete sweat that evaporates and thereby, cools the body.
4. The body of most mammals is covered with epidermal hair or fur, except in whales in which the hair are temporarily present in the embryos. The hairy coat of mammals acts as an insulating and thermal regulating organ, which helps in the conservation of their body heat. The hair covering enables most mammals even the tiniest ones to maintain homeothermy (thermoregulation process that maintains a stable internal temperature). In mammals like the spiny anteaters (*Tachyglossus*), hedgehogs (*Erinaceus*) and porcupines (*Hystrix*) the hair is modified into spines or quills which in addition to providing insulation and thermal regulation act as a defensive organ.
5. All mammals except for monotremes which are also called prototherians are viviparous and lay yolky macrolecethal eggs. The rest of the mammals, the marsupial and eutherian mammals that are collectively referred to as therian mammals give birth to young ones and so a viviparous
6. The internal body temperature of mammals, regardless of external. Influences is often, though not necessarily, higher than the immediate environment. Mammals similar to birds are endothermic (warm-blooded) homeotherms.
7. All mammals have four limbs (tetrapods). Some mammals walk on all four limbs, some walk on two limbs (bipedal) while, some can walk on both four and two limbs.
8. All mammals have paired lungs and breathe air.
9. A muscular diaphragm that separates the abdominal cavity from the thoracic cavity and helps in respiration is present in all mammals.
10. Among vertebrates, the mammals are the only members to have a large neocortex (the newer portion of the cerebral cortex which occupies 76% of the brain volume. This neocortex serves as the center of higher mental functions. Corpus callosum, the transverse band of nerve fibres connecting the two cerebral hemispheres, is present in the brain of most

mammals. It is rudimentary in marsupials and absent in monotremes. The cerebellum in the brain of mammals is large, complex and solid.

11. 12 pairs of cranial nerves are present.
12. The mammalian skull has a double exoccipital condyle which is a unique feature present in mammals.
13. Dentition is heterodont, thecodont and diphyodont except In toothed whales where the teeth are homodont. Heterodont dentition is marked by the presence of incisors, canines, premolars and molars.
14. Each half of the lower jaw or mandible is made up of a single piece of bone, called dentary. The lower jaw (dentary) articulates with the upper jaw posteriorly by the squamosal bone (squamosal articulation).
15. Most mammals have 7 cervical (neck) vertebrae. However, mammals like the three-toed sloth have nine or ten cervical vertebrae and the two-toed sloth and manatees have six cervical vertebrae.
16. The external fleshy pinna is present in most mammals but is absent in Monotremes (e.g. : platypus), Cetaceans (e.g.: whales) and Sirenians (e.g.: Dugong).
17. Mammals are the only amniotic vertebrates in which the middle ear has three ear ossicles (bones): malleus or the articular bone, the incus or quadrate bone and stapes or the hyomandibula. The middle ear of reptiles and birds as you will recall earlier has a single bone. The three ossicles of the middle ear of mammals conduct sound from the tympanic membrane to the inner ear. Internal ear of mammals has a spirally coiled cochlea, except in case of monotremes in which it is not coiled.
18. Eyes of mammals have upper and lower eyelids and often eyelashes. The nictitating membrane is translucent but is vestigial in higher mammals.
19. Mammalian heart is completely four-chambered. The sinus venosus and conus are absent in the mammalian heart and only the left aortic arch is present.
20. Renal portal veins are absent in mammals.
21. In mammals the red blood corpuscles are non-nucleated, biconcave and usually circular in form. However, in members of family camelidae that includes, camels, the red blood corpuscles are elliptical.
22. In the excretory system of mammals a ureter from each paired kidneys opens into a single urinary bladder which is present in mammals. Cloaca is absent in all mammals except in the monotremes
23. In mammalian males, paired testes, are present in the scrotal sacs which in most mammals are located outside the abdomen. The temperature of the scrotal sac is often 8°C less than that of the abdomen. However, In cetaceans, sirenians, hyraxes, elephants and in some insectivorous animals the testes are located within the abdomen.
24. In mammals fertilization is always internal.

17.3 FORM AND FUNCTION OF MAMMALS

Mammals have several external and internal features that are unique to them as discussed in Section 17.2). They also possess features which are similar to other amniotes. We will be studying the form and function of mammals in the present section.

17.3.1 Body Form

The basic body type of a mammal is a quadruped (walking on four limbs) or a bipedal (walking on two limb or legs) amniotic vertebrate. Most mammals are terrestrial but some mammals are adapted for life at sea, in the air, in trees and in the underground.

External Body

In mammals, the body is externally divisible (Fig.17.1) into four sections:1) A well-defined head that contains the brain, the major sense organs and the mouth; 2) a flexible neck that is present in most mammals and enables them to turn their head; 3) a trunk that contains the other organs and 4) a well-developed tail which is usually present but may also be absent.

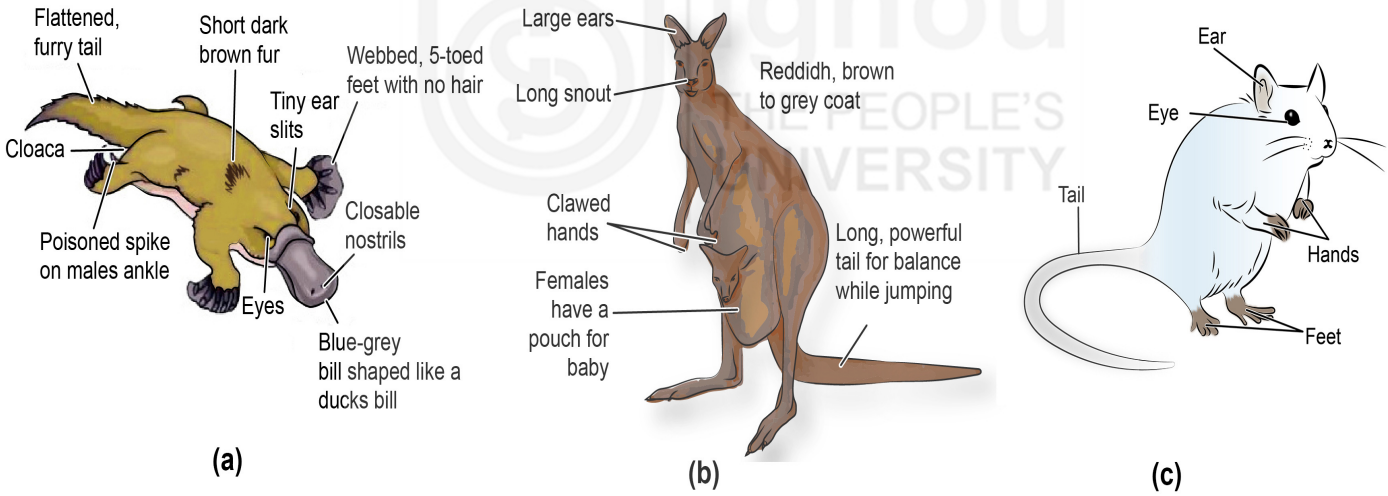
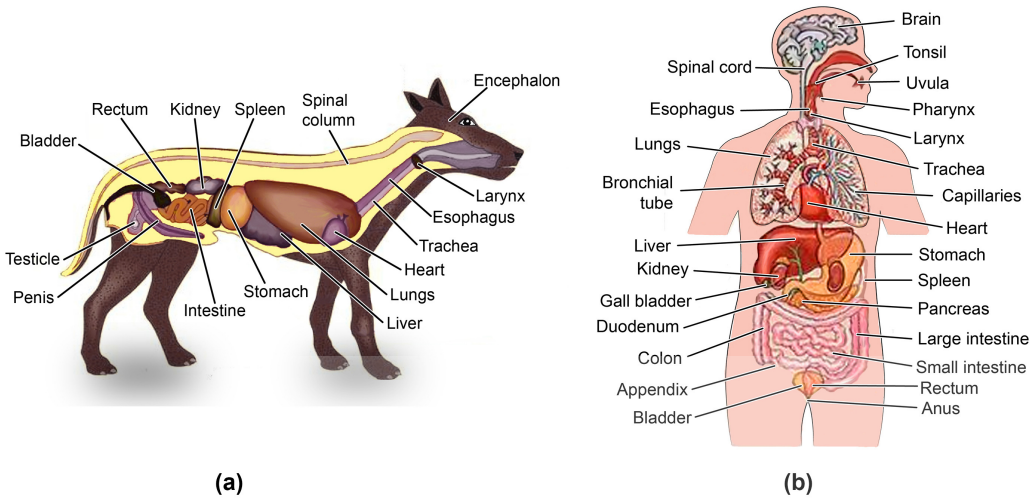


Fig. 17.1: External features of representative mammals belonging to three main types of mammals: a) A platypus which is a monotreme mammal and lays eggs; b) a kangaroo which is a marsupial mammal and has a pouch which is used to nurture the under developed young ones; and c) a rat which is a placental mammal and gives birth to well-developed young ones.

Internal body

Internally, the body of mammal has a body cavity, called a coelom which is full of fluid in which the organs are located. The coelom protects the organs and allows them to develop. In mammals, the body cavity is divisible into the thoracic (chest) and abdominal cavities which are separated by a dome-shaped, muscular structure called the diaphragm (Fig.17.2 a and b and Fig. 17.3). The diaphragm helps in the process of respiration.



(a) (b)

Fig. 17.2: General internal anatomy of a mammal as seen in a: a) quadruped (dog); and b) a bipedal human.

The thoracic cavity of mammals contains the heart and paired lungs, each of which is surrounded by its own membrane. The heart, is contained in a cavity called, the pericardial cavity while each lung is contained within their **pleural cavity** (Fig.17.3).

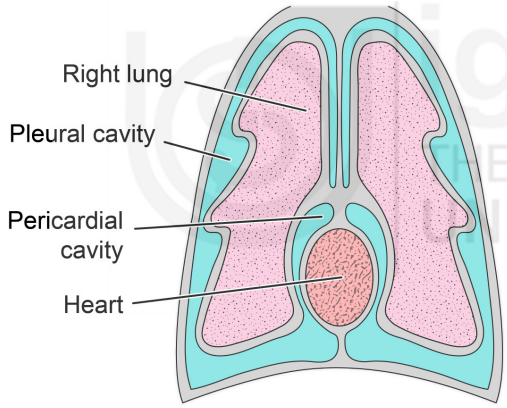


Fig. 17.3: Thoracic cavity containing the pericardial and pleural cavity.

SAQ 1

Fill in the blanks with correct words in the following statements:

1. Give four characters of Class Mammalia which are unique to mammals.
2. Which of the following groups contain mammals that lay eggs?
   - i) Marsupial
   - ii) Placental
   - iii) Monotremes
   - iv) None of the above.
3. A muscular structure that separates thoracic from abdominal cavities and helps in respiration is called.

i) Cerebral cortex

ii) Diaphragm

iii) Mammary glands

iv) Placenta

17.3.2 Integument

The mammalian integument or skin or (Fig. 17.4) is similar to other vertebrates and consists of two layers:

i) An external, superficial, nonvascular, epidermal layer called epidermis which is composed of several layers of flattened, squamous cells of which the outermost layer of cells are keratinized (impregnated with various tough proteins), and enucleate (lacking cell nuclei). The primary function of the outer layer of the epidermis is defensive and its keratinized structure is able to resist abrasion in areas which are subject to constant friction as in case of palms of the hands or soles of feet or nails or claws or hooves and hair.

ii) An internal dermal layer called the dermis which lies beneath the epidermis and nourishes it. The blood circulation in the dermis is extensive. Sensory nerve endings are also present in the dermis and alert the animal to pressure (touch), heat, cold, and pain. The main role of the dermis is to moderate body temperature and blood pressure which is accomplished by blood circulation and sensory nerve endings present in the dermis.

A subcutaneous layer which is not part of the skin called the hypodermis or hypodermal layer is present below the dermis. The hypodermis consists of a thick layer of fat that helps the animal to retain heat.

17.3.3 Integumentary Glands

Amongst all vertebrates, mammals have the greatest variety of integumentary glands all of which are epidermal in origin. Four types of glands that occur in mammalian skin are: (i) sweat glands, (ii) sebaceous glands (iii) mammary glands, and (iv) scent glands.

i) **Sweat or sudoriferous glands** (Refer again to Fig.17.4) are present over much of the mammalian body surface and are of two types: a) Eccrine sweat glands which secrete a watery fluid that helps in heat regulation by cooling the body; and b) Apocrine sweat glands which secrete a fluid that is not involved in heat regulation but is involved in the reproductive cycle. Sweat glands occur in most mammals but are absent in moles, sloths, scaly ant eaters, elephants and several marine mammals.

ii) **Sebaceous glands** are normally associated with hair follicles (Refer again to Fig.17.4), although some are free and open directly on to the body surface. The secretions of sebaceous glands help keep the skin and

hair pliable and glossy. Most mammals have sebaceous glands which are uniformly distributed over their entire body but in humans they are more numerous in the scalp and face.

iii) **Mammary glands** (Fig. 17.4 b) are modified sweat glands. They are usually well-developed and secretory in the female mammals. Mammary glands are also present in the males where they are however, rudimentary. In most mammals milk is secreted from the mammary glands via nipples but monotremes lack nipples and the female mothers simply secrete milk onto the fur of their belly (stomach area) where it is lapped up by the young ones.

iv) **Scent glands or musk glands** occur in nearly all mammals and secrete pheromones which are chemicals. The location and function of scent glands vary in different mammalian species. The scent glands, in several mammals may be located around the face, feet, or anus. Pheromones are useful to the animals as a means of chemical communication between the sexes of a species or members of a group within the species. Pheromones are involved in species and sex recognition, attracting males and females to meet and mate. The pheromones are also involved in defence and for asserting territorial dominance.

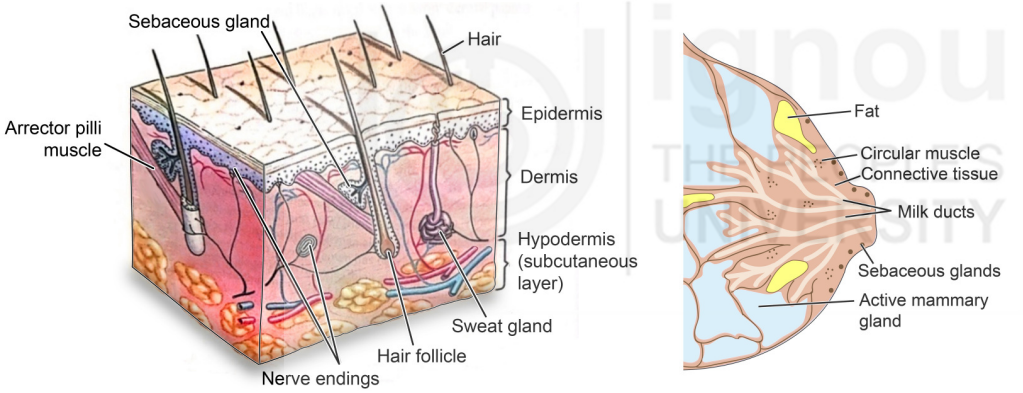


Fig. 17.4: a) A section of human skin: showing the epidermal, dermal and hypodermal regions and the hair and glands associated with it; b) Mammary glands in a female human:In all female mammals the mammary glands are specialised to secrete milk after the birth of a young one. In the female human, several ducts lead from the mammary glands to a nipple. Parts of the duct system just before and after pregnancy become enlarged to store milk. Suckling by the newborn infant initiates a hormonal response that causes the mammary glands to initiate milk secretion.

17.3.4 Exoskeleton

The exoskeletal structures of the mammals include hairs, hooves, nails and claws.

Hairs

The mammalian body is covered by hairs (Fig.17.5) which is a defining feature of this class of vertebrates. Hairs are rod-like structures, composed of

keratinized and largely dead cells and are epidermal in origin as each hair arises from a hair follicle which is an invagination (pocketing) of the epidermis. Each hair follicle is associated with nerve endings and a muscle called the “arrector pillus” (plural:pilli). When the arrector pillus muscle of a hair contracts, the hair stands upright. Arrector pilli muscles are under the control of the autonomic nervous system.

The body of several non-human mammals is covered extensively with soft and thick hair which is referred to, as fur or fur coat or pelage .The pelage whenever present consists of 2 types of hair: i) **under hairs,** which are short and soft and form dense hairs that provides thermal insulation and ii) **guard hairs** which are long and give protection against wear and tear and provide colouration to the animal. A few mammals however,like the naked mole rats have almost no pelage. The stiffer hair bristles present on mammals such as pigs are not generally referred to as fur. The presence of hair may also be reduced in some mammals as for instance in human beings who are not very hairy and in whales where only a few sensory, bristle-like hairs are present on the snout.

(a) (b)

Fig. 17.5: Arctic fox: a) with a white fur in winter; and b) with a grey fur in spring.

Mammalian hair is formed of dead cells and is moulted or periodically shed. In some mammals including us, moulting occurs gradually and may not be noticed as hair is shed and replaced throughout life. In other mammals hair loss occurs rapidly and may result in altered pelage characteristics. Many mammals which live in extremely cold climates acquire a thick coat of insulating underhair, and their pelage color also changes. For example, the Arctic fox gets a white or cream colour fur when it moults in autumn which helps it to blend in a snowy environment. However when it moults in spring it acquires a grey and yellow pelage (Fig. 17.5) in order to blend with the changed colours of a spring environment. Mammals in addition to hairs may also have scales as can be seen on the tail of rats.

Nails, Claws and Hooves

Nails are epidermal structures which are present on the digits also referred to as fingers and/or toes of all amniote classes including mammals and also us. Nails are formed by accumulation of keratin that cover the terminal phalanx (bone) of the digits or fingers/toes. Digits with well-developed nails are referred to as claws and are present in several mammals, including all carnivores. Claws are used for locomotion and offensive and defensive behaviour. In some mammals, like horses the nails become highly specialised and form hooves (Fig. 17.6).

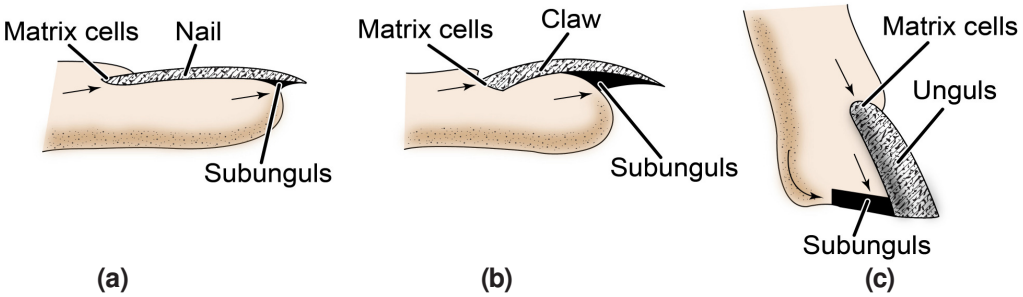


Fig.17.6: Side views of : a) nail; b) claw; and c) hoof- all of which are epidermal derivatives. In all cases the plate of keratinized, cornified epithelium grows outwards (arrows) from the proliferating matrix at its base and from the subunguis.

Horns and Antlers

Several hoofed mammals have horns or antlers that appear similar, but are fundamentally different (Fig.17.7). True horns are only found in members of family Bovidae which consists of sheep and cattle that includes cows and buffaloes. The horn is formed of hollow sheaths of keratinized epidermis which enclose a core of bone a rising from the skull. True horns are present in both sexes, grow continuously, are not shed and are not branched though they may be greatly curved. Horns of pronghorn antelopes are similar to true horns of bovids but they are not true horns as the keratinized portion of the horn is forked and shed annually.

Antlers are found in the deer family Cervidae and are branched and composed of solid bone when mature. Except for caribou only males have antlers.

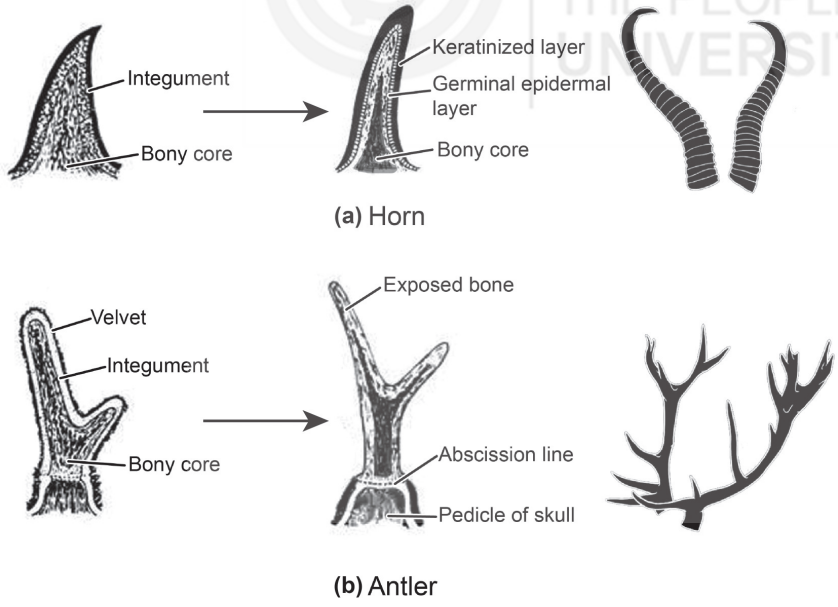


Fig. 17.7: a) A horn; and b) antler that occur in some mammals.

17.3.5 Endoskeleton

Mammals, as you have read earlier, similar to fish, amphibians, reptiles and birds are called **vertebrates**, a name that comes from the bony column of vertebrae (or vertebral column or spine) that supports the body and head. The skeleton of all amniotic vertebrates, including reptiles, aves and mammals, has the same basic design.

The four limbs of all the amniotic vertebrate groups as you will recall from unit 6 consist of the same basic pattern. Each limb is joined to the spine by means of girdles. The forelimbs (modified into wings in aves) occur at the level of the shoulder and are joined to the spine by the pectoral girdle. Howerer, he hindlimbs which are located at the back as in quadrupeds or at the lower ends as in the bipeds are joined to the spine by the pelvic girdle. Each limb consists proximally of one long upper bone and distal to it two long lower bones and several smaller bones that form the wrist or ankle and the five digits.

The huge range of lifestyles and habitats used by mammals has resulted in a great deal of variations in the skeleton between different mammalian groups. Some species lack a tail; others lack apparent hind limbs and the structure of the skull in various mammalian groups, exhibit wide variations.

Mammals have a skeleton which supports the muscles and ligaments. The skeleton of mammals (Fig.17.8) is well ossified and similar to other vertebrates is broadly divisible functionally into:

i) **an axial skeleton** which consists of the a) braincase (cranium) or skull; b) the vertebral column also called spine or backbone which contains the spinal cord; and c) the ribs;

II) **appendicular skeleton** which consists of the limbs and girdles of mammals and

III) **the visceral skeleton** which consists of skeletal elements, collectively derived from gill arches and includes the jaws, the hyoid apparatus supporting the tongue, and the auditory ossicles of the middle ear.

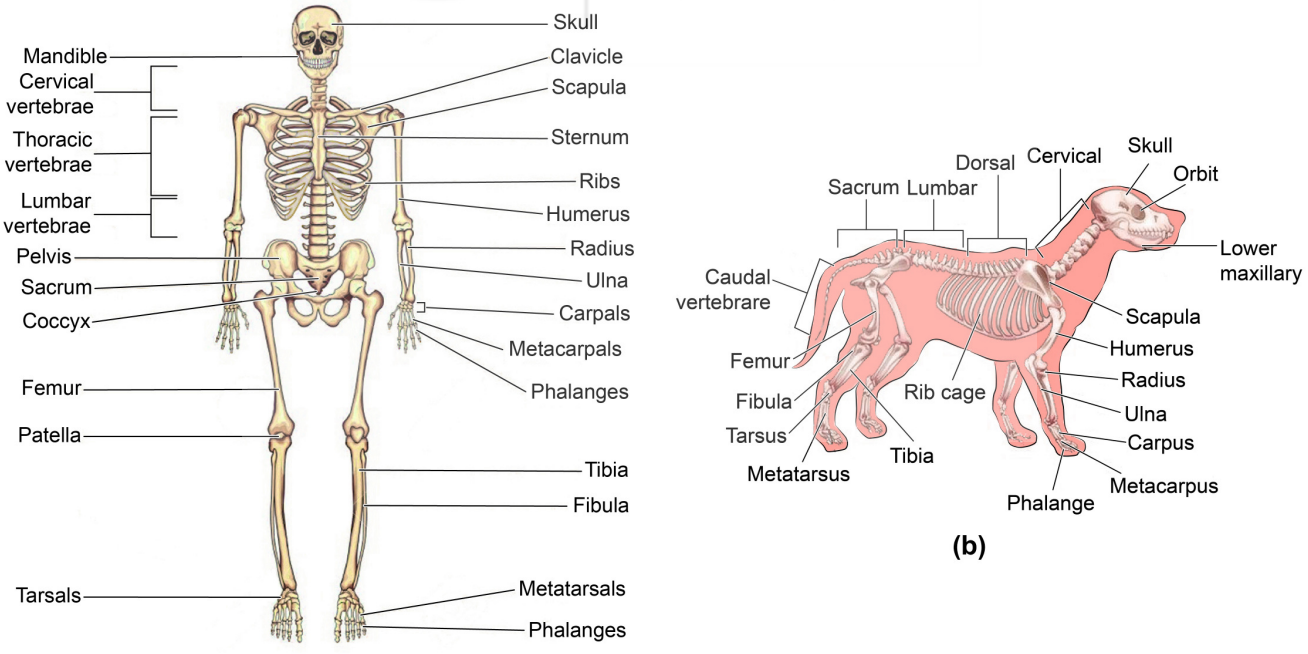


Fig. 17.8: Mammalian skeleton of a: a) bipedal (two legged) mammal (human); and b) a quadruped (four legged) mammal (dog).

I) Axial Skeleton

The primary function of the axial skeleton is to protect the central nervous system and consists of the skull and vertebral column.

Skull

The skull of mammal shows important modifications from the reptilian pattern due to the great expansion of the brain. The mammalian skull is a composite (made up of several parts) structure consisting of several separate bones which form a solid case protecting the brain and sense organs.

The mammalian skull can be divided into the following 3 basic parts:

1. The braincase or cranium which is large contains and protects the brain. The bony wall of the cranium encloses and protects the middle and inner ears and the organs of smell in the nasal cavity. Paired eyes sockets are present in the skull and contain and protect the eyes. A foramen magnum (meaning big hole) is present at the base of the cranium (Fig. 17.9). The spinal cord which is an extension of the brain passes into the vertebral column or spine through the foramen magnum which also bears on either side two small, smooth rounded knobs or condyles called the double exoccipital condyles.

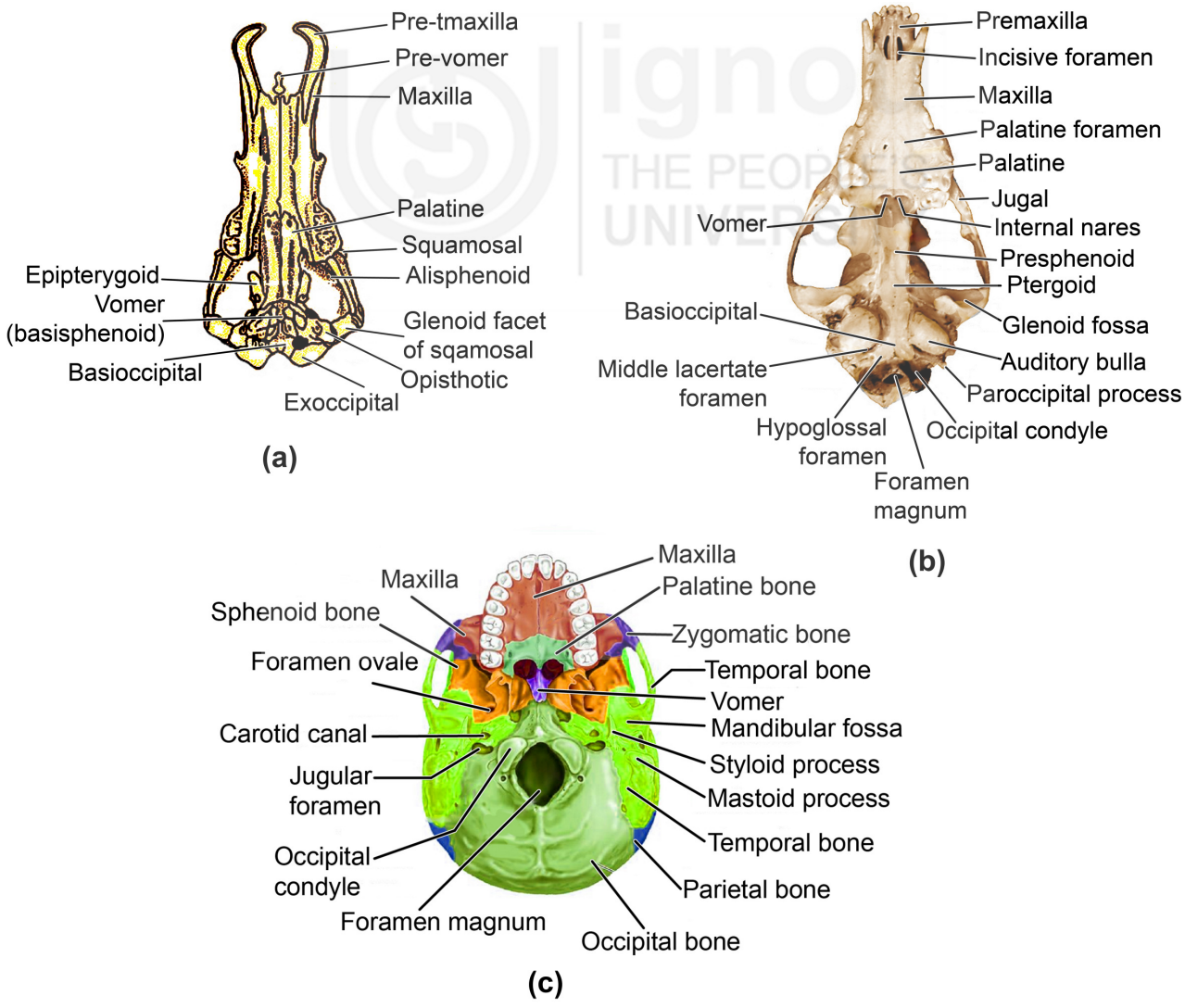


Fig. 17.9: Ventral views of the skulls of mammals: a) platypus; b) grey wolf; c) human (ventral view is also called inferior view in humans).

The double exoccipital condyles are unique to mammals and articulate (connect and move against) with the first vertebra of the vertebral column called the Atlas vertebra (Fig. 17.10).

2. The rostrum that forms the snout is present in most mammals but is absent in primates.

3. The jaws which consist of i) the fixed upper jaw, formed by the fusion of paired maxillary bones. The upper jaw of mammals contains a single hard palate in the mouth and ii) the lower jaw which is formed by two bones called mandibles that unite anteriorly. Each mandible is composed of a single bone, called dentary (plural: dentaries) and articulates posteriorly with the upper jaw by the squamosal bone of the skull. The dentary being a single bone is unlike the paired mandibles (lower jaws) of amphibians and reptiles which in them is formed by the fusion of several bones. However, in all the three groups of vertebrates the lower jaw forms the movable part of the jaw. The upper and lower jaws in mammals form the mouth structure and contain the teeth which are inserted into the sockets present in the mouth. The mouth forms the entrance to the pharynx (Refer again to Fig. 17.2).

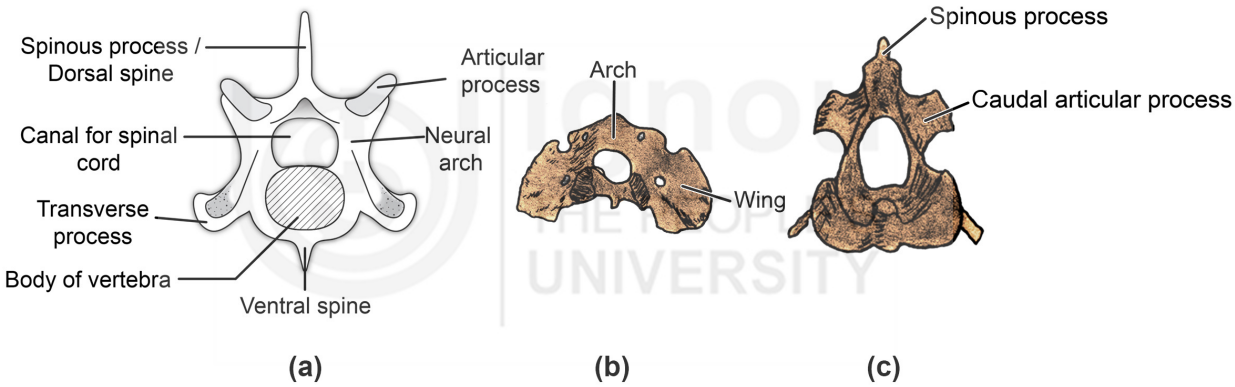


Fig. 17.10: Vertebrae of mammals: a) General features of a vertebra showing its various parts; b) Atlas vertebra; c) Axis vertebra.

The type of jaw articulation in the mammalian skull is used to distinguish it, from the reptilian skull. In reptiles, the jaw articulates with two small bones present at the rear end of the jaws while in mammals as you have read earlier, the upper and lower jaw articulate posteriorly on either side by a single squamosal bone. During the course of evolution, as you will study in Unit 18 the two bones that articulate posteriorly with the upper and lower jaws of the reptiles on either, side. However, in the mammals move into the middle ear, where these two bones along with the stapes or columella bone (which is the only bone present in the middle ear of reptiles and birds) form the three ear ossicles of the mammalian middle ear.

The vertebral column

In the vertebrates, including the mammals, the postcranial axial skeleton or vertebral column has generally remained rather unchanged during the course of evolution.

The vertebral column similar to reptiles and birds consists of a series of vertebrae (singular: vertebra) which are linked together to form a flexible

column with the skull at one end and the tail at the other end. Each vertebra similar to reptiles and birds (Fig.17.110 a) consists of a ring of bone which contains a central cavity for the spinal cord. The vertebrae of the vertebral column are linked to each other and from a continuous canal for the spinal cord. The spinal cord which is an extension of the brain passes through a cavity in the skull called foramen magnum which is located at the posterior end of the skull and enters into the central cavity of the vetebral column. The spiral cord is thus, enclosed and protected by the vertebral column. Each vertebrae also bears spinous processes protruding dorsally from it. Muscles are attached to the vertebral column, making movement of the body possible.

The vertebrae of the vertebral column or spine are named, according to their location in the vertebral column. In many mammals the vertebrae can be seen to be divided into five distinct regions, though in some groups such as the whales they are pretty indistinct. The region where the adjacent vertebrae meet each other have special smooth, flat surfaces called zygopophyses. These contact surfaces are protected by cartilage.

The vertebral column in mammals is generally divisible into the following five regions on the basis of their location in the body:

i) **Cervical vertebral region:** In the cervical vertebral or spinal region the first vertebra is the one immediately behind the skull and is called the 'Atlas' (Fig. 17.10 b). It has two large depressions in its front face which articulates with the two exoccipital condyles present on the posterior end of the skull, one on either side of the foramen magnum. The atlas also has a slot in its rear face to accept a forward, projecting bone called the odontoid process, which is present on the second vertebra called the Axis vertebra (Fig.17.11 c) of the vertebral column. The atlas and axis are specialised to support the head and allow it to nod "Yes" and shake "No". The rest of the cervical vertebrae which are usually five in number do not have special names and are often cemented together for extra strength in digging and swimming mammals. All mammals have seven neck vertebrae, except for tree sloths which have either six or nine cervical vertebrae while the manatees have six cervical vertebrae. Even giraffe and whale have seven neck vertebrae which are greatly elongated in the former and compressed in the latter.

ii) **Thoracic vertebral region:** Consists of thoracic vertebrae and is located after the cervical region, in the chest region. Thoracic vertebrae articulate with ribs and have special surfaces against which the ribs move during breathing. The anterior ribs converge towards the ventral midline in order to articulate with the breastbone or sternum and forms a semi-rigid thoracic basket-like structure for enclosing and consequently, protecting the heart and lungs.

iii) **Lumbar vertebral region:** Is present after the thoracic region. The lumber region usually consists of large strong vertebrae with prominent spines for the attachment of the large muscles of the lower back. The lumbar ribs are absent in mammals. The lumbar vertebrae support, the body but have little freedom of movement. The thoracic and lumbar vertebrae in mammals are similar to birds and form the trunk region

which is the middle segment of the vertebral column. The division of the vertebral column into the thoracic and lumbar region in mammals is correlated with their method of breathing.

iv) **The sacral vertebral region :** It is located after the lumber region and contains the sacral vertebrae which are usually 3–5 in number but can be more, up to 10 as in the Order Edentata. Sacral vertebrae are usually fused into one solid bone called the sacrum. The sacrum supports the pelvic girdles.

v) **The caudal or the tail bone vertebral region:** It forms the last part of the vertebral column and comes after the lumber region. It consists of the caudal vertebrae which are generally fused together and are smaller and less complicated than the vertebrae of the other regions. The vertebrae of the caudal region do not contain the spinal column which ends at or before the sacrum. However, the vertebrae of the caudal region do contain some nerves and blood vessels. In humans and chimpanzees, the caudal vertebrae are reduced to 4 in number and are fused to form the coccyx. The vertebrae of the sacrum or coccyx when fused together are unable to move independently.

Mammalian vertebra is generally of acoelous type since the articulating sides of the vertebra called the centrum plural: (centra) have flat ends (Fig. 17.10 a).

Sternum

The Sternum or breastbone is made up of a number of smaller bones called sternebrae.The front part of the sternum in some mammals for example in bats is keeled, in order to provide a larger surface area for the attachment of flight muscles as bats need to flap their wings. Several digging species like the moles which also need large muscles for digging with their forelimbs have keeled sternum as well.

Ribs

In mammals, the ribs normally arise from the thoracic vertebrae but in a few Orders such as Edentata and Monotremata, they arise from the cervical vertebrae. Ribs articulate with the sternum and form a cage-like structure, which encloses, supports and protects the vital organs namely, the heart and lungs. In mammals the ribs are double headed and the two heads of the ribs are called the capitulum and tuberculum (Fig. 17.11 b). However, in monotremes the ribs are single headed, except for their cervical ribs which are double headed.

The ribs end under or in front of the mammal, along each side of the sternum (breast bone). In many species the lower or posterior ribs do not meet the sternum, and such types of ribs are called floating ribs. In most mammalian groups the articulated ribs (those which meet and join with the sternum) outnumber the floating ribs easily, but in whales and dolphins it is reversed, partly because only 6 pairs of ribs can articulate with the reduced sternum present in them and also partly because of a greater number of paired ribs present in them.

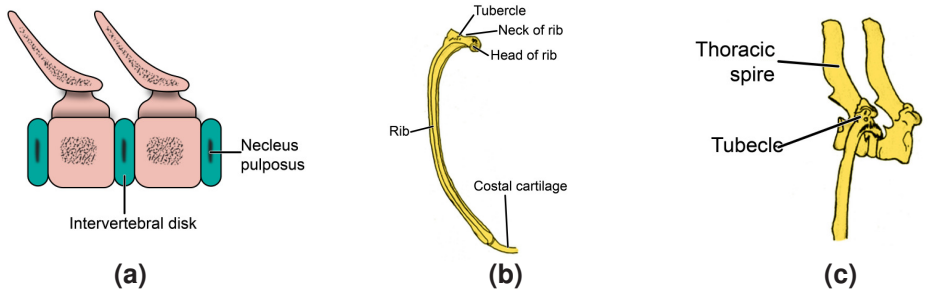


Fig 17.11: a) A side view of an acoelous vertebra; and b) a double headed rib of a mammal (dog)

II) Appendicular Skeleton

The limbs and girdles of mammals according to their type of locomotion have become greatly modified.

Girdles

In mammals similar to the reptiles and birds the pectoral and pelvic girdles are present in all. These girdles form the two main supporting areas of the vertebral column.

Pectoral girdle: In all tetrapod vertebrates as you the will recall from earlier units the pectoral girdle consists of two identical halves, each of which articulates dorsally with the vertebral column of its side by means of muscles and ligaments.

In general each half of the pectoral girdle consists of three bones: (i) a scapula (ii)a clavicle and (iii) a coracoid. A glenoid cavity of fossa is present scapula and is formed at the junction of the scapula and coracoid bone. The glenoid fossa articulates with the head of the humerus bone which is the first bone of the forelimb.

However, in mammals the structure of the pectoral girdle has undergone some modifications and consists of the following bones (Figs.17.12 a, b and c):
i) a broad large, flat scapula (shoulder bone) which contains the glenoid cavity and ii) the much smaller and more slender bone the clavicle or collar bone. The clavicle in most mammals extends from the far end of the scapula to the sternum, except in the monotremes where it meets the interclavicle instead. The clavicle is absent in some mammals such as horses, pigs, deer, buffaloes, whales etc. The front legs in the quadrupeds or the arms in bipedal mammals articulate with the glenoid fossa or cavity present at the far end of the scapula of the pectoral girdle. The coracoid bone in mammals is reduced and represented by a small coracoid process which is fused with the scapula.

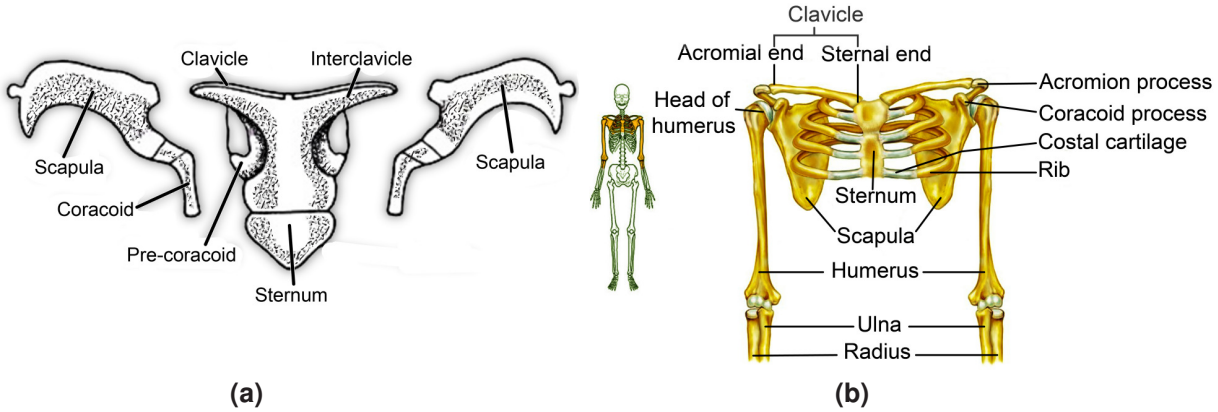


Fig. 17.12: Pectoral girdles of : a) platypus mammal showing reptilian features as well; b) human which is completely mammalian in nature.

The Pelvic girdle: The pelvic girdle or hip girdle is like a ring-like bony structure with a central cavity. The pelvic girdle consists of (Fig. 17.13 a & b) two indentical halves, each of which is called the innominate bone. Each innominate bone is made up of three bones which are fused together. Each innominate bone consists of the: (i) ilium bone which a fan like region that is the the largest part of the pelvic girdle (ii) the ischium which forms the posterior lower part of pelvic girdle and (iii) the pubic bones or pubis which forms the anterior part of the hip bone. The pubic bone of each part of pelvic girdle curves around and both join together medially at the anterior part of the body. The ileum, ishium and pubic bones of each half coverge to form a cup shaped cavity called the acetabulum. The head of the femur of the hind limb articulates with the acetabulum. In marsupials and monotremes another pair of bones called the epipubic bones are present whose exact role is still unknown.

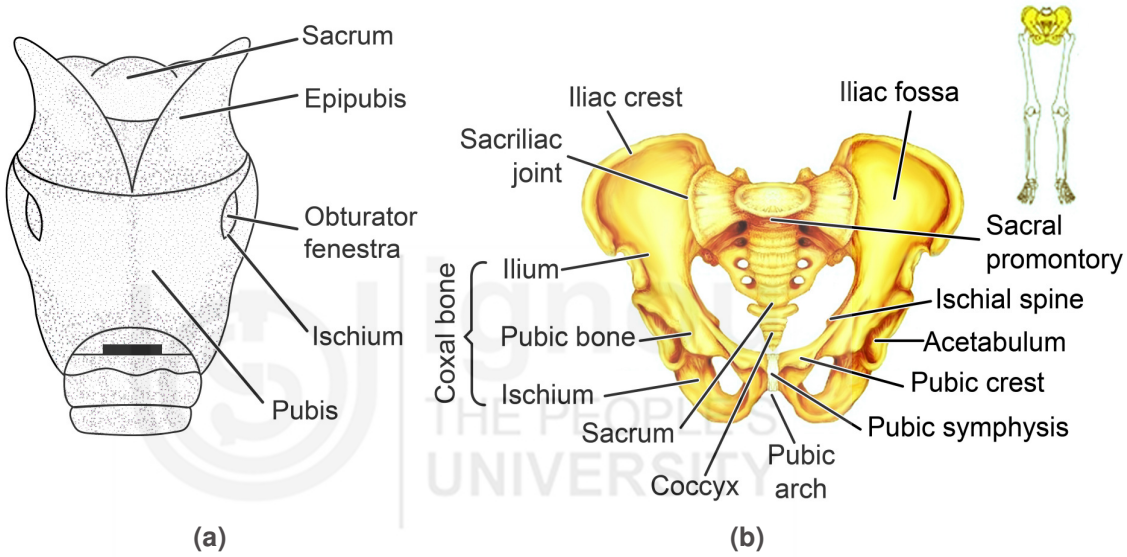


Fig. 17.13: Font views of pelvic girdles of: a) monotreme mammal (platypus); and b) eutherian placental mammal (human).

Limbs

The basic vertebrate limb evolved as the first amphibian left the warm seas for the new dry lands and is called the pentadactyl limb, since each limb ends in five digits (fingers or toes) or phalanges.The ancestral mammals also had well-developed pentadactyl limbs. In general, the pentadactyle limbs present in the extant mammals have not changed much from the ancestral mammals. Extant mammals have also retained the limb arrangement that was present in their ancestors (Refer again to Fig. 17.8).

Fore Limb

Each mammalian upper arm of the forelimb consists of a single, proximal humerus bone which articulate proximally with the glenoid cavity of the pectoral girdle and distally with two bones the radius and ulna. The radius and ulna form the lower part of the forelimb called the forearm which articulate distally with nine wrist bones called the carpals which are usually separate although some fusion may occur. The carpal bones articulate distally with the metacarpal bones which are elongated and articulate distally with the fingers of the hand. The fingers of the hand are composed of bones called phalanges.

Hind limbs are similar to the forelimb in structure. Each of the hindlimb at the proximal end has a single bone, termed as femur which articulates proximally with the acctabulum of the pelvic girdle and distally with two bones called the tibia and fibula. The tibia and fibula bones form the shank or lower leg of the hind leg and articulate distally with the seven ankle bones called the tarsals which articulate distally with the metatarsal bones. The metatarsal bones articulate with the phalanges also called the toes of the feet. Similar to fingers there are five toes composed of phalanges.

Most terrestrial mammals including us have a phalangeal formula from thumb onwards of 2-3-3-3-3 phalanges both in the hands (or paws) and feet. Primitive reptiles typically had the phalangeal formula 2-3-4-4-5, a pattern which with some modification, remained in many later reptiles and in the mammal-like reptiles. The phalangeal formula in the flippers of the marine mammals cetaceans is 2-12-8-1.

Extant mammals of different families show modification in limbs which involves reduction, loss, or fusion of bones. These modifications are a result of adaptations, during the course of evolution so that the mammals can live in various habitats and environments. In whales and dolphins for instance, the number of finger bones in the forelimb have greatly increased. This condition is known as hyperphalangy. In some families not all the bones mentioned above still exist as some have been lost during the course of evolution.

Secondary Palate

Mammals have a bony secondary palate (Fig. 17.14) which is formed by the union of pre-maxillae, maxillae and palatines. The secondary palate in mammals separates the nasal passage from the buccal cavity. In vertebrates the secondary palate has evolved twice: 1) in the archosaur lineage and 2) in the synapsid lineage. In some therapsids, small, shelf like extensions of bone (the hard palate) partially, separated the nasal and oral passage ways.

In mammals, the secondary palate is extended posteriorly by means of a fold of skin, called the soft palate. The soft palate almost completely separates the nasal passages from the mouth cavity. Unlike other vertebrates that swallow food whole or in small pieces, a large number of mammals chew their food. In mammals which chew their food the secondary palate is more extensive and separates the nasal passages from the mouth cavity which allows them to breathe while chewing. Breathing needs to stop only briefly during swallowing. A secondary palate is also essential in mammals as the young mammals need to breathe while suckling.

17.3.6 Dentition and Digestive System

Teeth and Dentition Mammals, such as deer and zebras which only feed on plants and vegetations are termed as herbivores, while mammals that only feed on animal flesh are termed as carnivores. Carnivorous mammals, like the ant eaters and the bats which are specialised for feeding on arthropods or soft-bodied insects are often referred to as insectivores. Mammals like humans, primates, pigs are omnivorous as they feed on a variety of plant and animal materials.

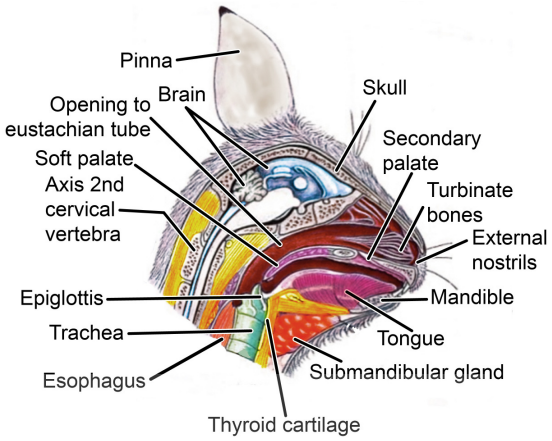


Fig: 17.14: Sagittal section of the head of a rabbit showing the secondary palate, which consists of a hard bony region and a soft non-bony region. The secondary palate separates the dorsally located air passage from the ventrally located the food passage.

In some mammals, the number of teeth is reduced while in some, the teeth are totally absent as for example in the giant anteaters and adults of cetaceans (e.g. whales) and prototherians (e.g. platypus). In armadillos during the course of evolution teeth have become peg-like and so are greatly reduced in structure.

In mammals, the teeth unlike those of reptiles, which are homodont (uniformly conical), are heterodont (of different types) and are well-developed. Heterodont teeth present in mammals are a result of their dietary modifications. Most mammals have two sets of teeth during their life time. The first set of teeth emerges before or shortly after birth and is called deciduous or milk teeth. These teeth are shed and replaced by permanent teeth. The condition of developing two sets of teeth during a life time is called diphyodont condition.

The permanent teeth of the adult mammals are of four types. (Figs.17.15 a, b and c):

i) **Incisors** which are the anterior most teeth in the jaw and so are present at the front of the jaw. Incisors are usually chisel-like and are used for cutting or gnawing the food and also for nipping at food. In rabbits and sheep the incisors are well-developed.

ii) **Canines** are present on the sides of the jaws behind the incisors. The canine teeth are often long, stout, and conical, and are generally used for catching, killing and tearing flesh. They are very well-developed in the carnivores. In rabbits and sheep canines are absent, due to which a wide gap called the diastema is present between the incisors and premolars on each side of the jaw.

iii) **Premolars** are located posterior to the canines on either side of the jaws and are used for chewing food.

iv) **Molars** are present at the extreme posterior end of the jaws, on either side and have broad surfaces for chewing. The premolars and molars are used for chewing and grinding food.

Specialisation in food habits in mammals has led to profound dental changes. As a result, mammalian teeth (dentition) in several species have become

specialised according to the particular diet adopted by them. Thus the structure and arrangement of teeth in mammals can indicate their dietary habit.

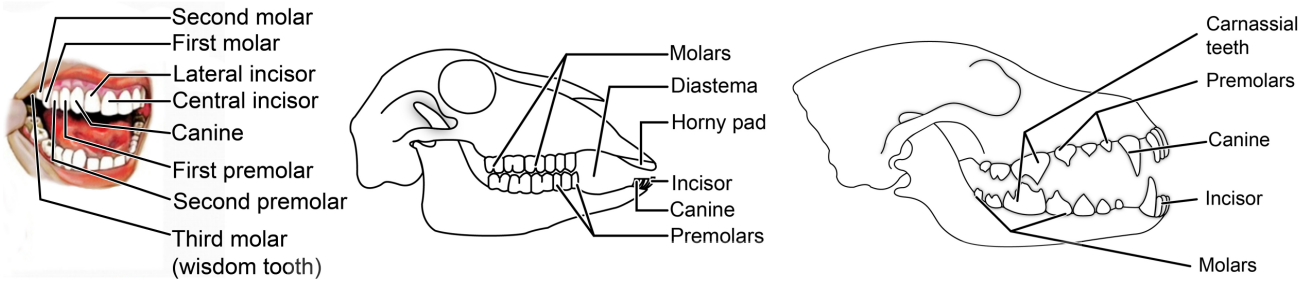


Fig. 17.15: Teeth of mammals: a) types of teeth present in an omnivore such as a human *(Homo sapiens)*; b) teeth of a herbivore such as sheep; and c) teeth of a carnivore such as a dog.

The type of teeth, their number and their arrangement in mammals is called dentition. The number of different types of teeth present in a particular species is called its dental formula. The dental formula varies in different adult mammalian species (Refer again to Figs.17.15 a, b and c) and so zoologists use the dental formula to characterise a particular mammalian taxa. The dental formula denotes the number of teeth of each kind present in one half of the upper and lower jaw.

Let us see how the dental formula is determind in the mammals: For this refer to the Fig. 17.16 showing the dental formula of humans. In the dental formula you can see that the number and type of teeth present in the upper jaw are listed above the number and type of teeth present in the lower jaw as shown in Fig. 17.16. As you can see in the figure the types of teeth are listed in the following order: incisors, canine, premolars, and molars which are represented by alphabets i, c, pm and m respectively. The number of each type of tooth may be given by only giving the number of teeth as given below on the left hand side of the figure or by writing, the indicative letter of the type of teeth before its number as shown on the right hand side of the figure (Fig. 17.16a). When the number of teeth present in the half part of the upper and lower jaw are added together and multiplied by two we get the total number of teeth for that particular animal. For example, the total number of teeth in human is 32 and the dental formula can be given as follows:

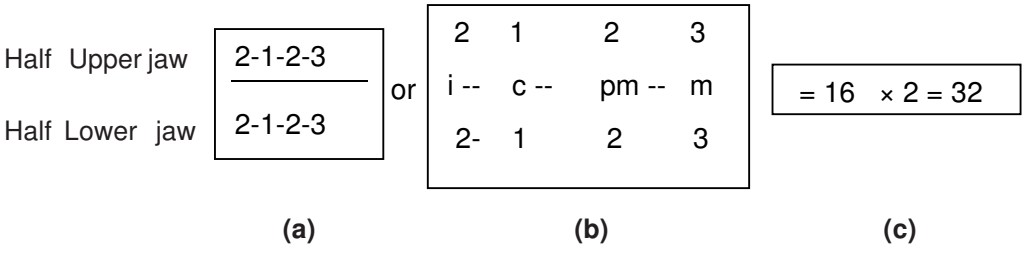


Fig. 17.16: Dental formula of Human beings : a) only depicted with the number of types of teeth; b) depicted with types of teeth and their number; c) calculation for total teeth present in the mouth.

Digestive system

The digestive tract of mammals is similar to that of other vertebrates and consists of mouth, teeth, pharynx, stomach, small intestine, large intestine and a rectum or cloaca (Fig. 17.17a). In mammals the digestive tract has become specialised, according to the feeding habits of various types of mammals. Different parts of the mammalian gut have different physiological environments which is essential for the action of different kinds of enzymes that act on the ingested food.

The alimentary canal in mammals has become adapted on the basis of the type of diet. Extreme specialisations of the gut are specifically seen in herbivores about which you will learn in more detail in the next course. Some mammals like shrews and rodents such as hares and rabbits and also some insectivores, exhibit coprophagy which is a unique practice. These mammals at intervals, reingest the faecal pellets excreted by them and so these reingested faecal pellets are once again passed through the alimentary canal. It is thought that coprophagy allows the animal to absorb in the upper gut the vitamins present in the faecal pellets from the upper gut as these vitamins are absorbable only in the upper gut, while they are produced by the microflora present in the lower gut where they are not absorbable. Coprophagy is obligatory (compulsory) in those animals which practice it.

17.3.7 Respiratory System

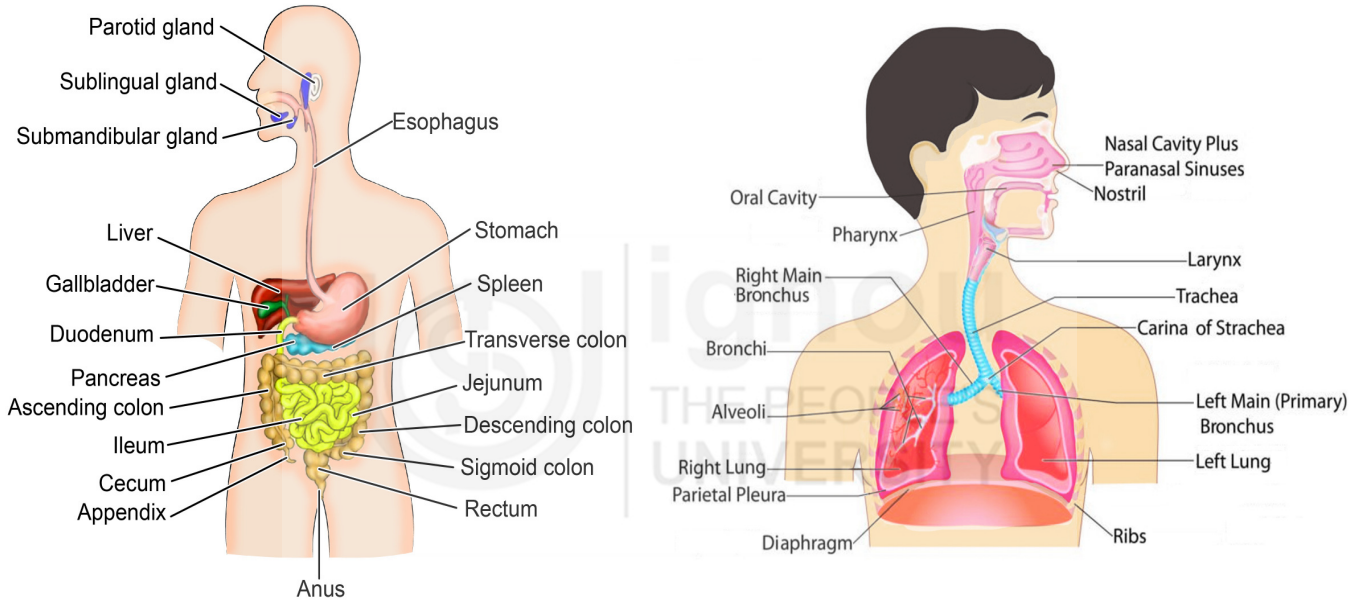
The respiratory system or the breathing or ventilatory apparatus in mammals is closely associated with the circulatory system. The high metabolic rate of mammals, requires adaptations for efficient gas exchange. The respiratory system of mammals consists of paired nostrils, a single pharynx, a single trachea, a single epiglottis, paired bronchi and paired lungs (Fig. 17.17 b).

Most mammals because of the presence of the secondary palate have separate nasal and oral (mouth) cavities. Each of the paired nostrils leads into the nasal cavity which provides an increased surface area for warming and moistening the inspired air. Both the nasal cavities then open into the single the median pharynx which is a common passageway leading from the oral and nasal cavities (that are present in the head), to the oesophagus and pharynx and trachea respectively. The larynx which is also referred to as the “voice box”, is present at the proximal end of the trachea. The larynx in mamals helps in producing vocal sound as vocal cords are stretched across it, which when vibrated by the forced expiration of air produce sound. In some groups of mammals the laryngeal apparatus may be greatly modified for the production of complex vocalisations as seen in howler monkeys and humans.

The larynx at its proximal end has the tiny flap of connective tissue called the epiglottis. The epiglottis covers the trachea during the process of eating or swallowing and so it prevent the food from entering into the trachea during swallowing and it also for prevents air from entering the stomach during breathing. The median trachea at its distal end branches at the level of the middle of the chest into the two main bronchi (singular: bronchus) each of which enters into the elastic lung present on its side. Each mammalian lung lies in a separate airtight compartment called pleural cavity which as

described earlier is located on either side in the thoracic cavity of the chest region (Refer again to Sub-section 17.3.1 and Fig. 17.3).The bronchus branches progressively within the lung which thus resembles a highly vascular sponge, unlike the saclike lung structures of amphibians and reptiles. The mammalian lungs contain many tiny air sacs called alveoli (alveoli: plural and alveolus: singular) which allow for rapid gaseous exchange. The mammalian lungs, due to the presence of these alveoli have a high surface area. However the lungs of mammals are not as efficient as the lungs of birds.

A muscular diaphragm as mentioned before, is present in mammals and separates the abdominal cavity from the thoracic cavity. The diaphragm helps in respiration as lowering and raising of the diaphragm, sucks in and pushes out air from the lungs respectively during the process of respiration.



(a) (b)

Fig. 17.17: a) The digestive system of a human who is an omnivore; b) Respiratory system of a human.

SAQ 2

1. Fill up the blanks in the following sentences with suitable words from among the words given in the parenthesis:

   i) Horses possess……at the end of their digits, (claws/ hooves).

   ii) Man has.....on his digits, (hoofs/nails).

   iii) Carnivores are provided with……on their digits, (nails/ claws)

   iv) Nails, hair, claws and hoofs are the……..exoskeleton of mammals. (mesodermal/epidermal)

v) The upper layer of the skin of mammals is the…… (epidermis/ dermis)

vi) Mammary glands are modified……..(sebaceous/ sweat) glands.

2. Tick the number of cervical (neck) vertebrae present in giraffes:

i) 1

ii) 5

iii) 7

iv) 6

17.3.8 Nervous System

The brain of mammals is comparatively larger and extremely well-developed when compared to other vertebrates (Fig.17.18).

Brain

The basic structure of the vertebrate nervous system including the brain is retained in mammals. The mammalian brain has retained the reptilian brain (R-brain) but has becomes much better developed due to the enlargement of the cerebral hemispheres and the large, complex and solid cerebellum. Cerebral hemispheres and the cerebellum being well-developed in mammals cause an enhancement in the nervous and sensory functions of mammals. The superficial layer of the cerebrum called the cerebral cortex or neocortex is especially well-developed in mammals and most of the integrative functions are located in it. In mammals the neocortex has a crumpled appearance, with many ridges and valleys covering most of the reptilian brain. Both the reptilian and mammalian brain contains the thalamus and the hippocampus.

Corpus callosum also callosal commissure is present only in mammals. It is a wide, transverse flat bundle of commissural nerve fibers which connects the two cerebral hemispheres and is the primary communication route between the right and left brain hemispheres in placental mammals. It is rudimentary in marsupials and similar to reptiles is absent in monotremes. In monotremes and marsupials the anterior commissure present in them provides an alternate communication route between the two hemispheres. 12 pairs of cranial nerves are present in the brain of all mammals. Corpora quadrigemina, which are reflex centers involving vision and hearing are present on the dorsal side of the mid brain in mammals.

Sense Organs

Sense Organs are well-developed in mammals and are as follows:

Sense of touch : It which is well-developed in mammals and consists of receptors which are associated with the base of the hair follicle and the integument.

Sense of taste : It is well-developed in mammals especially in humans, as the tongue has various receptors for taste of sweet, sour and salt.

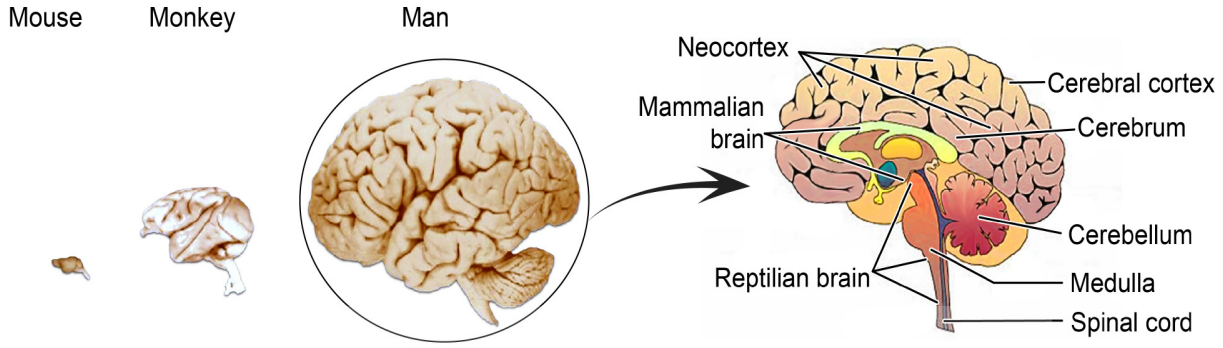


Fig. 17.18: Side views of the whole mammalian brains of: i) mouse in which the neocortical surface is smooth and covers only the top part of the brain; ii) monkey; and iii) human. In both monkey and human the neocortex has many sulci or wrinkles and covers almost the entire brain. The expansion of neocortex in mamals is one of the most characteristic features of mammals and is well developed in primates (especially humans), iv) A Labelled diagram of the human brain.

Olfactory sense or sense of smell : It is well-developed in mammals and helps them to detect olfactory stimuli over long distances due to which they are able to locate food, recognise members of the same species, and avoid predators from a distance. The olfactory region of the mammals consists of an expanded nasal chamber with complexly folded turbinate bones which provide a wide area for the detection of ordours. Turbinal bones help in catching bacteria and dust and also function in warming the air which is breathed in.

Vision or sense of sight : The eyes are main organ of sight or vision which is an important sense organ in most mammals. The structure of the mammalian eye is similar to that of other vertebrates. However; eyes of mammals have upper and lower eyelids and often eyelashes. The nictitating membrane is present in mammals and is hairless and translucent. The nictitating membrane however, is vestigial, in higher mammals. Colour vision is less well-developed in mammals than in reptiles and birds. Rods dominate the retinas of most mammals, which support the hypothesis that early mammals were nocturnal. Primates, squirrels, and a few other mammals have well-developed colour vision.

Auditory or hearing sense is well-developed and is important in mammals and so are discussed here in greater detail (Fig. 17.19 a). The structure of the ear is greatly modified in mammals in comparison to repitiles and aves.

The paired ears consist of: i) internal ear ii) middle ear and iii) inner ear

i) **An external ear** which in most mammals consists of paired, fleshy, external pinna which protects the opening of the external (auditory meatus) and the tympanic membrane of the external ear ear. an external ear pinna. The presence of the paired pinna in mammals is a recent adaptation as compared to other vertebrates. The pinna is absent in Monotremata (e.g. Platypus), Cetacea (e.g. Whales) and Sirenia (e.g. Manatee). On the other side of the tympanic membrane or ear drum and distal to it is the middle ear.

ii) **The middle ear** which consists of an air filled chamber with three ear ossicles. The three ear ossicles are a diagnostic feature for Class Mammalia because as you have studied before, the middle ear of other amniotes only has a single bone called the columella or stapes. In mammals however, the middle ear of the mammals consists of a set of three ear ossicles or bones, namely, the malleus (hammer) the incus (anvil), and the stapes (stirrup) which function collectively for transmitting sound waves from the tympanic membrane, or eardrum to the internal ear (Refer to Fig. 17.19). The stapes (Fig. 17.19 a & b) in the middle ear of mammals is homologous with columella of the reptiles. The incus bone is derived from the quadrate bone (which is involved in jaw articulation in reptiles) and articulates with the stapes in mammals. The malleus is homologues with the reptilian articular bone (refer again to Axial skeleton in Sub-section 17.3.5). The malleus rests against the tympanic membrane and articulates with the incus that conducts vibrations to the inner ear (Fig. 17.19 a, b).

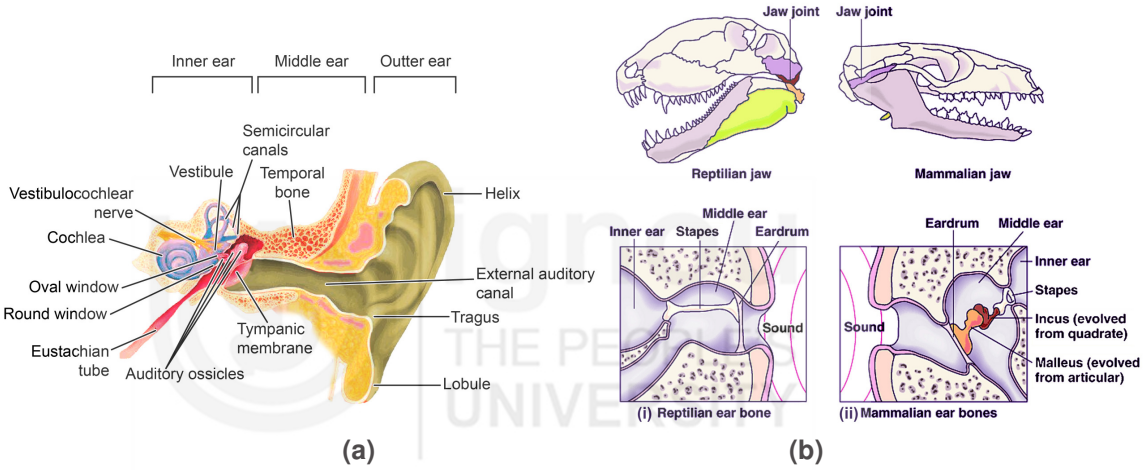


Fig. 17.19: a) Detailed structure of a human ear; and b) Generalized figure of ear bones of the middle ear of i) reptile ii) mammal.

iii) **The Inner ear** or labyrinth contains a long and coiled, sensory structure called the cochlea that has sound receptors. The cochlea provides more surface area for the receptor cells thus, making mammals more sensitive to pitch and volume of sound as compared to reptiles.

17.3.9 Muscular System

The muscular system of mammals is generally comparable to that of reptiles though changes in locomotion in mammals have correspondingly resulted in changes in the proportions and specific functions of some of the muscles. Despite this though, the relationships of these muscles in reptiles and mammals remain essentially the same. However, the muscles of the skin and of the jaw in mammals are considerably different from that of reptiles.

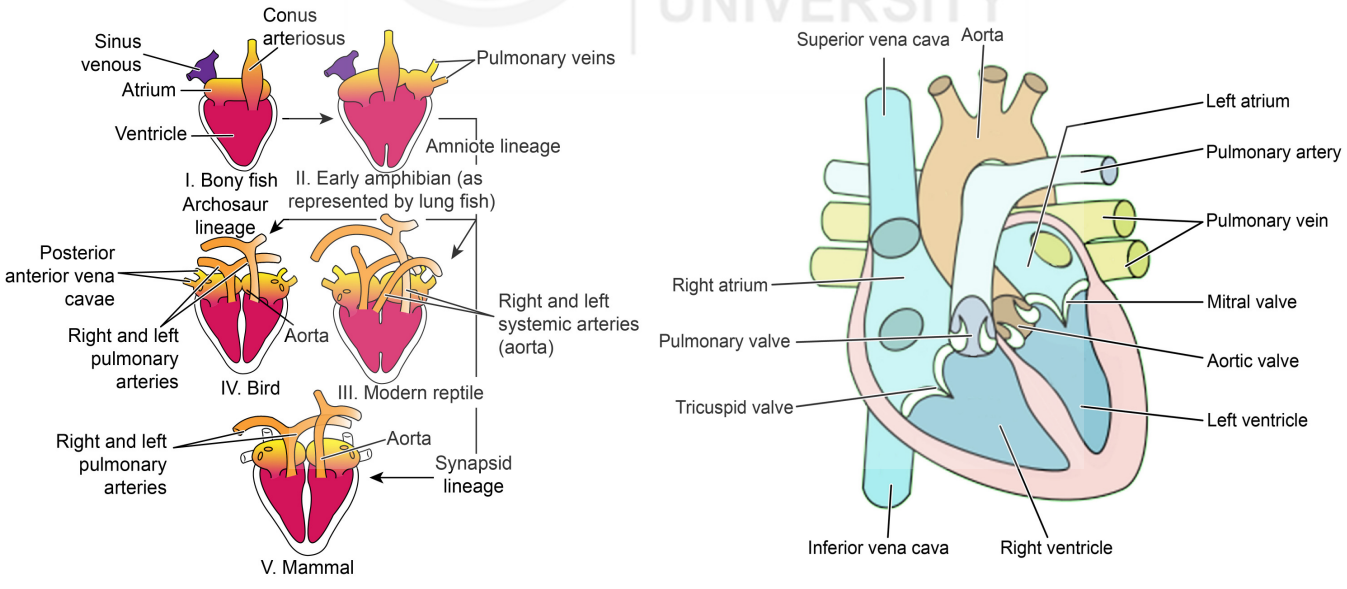
In many mammals, a sheath of muscle called the panniculus carnosus is present in the dermal region of the skin which allows the movement of the skin independent of the movement of deeper muscle masses. These movements include activities such as twitching of the skin to deter insect pests. In some mammalian species these muscles are also used for shivering. The dermal musculature of the facial region is particularly well-developed in primates and carnivores but occurs in other mammalian groups as well. Facial mobility

allows facial expressions that may be of importance in the behavioral maintenance of interspecific social structure.

17.3.10 Circulatory System

The heart of birds and mammals appear superficially similar as both are four-chambered muscular pumps that keep the blood in the systemic and pulmonary circuits of the body separate and both have evolved from the hearts of ancient reptiles.These similarities however, are due to adaptations to active lifestyles as the heart in birds and mammals have evolved from different evolutionary pathways. The mammalian heart has evolved from the synapsid reptilian lineage, whereas the avian heart have evolved from the archosaur lineage (Fig. 17.20 a).

The four chambered heart of mammals consist of two auricles (atrium) located above the two ventricles.The right auricle and the right ventricle are completely divided from the left auricle and the left ventricle (Fig.17.20 b). The opening between the left auricle and the left ventricle is guarded by the bicuspid valves while the opening between the right auricle and the right ventricle is guarded by the tricuspid valves. The presence of these valves is characteristic of mammals. Separate pulmonary and systemic circuits are present in the mammalian heart. Only one persistent left aortic arch is present in the mammalian heart which curves around to the dorsal side of the heart and so is referred to as the dorsal aorta. Among vertebrates, including mammals the contraction of the heart is generated by an oblong mass of specialised muscle cells called the sinoatrial node which is thus myogenic in origin. Sinus venosus and conus arteriousus as well as the renal portal veins are absent in mammals.



(a) (b)

Fig. 17.20: a) Possible Evolutionaary sequence of the vertebrate heart: i) heart of a bony fish; ii) Heart of a lung fish, showing a partially divided atria and ventricle which separate the pulmonary and systemic circuits. The heart of the lungfish is believed to be similar to that of primitive amphibians and early amniotes; iii) The heart of a modern reptile which has been derived from the pattern of the lung fish heart as given in a "ii"; (a) iv) the four chambered bird heart which has developed from the archosaurian lineage; (a) v) Mammalian heart which has evolved from the synapsid lineage and is completely, four-chambered heart ; b) Cross section of a four-chambered human heart.

As in all vertebrates the oxygen is transported by specialised red blood cells (RBCs), called erythrocytes which are present in the blood. The red blood corpuscles in mamals are generally but not always biconcave and usually circular in form. The mammalian erythrocytes when mature and functional, are enucleate (lacking a nucleus).

SAQ 3

1. Match the name of the mammal given in **Column A** with the its feature given in **Column B**.

	Column A		**Column B**
i)	Fox	a)	Cloaca
ii)	Echidna	b)	Pelage
iii)	Deer	c)	Coprophagy
iv)	Rabbit	d)	Blubber
v)	Whale	e)	Antler

2. The salient features of the mammalian heart are:
   i) Presence of sinoatrial node
   ii) Four chambered
   iii) Single persistent left aortic arch
   iv) All of the above
3. Match the mammalian feature given in Column A with its function in Column B.

	Column A		**Column B**
1)	Claws	a)	voice
ii)	Larynx	b)	protection of brain
iii)	Molar teeth	c)	defense
iv)	Cranium	d)	grinding food

17.3.11 Endothermy and Temperature Regulation

All mammals, similar to birds are endothermic (capable of the internal generation of heat), unlike reptiles, which as you will recall are ectothermic. Mammals are able to maintain and regulate their own body temperature which depending on the mammal species ranges from 98.6 F to 107.6 F (37°C to 42°C). The normal body temperature of humans is 98.6°F.

Nearly all mammals have to face temperatures that require them to lose excess heat occasionally and also to conserve or generate heat at other times. Mammals maintain their correct internal body temperature, by conserving or generating body heat in colder temperatures, as well as dissipating (losing) excess body heat in warmer temperatures by the following mechanisms:

Mechanisms for maintaining the internal body temperature in cold climates

Mammals can produce heat by two mechanism such as: 1) **Shivering thermogenesis,** which is a muscular activity that generates large amounts of heat by the rapid contraction and shaking of muscles, and 2) **nonshivering thermogenesis,** which involves heat production by general, cellular metabolism which is a chemical process that constantly occurs within the cells of the body and by which organic molecules are broken down and internal energy is produced. This process in addition to releasing energy also generates heat that warms the body.

Retention of heat produced by the body is possible because mammals are insulated by their pelage and/or fat deposits. Fat deposits are also sources of energy to sustain high metabolic rates. Heat is generated by the metabolism of special fat called brown fat.

The countercurrent heat exchange mechanism about which you have learnt in Unit 16 earlier also functions in mammals that live in extreme cold conditions and so enables them to maintain the temperature of their extremities at the same body temperature.

Mechanisms for maintaining internal body temperature in warm climates

The mammals in warm climates maintain their body temperature by losing excess body heat. They achieve this by releasing excess heat from the body into the environment, through their peripheral blood circulation, which is located very near the surface of the skin. Another method of losing heat by them is by producing sweat which cools the body and maintains the external body temperature . In some situations when heat is too extreme, mammals, similar to reptiles, often seek protection from the sun during the hotter daylight hours and resume their activity at night.

17.3.12 Excretory System

Mammals, like all amniotes, have metanephric kidneys however, unlike reptiles and birds which excrete mainly uric acid, they excrete urea which is a nitrogenous waste and is the end product of protein metabolism. Excretion in mammals is therefore called ureotelic. Urea is less toxic than uric acid and is highly water soluble and so is excreted in a liquid form as urine due to which some loss of water occurs in mammals during excretion.

The excretory system of adult mammals (Fig. 17.21) consists of paired kidneys and their ureters. The ureters usually open into a median, single urinary bladder. The paired mammalian kidneys consist of a large number of basic functional units called nephrons or uriniferous tubules. Nephrons are the tiny filtering structures of the kidneys. Each kidney contains more than a million nephrons that help clean our blood by removing excess water, wastes and other substances from the blood. You will be learning in detail about the fine structure of the kidneys, including the nephrons or uriniferous tubules in the next course.

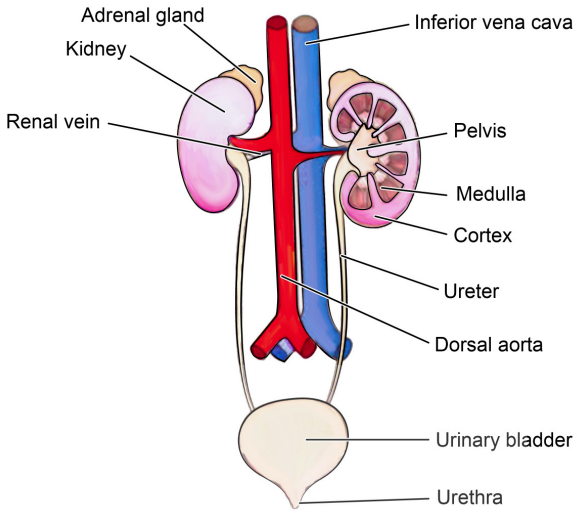


Fig. 17.21: Excretory system of a mammal (human).

17.3.13 Sexual Dimorphism and Reproductive System

In mammals the sexes are separate which is referred to as sexual dimorphism. The reproductive system in mammals has been modified according to their mode of giving birth. The reproductive organs of mammals produce the gametes. Male mammals produce the gametes called sperms while the female mammals produce the gametes called egg cells or ovas.Fertilization is internal in all mammals.

Female reproductive system

The female reproductive organs of therians consist of the ovary, uterus, fallopian tube, cervix (neck of uterus), vagina and vulva. However, the prototherian or monotreme mammals which indclude Platypus and Echidnas are oviparous and so lay eggs, instead of giving birth to an infant or embryo and so, as a result the uterus is absent in them. The vagina of the female reproductive organ is also absent in the prototherians mammal and all the non mammalian vertebrates.

Female mammals of therians have paired ovaries which are the organs that produce the eggs or ova (Fig.17.22 a, b and c). Ovaries in mammals are situated in the abdominal cavity, just ventral to the kidneys. A single oviduct called the fallopian tube is present close to each ovary. Fertilization occurs in the fallopian tubes which also transport the fertilised ovum to the pouch-like, muscular organ called the uterus (plural, uteri) within which the embryo or foetus develops. Muscular contractions of the uterus help to push the offsprings out, during birth. The uterus is present only in the marsupial and placental mammals which as you will recall from before are know collectively as therian mammals and are viviparous as they give birth to young ones.

In all therian mammals the **vagina** is a single, tubular passageway of the uterus through which the young one leaves the mother's body during birth. The male of the therian mammals, deposit the sperms during mating in a structure called the cervix which separates the uterus from the vagina or birth canal. The cervix has thick walls and a small opening which softens and relaxes to

allow a passageway for sperms during mating and for expulsion of the young one at the time of birth. During pregnancy, the cervix is filled with a thick mucous secretion known as the **cervical plug**, which protects the uterus from infections entering from the vagina.The cervical plug is expelled and the cervical opening begins to dilate prior to giving birth.

In monotremes a uterus is not present and so after fertilization the fertilised egg is coverd by a shell secreted by the shell glands after which the mother lays the shelled egg outside the body. Further development of the embryo occurs outside in the egg laid by the mother. The young ones produced by the metatheria mammals which are grouped under therian mammals are born as tiny, immature young ones. Eutherian mammals which are also grouped under therian mammals are born as relatively large, well-developed young ones.

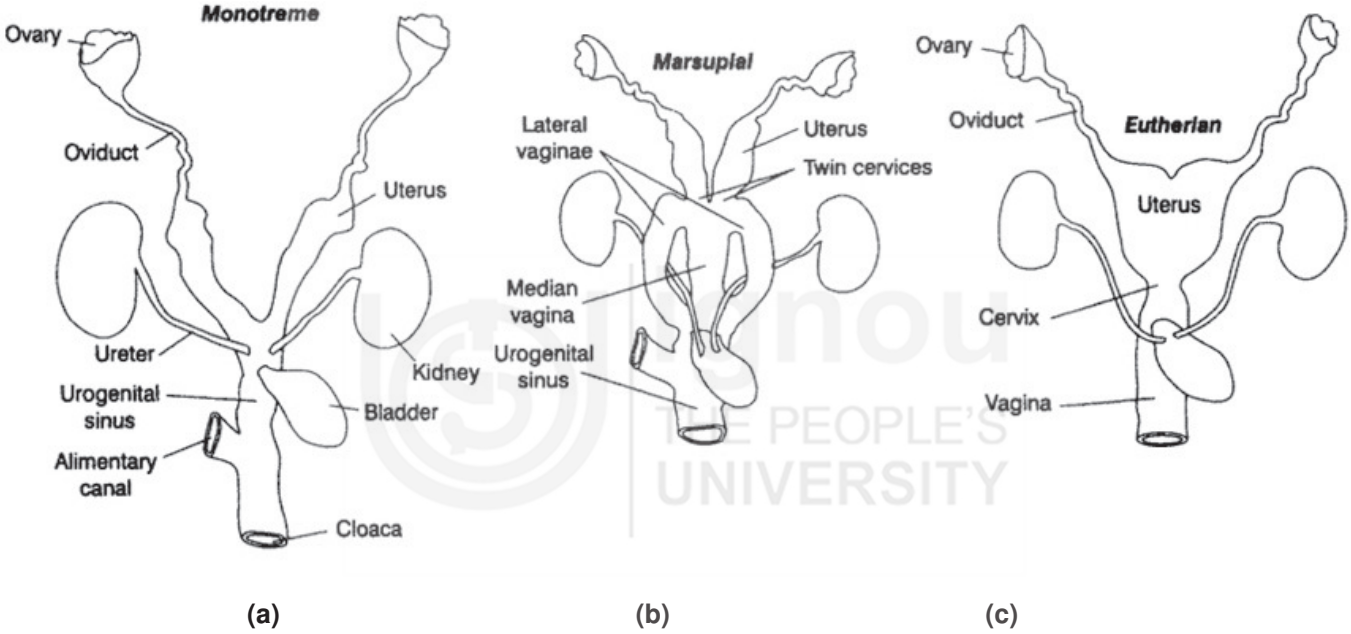


Fig. 17.22: Female reproductive system of a) a Monotreme (echidna); b) a marsupial; and c) a eutherian mammal. In monotremes the two separate uteri, a single bladder and paired ureters all open into a common urogenital sinus. Marsupials have paired, separate uteri, twin cervices (sing: cervix) and a vaginal complex consisting of two lateral vaginae for sperm transport and a median vagina which acts as a birth canal. In eutherian mammals there is a single vagina.

The male reproductive system

The reproductive system of mammalian males (Fig.17.23 a and b) consist of paired testes (singular: testis) or testicles that produce the sperms and some reproductive hormones. In most mammals, each testis is contained in an extra abdominal sac-like structure called scrotum. Each scrotum or scrotal sac is suspended between the thighs. The location of the scrotum or outside the abdomen ensures that sperms are maintained at a temperature lower than that of the main body. The temperature of the scrotal sac is often 8°C less than that of the abdomen. In cetaceans, sirenians, hyraxes, elephants and in some insectivore mammals however, the testes are located in the abdomen

and so are abdominal.

Each testis contains a mass of numerous coiled tubes called seminiferous tubules which produce the sperms. A tube like sperm duct called the vas deferens carries the sperms from the testis to urethra.. The urethra is a single, long tube which extends through the penis and opens externally on the surface of the body and conducts the semen containing the sperms to the outside during copulation. The same passage also functions to remove the urine from the urinary bladder by excreting it outside the body.

The other main organ of the male reproductive system is the single penis which is an intromittent (external to the body) organ and is inserted by the male into the vagina of the female during copulation. The penis internally consists of connective tissue with numerous small blood spaces in it which become filled with blood during sexual excitement, causing it to become erect. Several structures and glands like the seminal vesicle, prostate gland and Cowper's gland are also associated with the male reproductive system of mammals about which you will study in greater detail in the next course.

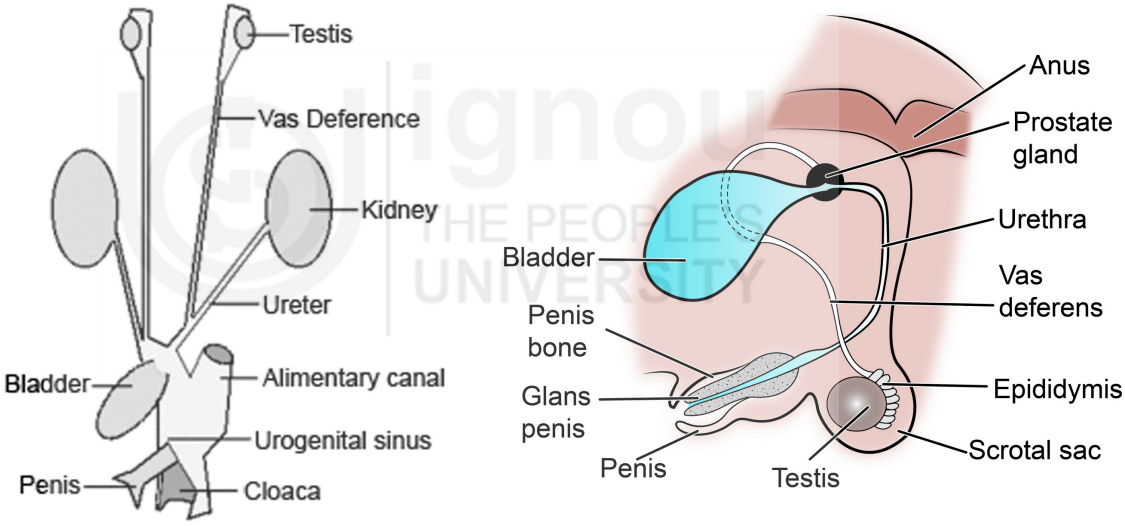


Fig. 17.23: Male reproductive systems of mammals: a) a diagrammatic sketch of the external view of the male reproductive system of platypus, (a prototherian), and b) the internal view of the male reproductive system of a dog (therian mammal).

17.3.14 Reproductive Cycle

Most mammals have a definite time or times during a year in which ova (eggs) mature and are capable of being fertilized. Mammals exhibit two types of ovarian cycles: 1) Estrus cycle which occurs in all non-primate mammals such as rats, dogs, cows etc. In this cycle the mammals are in heat or sexually receptive only at certain times of the year and so are sexually active only during that time of the year; and 2) Menstrual cycle which takes place in primates like humans, monkeys, chimpanzees etc. In this type of cycle females can be sexually active at any time of the year. In mammals fertilization usually occurs in the upper third of the oviduct within hours of copulation.

17.3.15 Viviparity and Modes of Development

Viviparity is most developed in mammals as compared to all other classes of vertebrates. Mammals are usually viviparous as the embryo develops within the uterus where it is attached with a placenta to the mother's uterus. In placental mammals including humans, four foetal membranes namely, amnion, chorion, allantois and yolk sac are present which sustain the foetus while it grows inside the mother's uterus till it reaches a relatively advanced stage of development and can be born. Placental mammals thus, give birth to relatively large and mature infants. In placental mammals the maternal bloodstream instead of yolk, supplies nutrients to the developing embryo.

In marsupials, most of the nourishment for the foetus comes from "uterine milk" that is secreted by the uterine cells. Some nutrients diffuse from maternal blood into a highly vascular yolk sac that is in contact with the uterus. This connection in marsupials is a primitive placenta. New born babies of marsupial mammals like kangaroos and opossums are incompletely developed at birth and continue to develop outside the womb of the mother by attaching themselves in the area of the mammary gland of their mother's body. In some marsupials the mammary gland area is covered by a pouch-line structure or fold of skin in which the suckling young is sheltered while developing outside the mother's womb.

Monotremes are the only oviparous mammals and in which them the embryo develops within the egg, which is laid outside the mother's body. In monotremes the ova has large quantities of yolk. After fertilization of ova the shell glands in the oviduct deposit a shell around it. Female echidnas incubate their eggs in a ventral pouch while the platypus lay their eggs in burrows.

The newborn babies of many therian mammalian species like deer and horses are able to walk and run shortly after birth (precocial), unlike those of humans who have to be looked after by the parents (altrical).

SAQ 4

1. List the names of the various glands associated with the male reproductive system.
2. Shell glands are present in:
   i) Marsupials
   ii) Placentals
   iii) Monotremes
   iv) All of the above
3. Choose the correct option from the words given in the brackets:
   i) Mammals, like all amniotes, have metanephric kidneys which excerte (urea/uric acid).

ii) All mammals are (ectothermic/endothermic).

iii) All non primate animals have (an estrous/a menstrual) cycle.

iv) The newborn babies of deer and horses are (precocial/altrical).

17.4 SUMMARY

1. Mammals represent a highly evolved group of amniote vertebrates.
2. Mammals are placed in Class Mammalia due to the presence of their mammary glands and hairs.
3. Class mammalia contains the (i) proto therian mammals aslo referred to as monotremes which are oviparous as they lay eggs and (ii) The therian mammals which are viviparous and give birth to young ones.
4. Mammals are endothermic (warm-blooded) a trait shared by modern birds.
5. **The defining features of all mammals are:**
   i) Their body is covered with integument which bears hair which are epidermal in origin;
   ii) The females of mammals nourish their young ones with milk which is secreted by the mammary glands that are a special group of glands present in both male and female mammals;
   iii) Their middle ear has three ear ossicles;
   iv) The lower jaw is made of only one bone which articulates posteriorly with the upper jaw of the skull by means of the squamosal bone;
   v) The structure and arrangement of teeth are important indicators of mammalian lifestyles. Specialisation in food habits among mammals has led to profound dental changes. Mammalian teeth (dentition) may be specialised for a particular diet. Specialised teeth which are of heterodont, thecodont and diphyodont type are present in mammals;
   vi) well-developed brain with neocortex that serves as the center of higher mental functions is present in mammals;
   vii) bicondylar skull is present;
   viii) four-chambered heart in which the pulmonory and systemic systems are entirely separate. In mammals only the left aortic arch is present;
   ix) well-developed respiratory system consisting of a larynx (sound box), trachea, paired bronchus and paired lungs;
   x) a muscular diaphragm, which separates the abdominal cavity from the thoracic cavity and helps in respiration; and
   xi) a secondary palate which separates the air and food passage.
6. An exoskeleton is present in mammals and consists of structures such as nails which are present on the digits (fingers and toes) of all amniote

classes including mammals. Nails may be modified into claws and hooves.

7. Horns or antlers are also part of the exoskeleton and are present in several hoofed mammals. Horns and antlers appear similar but are fundamentally different.

8. Endoskeleton of mammals is well-ossified and is similar to other amniotic vertebrates. It is broadly divisible into: I) an axial skeleton which consists of the: a) braincase (cranium) or skull; b) the vertebral column also called spine or backbone; and c) the ribs and II) appendicular skeleton which consists of the limbs and girdles of mammals; and III) the visceral skeleton which consists of skeletal elements collectively derived from gill arches and includes the jaws, the hyoid apparatus supporting the tongue, and the auditory ossicles of the middle ear.

9. The senses of taste, touch, hearing, smelling, and sight are well developed in mammals.

10. The muscular system of mammals is similar to that of reptiles.

11. The excretory system of mammals consists of paired kidneys, paired ureters and a single urinary bladder. The main excretory product is urea which is excreted in the form of urine.

12. Sexes are separate in mammals and the reproductive system is well-developed. Fertilization is internal in mammals.

13. Most mammals are viviparous except for monotremes which are oviparous.

17.5 TERMINAL QUESTIONS

1. List and give one function of the 4 glands of the skin of mammals.

2. Differentiate between horns and antlers.

3. Describe the axial skeleton of mammals.

4. Discuss the modes of development of mammals.

5. State in the box provided whether the following statements are True (T) or False (F):

   i) Elephants are the largest land animals. ( )

   ii) Blubber is found in monkeys. ( )

   iii) Carnivores are grass eating mammals. ( )

   iv) Kangaroos are egg laying mammals. ( )

   v) Cows provide milk. ( )

   vi) Monotremes are viviparous. ( )

17.6 ANSWERS

Self Assessment Questions

SAQ 1

i) Mammals have hair; ii) they have mammary glands; iii) The middle ear of mammals have three bones or ossicles; iv) Mammals have a diaphragm that aids them in respiration. (Refer also to Section 17.2)

2. iii) Monotremes

3. ii) Diaphragm

SAQ 2

1. i) hooves; ii) nails; iii) claws; iv) epidermal; v) epidermis; vi) sweat.

2. i) 7

SAQ 3

1. i) b; ii) a; iii) e; iv) c; v) d

2. All of the above

3. i) c; ii) a; iii) d; iv) b

SAQ 4

1. Prostate gland and Cowper's gland

2. iii)

3. i) urea; ii) endothermic; iii) an estrous; iv) precocial

Terminal Questions

1. Refer to Sub-section 17.3.3.(Integumentary glands)

2. Refer to Sub-section 17.3.4 (Horns and antlers).

3. Refer to Sub-section 17.3.5 (Endoskeleton – Axial skeleton).

4. Refer to Sub-section 17.3.15 (Viviparity and Modes of Development).

5. i) true; ii) false: iii) false; iv) false; v) true; vi) false;

UNIT 18

EVOLUTIONS AND CLASSIFICATION OF MAMMALS

Structure

18.1 INTRODUCTION

In the previous three units you have studied the defining features of three groups of amniotic tetrapod (four legged) vertebrates: namely reptiles, birds (aves) and mammals. You have also learnt in the previous two units (Units 15 and 16) that members of classes Reptilia and Aves have evolved shelled, amniotic eggs which minimize water loss and thus allow them to raise their offsprings without being dependent on a watery environment.

In Unit 17, you have studied about mammals which in all groups except monotremes, are viviparous as they have evolved better reproductive strategies than reptiles and birds by not laying shelled egg that contain the developing embryos; instead by allowing their embryos to develop within a fluid filled amniotic sac contained in the mother's body. In viviparous mammals the fertilised egg is retained inside the uterus of the mother which is connected to the mother by a structure called the placenta. The developing

embryo receives nutrition and oxygen through the placenta which also helps to expell its nitrogenous wastes and carbon dioxide. In Unit 17 you have also learnt that mammals are uniquely different in several features from other amniotic vertebrates. As you will recall that mammals are the only amniotic vertebrates to possess mammary glands that secrete milk and that mammals, have hair, unlike reptiles and fishes that have scales covering the body and birds that have feathers. You will further recall from the previous unit that only mammals have three bones in the middle ear and a single bone in each half of the lower jaw and that the brain of mammals is the most developed in comparison to other classes of vertebrates. You also know that a diaphragm is present in mammals which aids in their respiration and that mammals similar to crocodiles and birds, have a four chambered heart and are endothermic and so are able to maintain a high metabolic rate.

In the present unit we will begin by tracing the origin and evolution of mammals from their synapsid ancestors. Fortunately mammals have a well-documented fossil record that is also supported by modern molecular tools. We will then focus on the classification of extant mammals based on distinctive characteristics that have resulted in them being classified into 29 Orders. We will also briefly describe these 29 mammalian orders.

Objectives

After studying this unit, you will be able to:

- differentiate between the non-mammalian early synapsids and later synapsids called therapsids;
- describe the progressive evolution of mammals from their synapsid ancestors;
- explain the success of members of Class Mammalia on the basis of their derived characteristics; and
- classify the extant mammals upto the level of order based on their distinguishing features.

18.2 ORIGIN AND EVOLUTION OF MAMMALS

Early in their evolutionary history amniotes split into two evolutionary lineages that dominate the terrestrial environment today. These two lineages are: i) the Sauropsida which is represented by reptiles and birds and about which you have already learnt in Units 15 and 16 of this course respectively, and ii) the Synapsida which is represented by extinct and living mammals. Both these lineages have independently and separately evolved derived characters that were essential for living on land.

You will recall from Unit 15 (Refer again to Sub-section 15.2.1. and Fig.15.1) of this course that the amniote skull on the basis of absence or presence of temporal fenestrae or openings (temporal opening are used for the fixation of jaw muscles) and the number of fenestrae present have been used to distinguish between the three groups of terrestrial amniotes all of which have diverged from a common ancestor. These three amniotes groups as you will

recall are: i) **anapsids** in which the skull does not have an opening or fenestra in the temporal region of the skull behind the orbit ii) **diapsids** in which two temporal openings, one pair low on the cheek and the other above it on the skull roof and separated from the lower opening by a bony arch are present; and iii) **synapsids,** in which the skull has a single pair of temporal openings located low on the cheek and bordered by a bony arch (see Fig.18.1 and 18.2). **The term synapsid is often mistakenly used to refer to extinct non-mammalian forms but it includes all amniotes that have descended from a common ancestor whose skull was of synapsid type.**

The evolution of mammals from their earliest amniotic ancestor has been uncovered from their fossil history. Most of the fossil remains of mammals that have been found are hard boney parts like: i) skull ii) teeth and iii) skeleton, as these are more easily preserved. The fossil history of mammals can be traced through three distinct phases. Refer to the geological time scale given at the end of the unit, while reading this section as it will help you to understand the timeline of the evolutionary history of mammals.

18.2.1 The Diversification of Synapsids

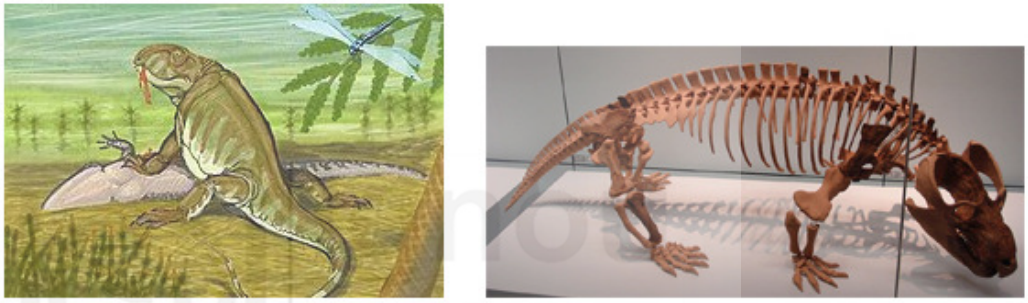
The synapsids were the first amniotes to spread widely on land. Their fossil remains that have been found are determined to be from the Pennsylvanian Period which was about 305 mya (million years ago) in the Paleozoic Era. These early synapsids are considered to be non-mammalian as they: 1) had a sprawling gait, 2) did not have hair and 3) laid eggs. Their distinctive synapsids feature was the synapsid skull that had a single pair of openings through which the jaw muscles passed and attached to the temple (the side of the head behind the eyes).

The first major non-mammalian synapsid group consisted of pelycosaurs which were the most common amniotes in the Permian period. These pelycosaurs (Fig.18.1 a) were both carnivores and herbivores and looked like lizards but were not closely related to them as they had a synapsid skull while lizards as you will recall have a diapsid skull. Pelycosaurs were thus synapsids and not reptiles.

A group of carnivorous pelycosaurs gave rise to the therapsids (Fig. 18.1 b) which were the only synapsids that survived beyond the Paleozoic era. Therapsida is the group of synapsids that contains the mammals and their ancestors. Therapsids had a more erect gait (way of walking) and their limbs were positioned below the body rather than at the sides. As a result their body was raised from the ground. The raised body of this group of synapsids required better coordination of their muscles in order to maintain their gait. Maintenance of gait was achieved by the evolution of a larger cerebellum which is the region of the brain that is responsible for muscular coordination. Correspondingly the structure of the skull was also changing at that time due to which the muscles of the jaws became more powerful, thus increasing the feeding efficiency of these animals. Therapsids diversified into many herbivorous and carnivorous forms but most of them disappeared during the great extinction at the end of Permian period.

18.2.2 Origin and Diversification of Mesozoic Mammals

A group of synapsid therapsids called the cynodonts, survived into the Mesozoic era and evolved several new features. These new features enabled the cynodonts to support a high metabolic rate and develop more powerful jaw muscles that enhanced their biting capacity and allowed them to grip their prey better. Cynodonts also developed heterodont teeth (more than a single type of teeth) which permitted them to chew and grind different kinds of foods. The nasal cavity of cynodonts developed turbinate bones (Long narrow curled shelf of bones in the nasal cavity) which helped them in retaining body heat. A secondary palate also developed in the cynodonts which allowed the cynodonts to breathe, even while holding the prey in the mouth or while chewing food and would in future be useful during suckling (drinking milk from mother's breast) by the young ones. The lumbar ribs that were present in other amniote groups were lost in the synapsid cynodonts. This loss can be correlated to the evolution of the diaphragm that occurs only in mammals.



(a) (b)

Fig. 18.1: Ancestors of mammals: a) Pelycosaurs like the one shown in the figure (*Pantelosaurus)* belong to a non-mammalian synapsid group; b) Fossil of *Chiniquodon,* a cynodont which belonged to a group of therapsids that gave rise to modern mammals, including humans.

The cynodonts diversified in the Triassic and Jurassic periods into several groups. Out of these groups one small carnivorous group called trithelodontids, though not true mammals, resembled the mammals especially with reference to the features of the skull and teeth. The therapsids gave rise to the first mammals in the late Triassic period (Fig.18.2*)*.The first mammals were small, almost shrews sized and had a large brain case and diphyodont dentition (the teeth are replaced only once).

Fig.18.2: The hypothetical ancestor of all placental mammals was a small, furry animal that ate insects.

Fossil evidence has also shown that the mammalian jaw was gradually remodeled in successive lineages of earlier mammalian synapsids during the course of evolution. Another important feature that evolved in these mammals was, as you have read in Unit 17, the formation of three bones in the middle ear namely, i) malleus; ii) incus; and iii) stapes, all of which function collectively in transmitting sound waves to the inner ear. Among the three bones the stapes are homologues with the columella of reptiles, birds and early synapsids, all of which function in hearing. Malleus and incus bones of the middle ear of mammals originated respectively from the articular and quadrate bones of the jaw joint of reptiles, birds and early synapsids as the articular and quadrate bones and later in mammals became reduced in size and got relocated to the middle ear (Fig. 18.3). A pair of new bones the

squamosal developed in the mammals which formed a joint with the dentary of the lower jaw. This joint is the defining feature of mammals and has also been found in all the mammalian fossils. The early mammals were small sized and were contemporaries of Mesozoic reptiles such as pterosaurs, crocodiles and dinosaurs.

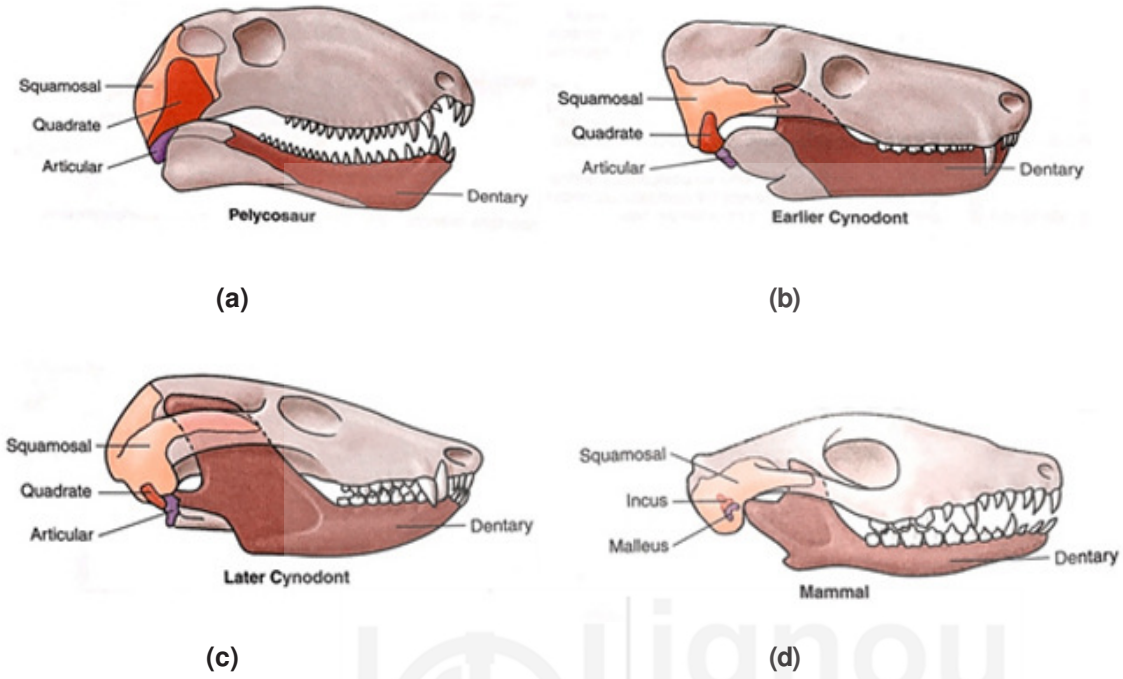


Fig.18.3: Evolution of the jaw joint and middle ear bones during the course evolution of mammals: a) the jaw joint in the earliest synapsids, the pelycosaurs, was between the articular and quadrate bones; b) and c) A new joint between the dentary and squamosal bones evolved in the cynodont lineage related to mammals; d) In mammals, the articular and quadrate no longer functioned as a jaw joint, instead they evolved for transmitting sound vibrations in the middle ear as the malleus and incus.

The three groups of mammals that still exist today namely, the prototherians (monotremes), and the therians, which include (i) the metatherians, consisting of living marsupials and their close fossil relatives and (ii) eutherians (consisting of living placentals and their close fossil relatives appeared (Fig.18.4) during the Cretaceous period of the Mesozoic era, which as you are aware was dominated by the dinosaurs. All the three groups of mammals have originated from a common ancestor. The earliest mammals were the ancestors of present day monotremes which are represented today by two species of echidnas and one species of platypus. The most recent common ancestors of the therian group which include the extant marsupials and placentals and all their descendants are the boreosphenidan mammals.

The most recent and comprehensive **molecular clock divergence estimate**, places the origin of the clade Theria approximately 170–190 million years ago. The metatherians and eutherians are believed to have diverged from each other about 160 million years ago. The oldest therian fossil that has been identified is the eutherian mammal *Juramaia* from the early Late Jurassic (ca. 160 million years old) period whose fossil was found in China.

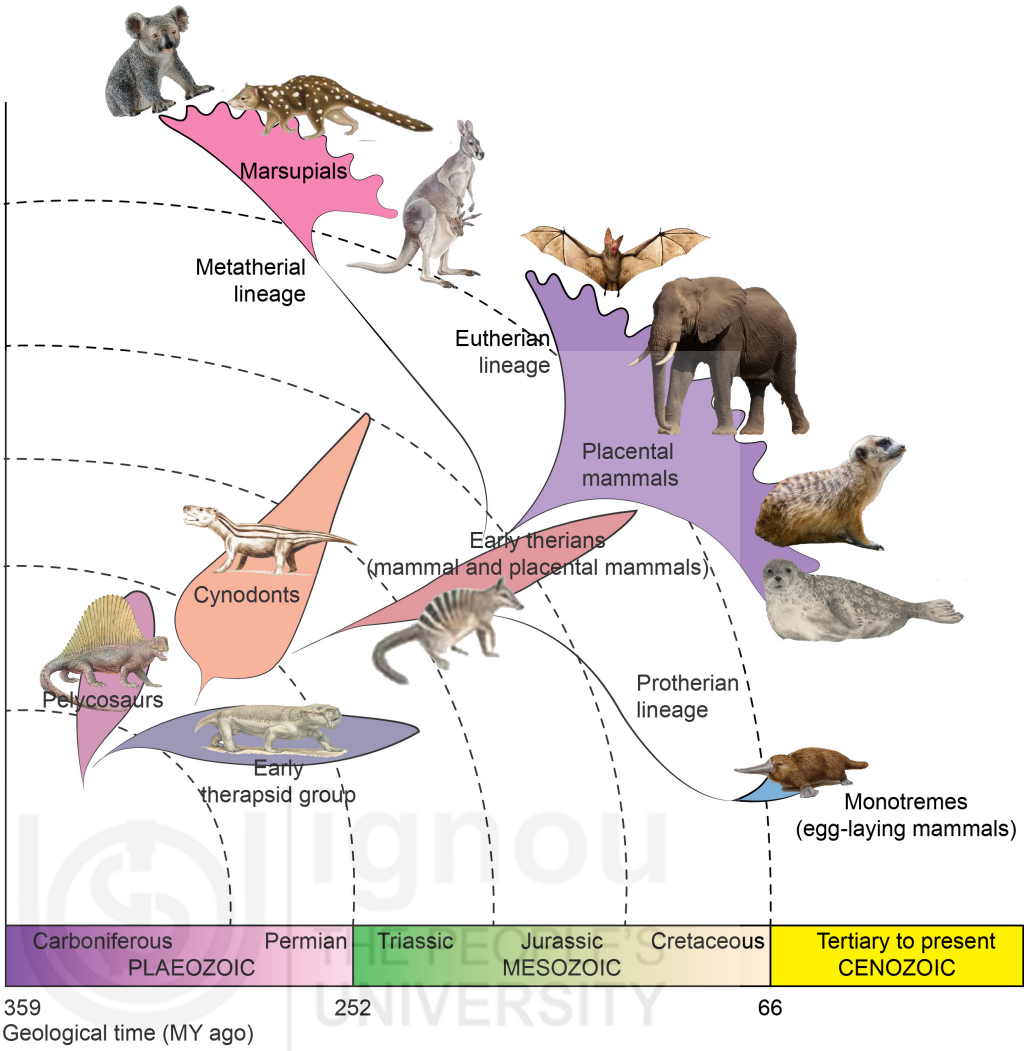


Fig 18.4: Evolution of the major groups of synapsids: The distinguishing features of members of the synapsid lineage are the lateral temporal openings present in the skull which first appeared according to evolutionary records in the pelycosaurs which are the early amniotes of the Permian period. The pelycosaurs underwent extensive diversification and evolved changes in their jaws, teeth and body form indicative of a number of features that would develop in the mammalian lineage. The evolution of features of mammals continued in the therapsids which were the successors of pelycosaurs. These changes were distinctly seen in the cynodonts, belonging to the therapsids. One lineage of cynodonts gave rise to early mammals in the Triassic Period. Present day evolutionary biologists believe that all groups of extant mammals – monotremes, marsupials and placentals have evolved from the same cynodonts lineage. The vast diversification of placental mammals took place during the Cretaceous and Tertiary Period.

The wide diversification of mammalian lineages as seen today, is believed to be due to the extinction of the dinosaurs as their disappearance may have opened up many niches for the mammals to occupy .The Cenozoic Era is thus known as the **"Age of Mammals".**

18.2.3 Features of Early Mammals

The early mammals according to scientists are considered to be warm blooded, since fossil records show that during the Mesozoic era which was

dominated by the dinosaurs, the early mammals in order to evade the dinosaurs adopted a nocturnal lifestyle or limited themselves to rocky or underground habitats. According to scientists the lifestyle adopted by the early mammals could only be possible if they were warm-blooded creatures, who could maintain a body temperature necessary for nocturnal activities. Furthermore, the early mammals were small, and so the physical requirements of them getting around required them to the develop agility and coordination. Such activities also required a higher metabolism, and so consequently more nutrition or food. These early mammals thus developed a carnivorous diet for which they developed enhanced vision. The nocturnal life style of the earlier mammals resulted in their eyes becoming relatively larger, hearing becoming more acute and the nose becoming more sensitive to smells. In addition to this, it is believed that in these early mammals the whiskers and vocal cords became more developed. These various features present in the small early mammals caused them to develop an awareness of their environment, due to which there was constant adaptation in the integration between the cerebral part of the brain and the physical features of these early mammals. These features of the early mammals provided them with an opportunity for evolving, reproductive strategies, maternal behaviour, parental care, and enhanced learning capacity and communication between individuals.

In short we can summarize that, while the dinosaurs were evolving enhanced physical features by becoming larger and developing extensive defensive and offensive tools, the early mammals used their energy in evolving their brain and behavioural characters.

18.3 DEFINATION OF MAMMALS

Mammals are defined as **"endothermic vertebrates which possess mammae or teats for suckling the young"**. They range in size from the tiny 1–2 inch bumblebee bat to the 108-foot blue whale and include the largest, living terrestrial and aquatic vertebrates namely, the African elephant and the blue whale respectively. Mammals, exhibit vast diversity in shape as compared to other amniotic vertebrates - a bat differs greatly from a whale. Even terrestrial mammals show great variation in shape amongst themselves. For example, a rat differs greatly from a giraffe.

Mammals are the only animal group that evolved to live on land and then back to live in the ocean. Whales, dolphins, and porpoises have all adapted from land-dwelling creatures to a life of swimming and reproducing in the water. Thus, Mammals have evolved specialised features to inhabit all types of environments: terrestrial, aquatic and aerial and so are now a hugely successful and diverse group.

In the forthcoming sections of the present unit we will be giving you the complete classification of extant mammals upto the level of order, based on their distinguishing features. In this unit we have followed the "classification of mammals", given by Wilson and Reeder in 2005. Wilson and Reeder have given their classification of mammals on the basis of phylogenetic analysis of DNA sequences of various mammals and have recognised 29 living

mammalian orders which include: i) one monotreme order, ii) seven marsupial orders, and iii) 21 placental orders. Phylogenetic analysis of DNA sequences has led to several changes in the classical mammalian classification. For example, the former order Insectivora has now on the basis of analysis DNA sequences analysis been found to be polyphyletic and so its members are now placed in three different orders namely, Afrosoricida, Soricomorpha, and Erinaceomorpha, in accordance to Wilson and Reeder classification.

18.4 CLASSIFICATION CLASS MAMMALIA

You will recall from the earlier unit (Unit 17) that Mammals are placed in Class Mammalia and have evolved several specialised features which are unique to them and a number of features that are similar to the other classes of amniotic vertebrates.

In the present section we will be studying the classification of mammals upto the level of order, as given by Wilson and Reeder in 2005.

Class Mammalia includes about 5488 living species and many extinct ones. Traditionally the Class Mammalia has been divided into three subclasses (Fig.17.21), which are as follows:

1. **Allotheria (multituberculates):** which have become extinct. Fossil forms of Allotheria have been found from the sediments of the Jurassic age. Members of this group were highly specialised and their teeth pattern indicates that they were herbivorous. We **will not be studying this subclass in the present unit as we will be dealing only with the classification of extant mammals**;
2. **Prototheria:** which include the monotremes (egg-laying mammals); and
3. **Theria:** consisting of marsupials or pouched mammals (metatherians) that give birth to live but relatively altrical young ones and placental mammals (eutherians).with well-developed placenta that give birth to live, precocial, young ones.

   In the present unit only the two Subclasses of Class Mammalia namely 1) Subclass Prototheria; and 2) Subclass Theria, both of which contain extant mammals are discussed.

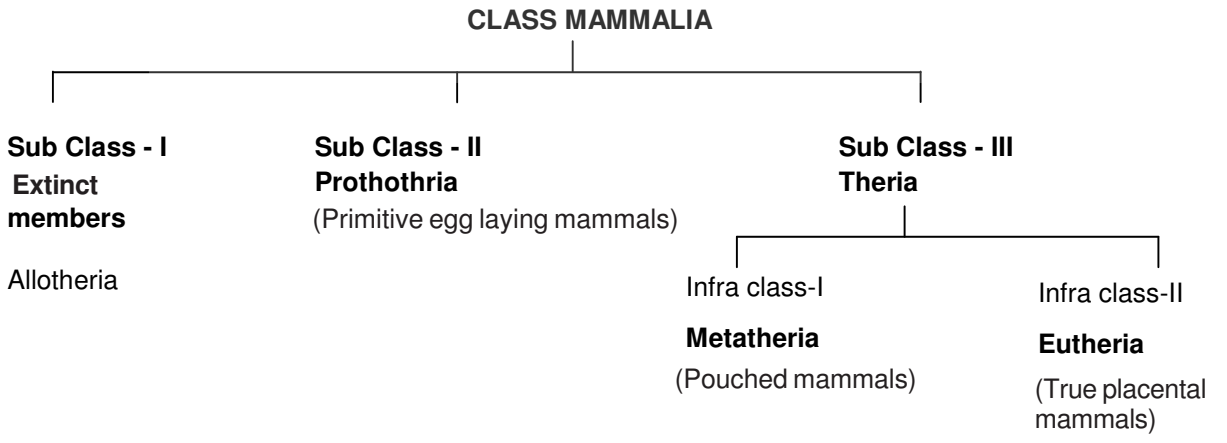


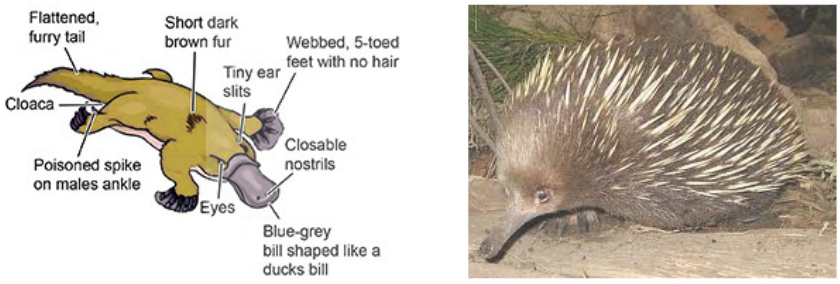
Fig. 18.5 : Class Mammalia is divided into three Subclasses of which in one the mammals are extinct. The other two subclasses consist of extant mammals.

18.5 SUBCLASS PROTOTHERIA

Monotremes belong to Subclass Prototheria (^pro-toe-thiree-a) and include the mammals namely, platypus and echidnas.

18.5.1 Characteristic Features of Subclass Prototheria

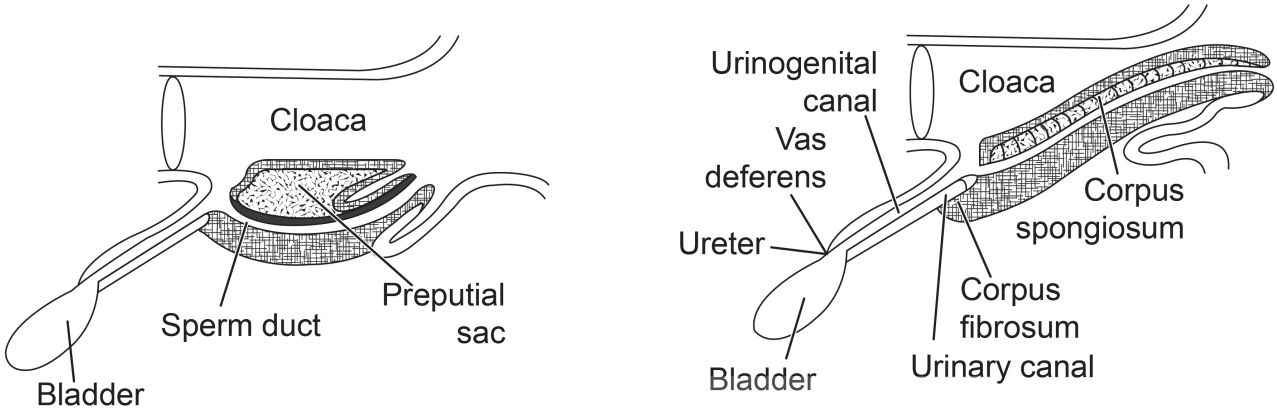
1. The monotremes (Fig.18.6 both a and b) differ from other mammal as they share some features of birds and reptiles. Similar to birds they are oviparous and so lay eggs and also incubate them.



(a) (b)

Fig 18.6: Monotremes: a) A Platypus; b) An Echidna.

2. The primitive reptile like, egg-laying (oviparous) monotremes produce large, cleidoic and macrolecithal (also called polylecithal: full of yolk) eggs.
3. Mammary glands are present in monotremes but teats are absent. The tubular mammary glands open outside in shallow depressions on the ventral side of the body.
4. Milk is secreted by mother onto the abdominal fur in the platypus or into a temporary pouch in echidna and licked off the skin by the young ones.
5. Teeth in echidnas are absent in all stages of development. In Platypus teeth are only present only in the embryonic stage. The adult platypus and echidnas chew food with their tongue and bony plate which are present at the roof of the mouth in echidna while the platypus uses its roughened gums to chew food.
6. Monotremes have a birdlike skull with a rostrum (snout), which is elongated into a leathery beak or bill. The beak has receptors that can sense electromagnetic signals from the muscles of other animals enabling, them to however, detect their prey underwater or in a termite nest. The beak of monotremes, differs both in structure and function from the horny beak of birds.
7. The cerebrum of brain of monotremes is smooth and does not cover the cerebellum. Corpus callosum is absent in monotremes.
8. Ear pinna is absent in the egg-laying prototherians.
9. Fertilization in all mammals, including prototherians is internal.
10. Monotremes similar to reptiles have a single cloaca for their urinary, defaecatory, and reproductive systems. Thus, in monotremes both the excretory and reproductive tracts open into a single cloaca (Fig.18.7).



(a) (b)

Fig. 18.7: Showing the relationship between cloaca and urinogenitial sinus and penis of monotreme: a) Penis retracted; b) Penis protruded.

11. In monotremes the uterus(Fig.18.8 a) nourishes the eggs and produces a secretion that hardens to form a shell around each fertilised egg which helps to protect the egg protected.
12. In males an extensible penis (Fig.18.8 b) is present for depositing the sperms internally into the females and is similar to that of turtles. The penis is covered by a preputial sac. In monotremes only semen passes through the penis and urine is excreted through the cloaca (Refer again to Fig.18.7a and b).
13. Male prototherians have a hollow, horny, tarsal spur on each hind leg, which is internally connected to a crural gland and is seasonally active. In platypus the crural glands present in the leg spur contains poison which is used by them as a weapon. However, in male echidnas the crural gland contained in the spur of each hind leg, acts more like a scent gland and produces a waxy secretion which enables them to mark their territory in order to deter their peers.
14. Monotremes as you have studied in Unit 17, like most mammals possess seven cervical vertebrae. They have the epipubic bones also called epipubic that come up from the pelvis along the ventral surface.
15. The pectoral girdle of monotremes as you have studied earlier, is reptilian-like with distinct coracoids bones and a T-shaped interclavicle bone.
16. Pelvic girdle of monotremes is mammal-like.
17. Prototherians, similar to other mammals have a four chambered heart and an unpaired aortic arch. RBCs in prototherians are non-nucleated.
18. Body temperature in monotremes varies between 25–28°C.
19. Tail in monotremes may or may not be present.

18.5.2 Infraclass Ornithodelphia (Ornee-tho-del-fee-aa)

All monotremes are grouped in infraclass Ornithodelphia and consists of only one Order, Monotremata.

18.5.3 Order Monotremata

Members of this order include platypus and echidnas which are all oviparous and occur only in Australia and New Guinea. Order Monotremata consists of two genera: I) Genus *Ornithorhynchus* (Platypus) and II) Genus *Tachyglossus* (Echidna).

i) Genus *Ornithorhynchus* which consists of only one species the *Ornithorhynchus* anatinus which is commonly referred to as duck-billed mole or platypus/(Rere again to Fig. 18.6a). The Distinguishing features of a platypus are a streamlined body with a broad bill and flat tail, short limbs with webbed feet; dense dark brown to reddish brown fur. Platypus is best described as a mixture of duck (bill and webbed feet), beaver (tail) and otter (body and fur) Males are venomous as they have paired spurs present on the heels of each of they rear feet that contains the venom. Platypus mates are thus able to deliver a strong toxic blow the vendom.

ii) Genus Tachyglossus commony referred to as echidna or spiny anteater (Fig. 18.6b) consists of four species. Echidnas have a long narrow snout, dapted for feeding on ants which are their chief food.

18.6 SUBCLASS THERIA

Members of Subclass Theria (^ thireea) are considered to be modern mammals. The Characteristic features of Subclass Theria are as follows:

18.6.1 Characteristic Features of Subclass Theria

1. Therians are viviparous and give birth to young ones
2. Ear pinna is present.
3. Mammary glands are provided with nipples or teats
4. The ureters open directly into a urinary bladder.
5. Uterus and vagina are present in the females.
6. Male testes are located in the scrotum.
7. Placenta is present in females.

The Subclass Theria has been further divided into two infraclasses :(I) Metatheria, comprising of marsupials and (II)Eutheria.

18.7 INFRACLASS METATHERIA (^META-THEE-REE-AA)

Examples: Kangaroos, Wallabies, Koalas and Possums.

Characteristic features

The distinguishing characteristics of mammals belonging to Infraclass Metatheria are as follows:

1. Mammals of infraclass Metatheria are termed as marsupials.
2. The female reproductive system of the marsupial females have 2 vaginas, and 2 uteri. Marsupials males have a well developed, bifurcated

penis (Fig. 18.9 b) The two ends of the bifurcated penis correspond to the two lateral vaginas of the females.

Fig. 18.9: Young ones of Metatheria (Opossum) being nursed by the mother within her marsupial pouch.

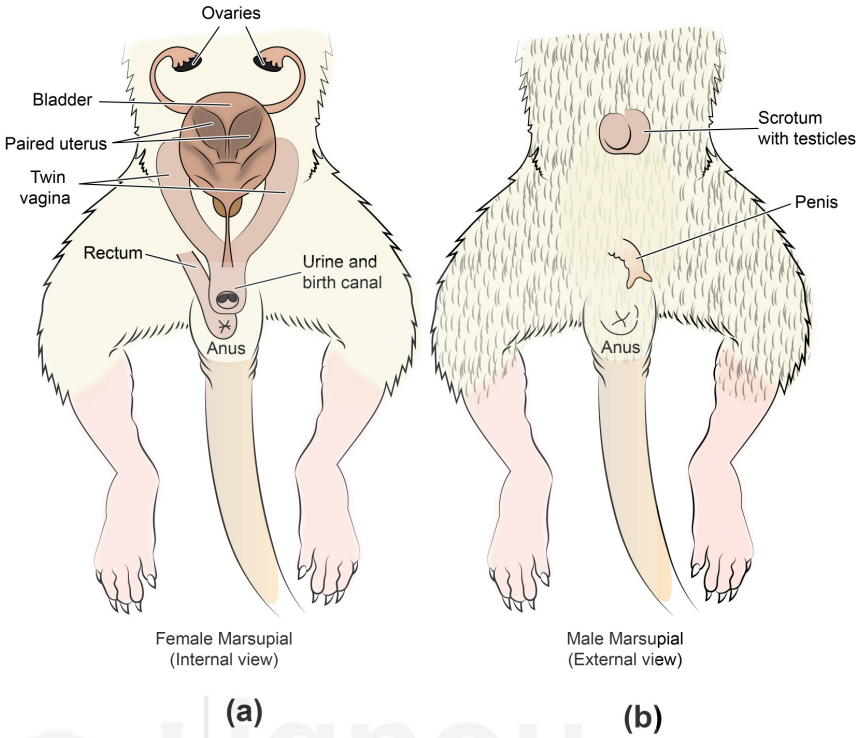


Fig. 18.8: Reproductive system of marsupials: a) Internal view of the reproductive system of a female marsupial; and b) External view of the reproductive system of a marsupial.

3. Metatherians are viviparous mammals with primitive placenta.
4. Most of these mammals have a pouch called marsupium which is present on their abdomen and within which their immature young ones develop.
5. Marsupials give birth to altrical young ones which are born in an undeveloped state and require care and feeding by the parents after a relatively brief gestation (period of embryo development within the mother's body) period, when compared to placental mammals
6. The young ones of marsupials are called joeys and are born early. They are often carried in a marsupial pouch on the mother's belly and complete their further embryonic development outside the mother's body while being nursed by the mother (Figs.18.9 and 18.10).The young ones of the red kangaroo, for example, are born just 33 days after fertilization and are about the size of a honeybee. Their back legs are merely like buds but the front legs are strong enough for them crawl from the exit of their mother's reproductive tract to a pouch that opens to the front of the mother's body. This journey up to the front of the mother's body lasts a few minutes. In other species such as in greater bilbies, the marsupium opens to the rear of the mother's body as this type of marsupium in greater bilbies protects the young when their mother needs to burrow in the dirt.
7. More than 44 teeth present are present in the metatheria mammals.
8. Corpus callosum is small or absent in marsupials.

SAQ 1

1. Match the group of animals given in Column A with their feature given in Column B:

	Column A		Column B
i)	Anapsids	a)	erect gait
ii)	Early synapsids	b)	presence of a secondary palate
iii)	Therapsids	c)	Most common amniote in the Permian period
iv)	Cynodonts	d)	Single pair of temporal openings in the skull
v)	Pelycosaurs	e)	Skull without an opening in the temporal region of the skull behind the eye orbit

2. In the following statements choose the correct option from the parenthesis:
   i) Teeth of mammals are (homodont/heterodont).
   ii) Synapsid skull has a (single/double) pairs of temporal openings.
   iii) Pelycosaurs have a (synapsid/diapsid) skull.
   iv) Cynodonts developed (homodont/heterodont) teeth.
   v) The Mesozoic era was dominated by mammals/reptiles.
   vi) Early synapids are considered to be mammalian/non-mammalian.
3. Which among the following mammalian group are primitive and have both reptilian as well as mammalian characters?
   i) Platypus
   ii) Cat
   iii) Monkey
   iv) None of the above.
4. In the following statements choose the correct option from the alternatives provided in the parenthesis:
   i) The subclass Theria is classified into 2 (Infraclass/Orders).
   ii) Metatheria includes the (Monotremes/Marsupials).
   iii) Mammary glands are provided with teats in (Marsupials/ Monotremes).
   iv) Platypus are (oviparous/viviparous).
   v) Females of infraclass Metatheria have (one/two vaginas).

18.7.1 Orders of Infraclass Metatheria

1. Order Didelphimorphia (^die-del-fee-morphee-aa) – Example: American Opossums

Didelphimorphia means an animal with two uteri (sing: uterus) or wombs. However all marsupials have two uteri. Most didelphids but not all, have an abdominal pouch or marsupium, in which the mothers rear their young. Opossums (Fig. 18.10 a) have a prehensile tail which can curl around things and hold onto them. Majority of didelphids species are

found in Central and South America, but one species, the Virginia opossum, *Didelphis virginiana* is widespread in North America. Total numbers of species in this order are 87.

2. **Order Paucituberculata (^pausee-tuber-cue-lataa) - Example: shrew opossum.**

   This order consists of six species of small, shrew-like marsupials called, shrew opossums (Fig. 18.10 b), which are about the size of a rat. Shrew opossums are mostly carnivorous and eat insects, earthworms and small vertebrates. Females of this order lack a pouch. Members of this order live in Western South America.

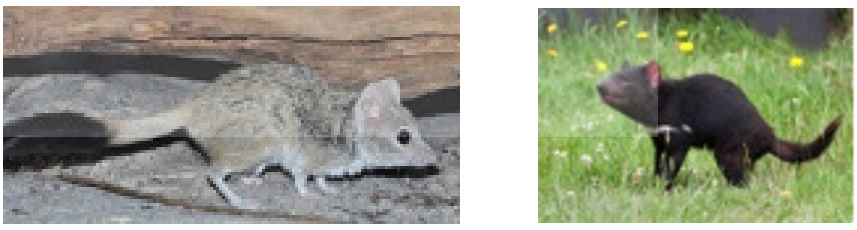
3. **Order Microbiotheria (^micro-bio-thee-ree- aa) - Example: Monitos del monte.**

   This order includes one extant species (Fig.18.10 c) called *Dromiciops gliroides* which is commonly referred to as called Monitos del monte or little mountain monkey. Monitos del monte is a mouse-sized, semi-arboreal, South American marsupial that scientists believe is more closely related to Australian marsupials. It has a prehensile tail, brown fur, short, round ears and black rings around its eyes.

(a) (b) (c)

Fig. 18.10: Representative member of marsupials: a) Virginia Opossum of Order Didelphimorphia; b) Shrew opossum of Order Paucituberculata; and c) A Monitos del monte of Order Microbiotheria.

4. **Order Dasyuromorphia (^dasee-euro-morfee-aa) -** Examples: brush-tailed marsupial rat (Fig.18.11 a), Tasmanian devil (Fig.18.11 b) and a number of small marsupials “mice” This order contains the carnivorous, Australian marsup ial mammals. There are 71 species in this order, all of which are confined to Australia, Tasmania and New Guinea.



(a) (b)

Fig. 18.11: Representatives members of Order Dasyuromorphia: a) The kowari (*Dasyuroides byrnei*), also known as the brush-tailed marsupial rat; and b) Tasmanian devil. (*Saxcophilus harrusii*)

5. **Order Peramelemorphia (^peraa-mel-ee-morfee-aa) - Examples: Bandicoots (Fig. 18.12a i) and bilbies (Fig. 18.12a ii).**

   Peramelemorphians are terrestrial, rodent like marsupials with small, compact bodies, pointed heads and strong front claws. The pouch of these mammals opens from the back. Similar to placentals mammals

this group has a chorioallantoic placenta and a relatively high rate of reproduction. There are 22 species in this order, all of which are confined to Australia, Tasmania and New Guinea.

6. Order Notoryctemorphia (^noto-rik-tee-mor-fee-aa) - Example: marsupial moles.

This order of metatherians contains two species of marsupial moles namely the southern marsupial mole and the northern marsupial mole, both of which live in the deserts of Western Australia. Members of this order look very similar to the eutherian golden moles in size and shape, and in the silky, iridescent (sparkling) texture and appearance of their fur (Fig.18.12 b). The marsupial moles have vestigial, non functional blind eyes that lack both lens and pupil. Furthermore, their fore claws are modified to be like miniature spades, as the third and fourth digits of the forefeet are greatly enlarged and bear enormous triangular claws.

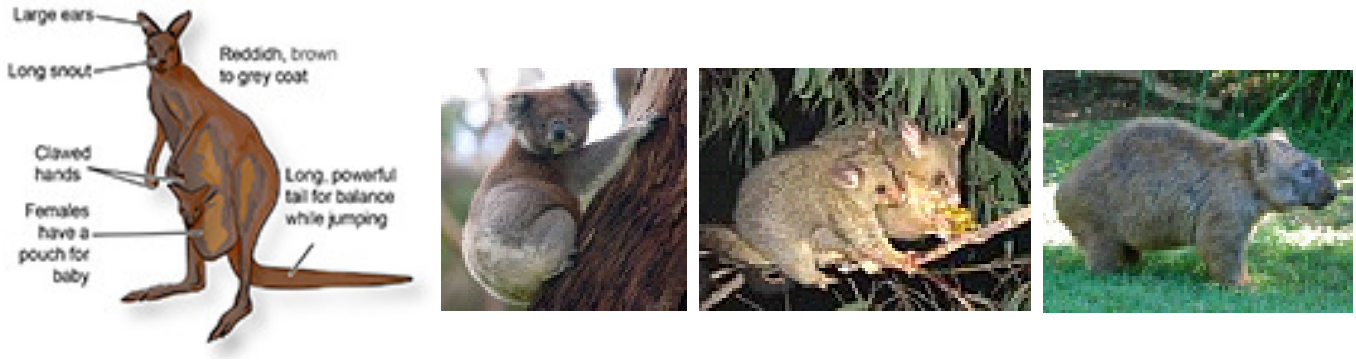
(a.i) (a.ii) (b)

Fig. 18.12: Representatives members of marsupials: a.i) An eastern barred bandicoot; a.ii) Bilby, both of which belong to Order Peramelemorphia; b) A marsupial mole which belongs to Order Notoryctemorphia.

7. Order Diprotodontia (^dipro-to-don-shee-aa) - Examples: kangaroos (Fig.18.13.a), koalas(Fig.18.13 b), Common brush tail possum (Fig.18.13 c), wombats (Fig.18.15 d) and wallabies etc.

Order Diprotodontia consists of the largest number of diverse marsupials. The order has 143 species which are found in Australia, Tasmania, and New Guinea and several islands of the East Indies. The two defining feature of diprotodonts are: 1) the dentition of the lower jaw, in which only two developed incisor teeth are present at the front of the lower jaw. This arrangement is known as diprotodonty (meaning two first teeth); and 2) the syndactyly (fused fingers), in which the second and third toes on the hind feet of diprotodonts are fused together (Fig. 18.14).

Fig.18.14: Showing syndactyly, in which the second and third digits of the feet of the hind limbs except for the claw are completely fused together.



(a) (b) (c) (d)

Fig.18.13: A few representative members of Order Diprotodontia belonging to Metatheria: a) A labelled figure of a Kangaroo; b) Koala bear; c) common brush tail possum and d) wombat.

18.8 INFRACLASS EUTHERIA

Infraclass Eutheria (^You-Thee-Ree-Aa) includes Examples: Squirrels, Whales, Elephants, Shrews, Armadillos, Dogs Cats, Sheep, Cattle Rabbits, Humans, Etc.

Eutherian mammals also referred to as placental mammals are placed in the infraclass Eutheria. The term "placental mammals" for eutherians is however, somewhat of a misnomer because marsupials also have a placenta which similar to eutherians is derived from the same membranes that surround the embryos in the amniote eggs of reptiles, birds, and monotremes. The difference is however, that the placenta of marsupials is very short-lived and does not make as much of a contribution to foetal nourishment as it does in the eutherians mammals. The distinguishing characteristics of mammals belonging to Infra class Eutheria are as follows:

Infraclass Eutheria: Characteristic Features

1. Most mammal species, including humans, are placed in the infraclass Eutheria.
2. Nearly 94% of all mammal species are eutherian mammals and are found on all continents, on land, in the air, and in the seas
3. Marsupium is absent in eutherian mammals and the number of teeth is limited to 44.
4. Corpus callosum is well-developed in eutherian mammals.
5. Mammary glands have well-developed teats.
6. Eutherian mammals, give birth to young ones which are usually born in a more advanced developmental state (precocial).
7. Eutherian mothers carry their unborn children within the uterus, where they are nourished and protected until an advanced stage of development is reached. This is made possible by the umbilical cord and the presence of an allanto – chorionic placenta which connects the foetus to the uterine wall and enables nutrients and oxygen to get to the offspring as well as provides a means of eliminating its waste. The placenta also functions as a barrier to keep the blood cells and other components of the immune systems of the mother and her foetus separate in order to prevent their destruction.
8. All eutherian mammals bear well-developed, live, young ones, except for giant pandas which produce babies that are born at only 1/4 the size, from the general predicted pattern for placental mammal.
9. All extant eutherians lack the paired epipubic bones (which are a pair of bones that project forward from the pelvic bones. Epipubic bones are present however, in monotremes and marsupials
10. Placental mammals have been extremely successful in competing against the monotremes and marsupials for ecological niches due to the fact that their babies are born more mature, which increases their chances of survival.

11. Eutherian mammals are a diverse group, with nearly 4000 described species, most of which belong to the orders rodents and bats.

12. Infraclass Eutherian has 19 orders.

18.8.1 Orders of Infraclass Eutheria

1. Order Afrosoricida (^afro-sorry see-daa) - Examples: Tenrecs (Fig. 18.15 a) and golden moles (Fig. 18.15 b).

Members of this order occur in Africa and Madagascar. They are small, insectivorous, placental mammals which appear to be quite diverse. However, they are all placed in the same order on the basis of having a cloaca (common opening for anal and urogenital tracts) and on the basis of genetic studies. This order has 51 species.

(a)

(b)

Fig. 18.15: Representative members of Eutheria, belonging to Order Afrosoricida: a) Tenrecs; and b) The Cape Golden mole, which is a small, blind, mammal that can only detect light and dark.

2. Order Macroscelidea (^macro- see-lidee-aa) - Example: Elephant shrews (Fig. 18.16a).

Order Macroscelidea consists of elephant shrews which are also called jumping shrews or sengis. Elephant shrews are small, insectivorous mammals with elongated snouts, long hind legs, big ears and eyes and a long, scaly tail. Their long hind legs make them very good jumpers. This Order has 15 living species which are widespread in Africa.

3. Order Tubulidentata (^tube-you-lee-dentaa-taa) - Example: Aardvarks.

This order consists of only one living species called, the “aardvark” which means “earth pig”, in Dutch. Aardvarks (Fig. 18.16 b) are native to Africa. They are pig-sized, nocturnal, burrowing, animals with a long pig-like snout, which is used to sniff out food. They have large rabbit-like ears, short legs, and long, flat, front claws which they use for digging out termites and ants from mounds. Aardvarks also have a very thick skin which protects them from the biting ants.

(a)

(b)

Fig.18.16: Representative members of Eutheria: a) A black rufous or elephant shrew which belongs to Order Macroscelidea; and b) An Aardvark which belongs to Order Tubulidentata.

4. Order Proboscidea (^pro bo-seedi-aa) - Example: Elephants

Order Proboscidea contains the elephants (Fig.18.17 a and b) which are strictly herbivorous and the largest of land living animals.Extinct members of this order include the Mastodons and mammoths. Both extinct and extant members have upper incisor teeth that emerge from the skull as tusks and have well-developed molar teeth. Extant elephants are distinguished by their enormous size and the presence of tusks, large pinna and long, muscular trunks formed from the upper lip and the nose. Order Proboscidea consists of two living species: 1) the African elephant (*Lonxodonta africana*); and 2) the Asian elephant (*Elphas maximus*) which is found in India, Nepal, and Southeast Asia.

(a) **(b)**

Fig. 18.17: Representative members of Order Proboscidea of Eutheria: a) An African bush elephant; b) An Asian elephant with her calf.

5. Order Hyracoidea (hi-ra-coidee-aa) - Example: Hyraxes (coneys) also called dassies.

This order has four extant species of hyraxes which are herbivores and are restricted to Africa and Syria. Hyraxes (Fig. 18.18 a) superficially resemble, short-eared rabbits in appearance and size but have tusk like upper incisor teeth that resemble the tusks of elephants rhinoceroses. They have short necks, round heads, short tails and three toes on their hind feet and five on their forefeet. Hyraxes have small hooves on the first and third digits of the hindfeet in which the middle digit is clawed. They also have rubbery pads on the ventral side of their feet. These pads are provided with numerous sweat glands. The feet are well adapted for running as their feet sweat. The feet of hyraxes are closely related to elephants and manatees. Hyraxes share numerous features with elephants, such as the shape of some of their bones, toenails, excellent hearing, sensitive pads on their feet, small tusks, good memory and high brain functions compared to other similar mammals.

6. Order Cingulata (^sin gu-laa-taa) - Example: Armadillos.

Order Cingulata contains the armadillos (Fig. 18.18 b) which are insectivorous in nature and are closely related to anteaters and sloths. They are odd looking, armoured creatures as the dorsal surface of their body is covered by armour, formed of osteodermal plates (plates of dermal bone).The dorsal armour, around the center of the body in the armadillos is arranged into bands of plates which are separated by soft skin. This enables the animal to bend its body. The number of bands is often a useful character in distinguishing between different armadillo

species. Armadillos have small peg-like teeth and generally eat termites and ants. Order Cingulata has 20 species which are found in South and Central America.

7. Order Scandentia (^scan-den-she-aa) - Example: Tree shrews.

Members of this order are generally referred to as tree shrews (Fig. 18.18 c) but despite their name, many are not well-adapted for an arboreal life. Some are almost totally terrestrial. Order Scandentia contains 20 species, all of which are native to the tropical rain forests of Southern and South eastern Asia.

(a) (b) (c)

Fig. 18.18: Representative members of Eutheria: a) A yellow-spotted Hyrax which belongs to the Order Hyracoidea; and b) A nine-banded Armadillo which belongs to the Order Cingulata; c) A common tree shrew belonging to Order Scandentia.

8. Order Sirenia (^sirenee-aa) - Examples: Dugongs and manatees (sea cows).

Order Sirenia, contains the sirenians which are fully aquatic, herbivorous mammals that inhabit swamps, rivers, estuaries, marine wetlands, and coastal marine waters. Members of order Sirenia (Fig. 18.19) are well-adapted to their aquatic environment and may be marine in nature or may live in fresh waters. Sirenians have a large head with two nostrils located on the top or at the front of a thick muzzle. Sirenians lack ear pinna.The forelimbs of members of this order are modified into flippers and the hindlimbs are absent in them. The tail of sirenians is horizontally flattened tail. This order has four extant species of which there is only one dugong species which occurs around the tropical coastlines of East Africa, Asia, and Australia. The remaining three are, species of manatees which are found in the Caribbean area, Florida area, Amazon River and in West Africa.

(a) (b)

Fig. 18.19: Representative members of Aquatic Eutherians: a) Dugong; b) Manatee, both of these belong to Order Sirenia.

9. Order Pilosa (^pillow-saa) - Example: Sloths and ant eaters.

Members of Order Pilosa are extremely hairy and consist of :1) sloths (Fig. 18.20 a) which are leaf-eaters, arboreal and spend the majority of their lives in trees; and 2) ant eaters (Fig. 18.20 b) which are toothless mammals and use their long tongues to feed on ants and termites. Order Pilosa has ten species which are all restricted to Central and South America.

(a) (b)

Fig. 18.20: Representative members of Eutheria belonging to Order Pilosa: a) A mother sloth with its baby; b) A giant ant eater.

10. Order Dermoptera (^der-mop-teraa) - Example: colugos or flying lemurs or cobegos.

Members of this order are not true lemurs (which are primates) despite their resemblance to them. They are related to true bats and are the size of a domestic cat. Flying lemurs (Fig. 18.21a) are arboreal and cannot fly, instead they glide like flying squirrels due to the attachment of a skin fold called the patagium which is attached from behind the neck and extends to the two pairs of limbs till the tail end. Colugos have webbed fingers and toes. Order Dermoptera consist of a single genus which has two species both, of which occur in the Malay Peninsula in the East Indies.

11. Order Pholidota (^folly-doe-taa) - Example: Pangolins (Spiny ant eaters).

Order Pholidota consists of eight living species of pangolins (Fig.18.21 b) which are nocturnal and insectivorous and occur in tropical Asia and Africa.The body of the pangolin except for its face and belly is covered with overlapping, large scales formed from fused bundles of hair. Pangolins have a slender and an extraordinarily long and muscular tongue which when extruded can be longer than the animal's head and body. They lack teeth and their diet consists mostly of various species of ants and termites. Pangolins tend to eat only one or two species of insects, even when many other species are also available to them.

(a) (b)

Fig.18.21: Representative members of Eutheria: a) A Flying lemur (Colugo) belonging to the Order Dermoptera; b) A Pangolin which belongs to the Order Pholidota.

12. Order Lagomorpha (^lego-mor-faa) - Examples: Rabbits, Hares and Pikas.

Lagomorphs are small to medium-sized herbivorous animals and resemble large rodents because similar to them they are characterised by the presence of four, constantly growing upper incisors. However they differ from rodents as rodents have a pair of incisors on both the lower and upper jaw**.** Rabbits (Fig. 18.22 a) and hares, characteristically have long ears, a short tail, and strong hind limbs that enable them, to jump high. In contrast, the pikas (Fig. 18.22 b) are smaller, have shorter, rounded ears, no external tail, and less developed hind limbs so they can only scamper. Order Lagomorpha has 92 species all of are cosmopolitan in distribution.

(a)

(b)

Fig. 18.22: Representative members of Eutheria of Order Lagomorpha: a) Rabbit; b) Pika.

13. Order Rodentia (row-den-she-aa) - Examples: squirrels, mice (Fig.18.23 a), gerbils (Fig. 18.23 b), rats and woodchucks etc.

This order includes small, gnawing (biting or chewing continuously with the teeth) mammals that are characterised by two pairs of chisel-like incisors that grow throughout their life and are adapted for gnawing. Canines are absent in rodents due to which a toothless gap called diastema is present in the jaw. Most rodents are herbivores. Order Rodentia has the maximum number and of species among all orders of mammals. They make up almost half of the entire mammal species. There are 2277 species in this order.

(a)

(b)

Fig. 18.23: Representative members of Order Rodentia: a) An eastern spiny mouse; b) A wild gerbil.

14. Order Soricomorpha (sor' i-co-mor'-faa) - Examples: True shrews and moles.

Soricomorphs (Fig. 18.24 a and b) are among the smallest mammals and are sharp-snouted. They feed mainly on small invertebrates and live most of their lives underground or undercover. There are 428 species in this order, all of which are found worldwide but are absent in New Zealand and Australia.

(a) (b)

Fig. 18.24: Representative members of Order Soricomorphia: a) Pen-tailed tree shrew; and b) a European Mole.

15. Order Erinaceomorpha (^Erinaa-see-o-morfa) - Examples: hedgehogs and Gymnures (moon rats).

Order Erinaceomorpha contains 24 species of hedgehogs (Fig.18.25 a) and Gymnures (Fig.18.25 b). Hedgehogs are burrowers. They are nocturnal and omnivorous mammals and occur in Eurasia and Africa. The upper body and flanks of hedgehogs are covered with numerous hairs which are modified into sharp spines that form a protective covering over them. Many species of hedgehogs can roll up into a ball, hiding all vulnerable areas of the body under the protective spines. The Gymnures are larger than hedgehogs. They however, lack spines, have normal hair and resemble shrews due to their long snouts and short tails. Gymnures are found in South East Asia. Anal scent gland is present in most erinaceomorphs and is more developed in gymnures due to which they often have a powerful odour.

(a) (b)

Fig. 18.25: Representative members of Eutheria of Order Erinaceomorpha a) A Hedgehog; b) A Gymnure.

SAQ 2

1. Match the name of the animals given in Column A with its Order given in Column B:

	Column A		Column B
i)	Tasmanian devil	a)	Lagomorpha
ii)	Dugong	b)	Soricomorpha
iii)	Tenrec	c)	Rodentia
iv)	Gerbil	d)	Afrosoricida
v)	Rabbit	e)	Dasyuromorphia
vi)	Sloth	f)	Pilosa
vii)	True shrew	g)	Erinaceomorpha
viii)	Hedgehog	h)	Sirenia

2. Which of the following Order has the largest number of species?

   i) Dermoptera

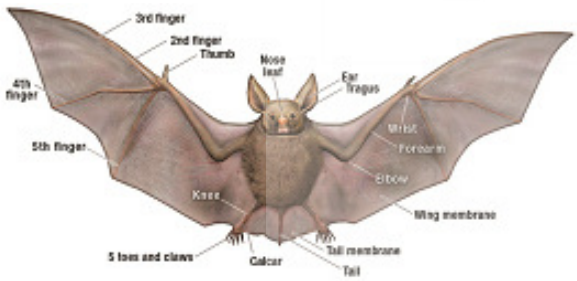
   ii) Rodentia

   iii) Pholidota

   iv) Cingulata

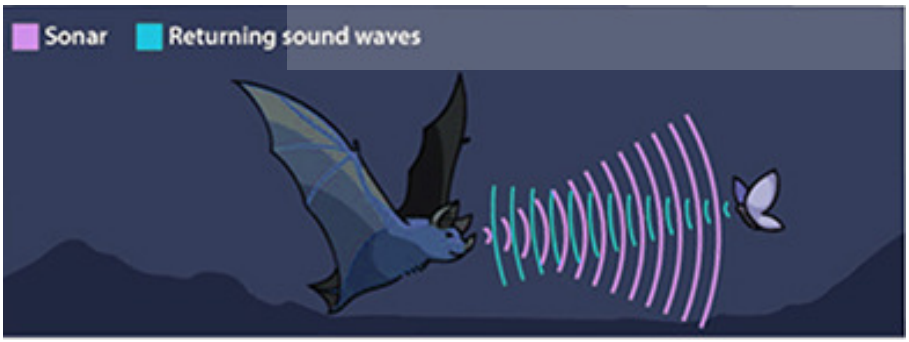
16. Order Chiroptera (cairop+teraa) - Example: Bats

Bats, belonging to this order are the only true flying mammals (Fig. 18.26 a and b). The wings of bats (Fig. 18.26 a) are formed by the modification of their forelimbs, in which the second to fifth digits are elongated to support a thin integument (skin) membrane that enables them to fly. The first digit forms the thumb and is provided with a claw. Bats have small, sharp teeth. Eyes are poorly developed in most bats and they mostly rely on echolocation for locating and identifying objects (Fig. 18.27 c). During echolocation bats produces sound waves (sonar waves) of 50,000 cycles/sec frequency by using their nose or mouth. When these sound waves strike the objects and return back as an echo the bats are able judge and analyse the reflected sounds and so can accurately identify and predict the distance of the objects. Most of the bats are nocturnal insect-eaters while the rest are frugivores (fruit eaters). A few species of bats like the vampire bats are haematophagous as they feed on blood of animals. Order Chiroptera consists of about 1,240 bat species. Bats occur worldwide including New Zealand but are absent in the Antarctica.



(a)

(b)



(c)

Fig. 18.26: Bats belong to Order Chiroptera: a) a labelled diagram of a fruit bat; b) photograph of bats called Indian flying foxes; and c) a bat finding and identifying its prey by echolocation.

17. Order Carnivora (^car-nee-vo-raa) - Examples: Terrestrial members namely, Dog Family, Cat Family, Bears, Raccoons, Skunks, Badgers, Civets, Mongooses and Hyenas,Otters etc. Marine Aquatic members namely Sea Lions, Seals, Walruses, Weasels etc.

This order includes meat eating mammals which are also referred to as carnivores. The word “carnivore” which is often popularly applied to members of this group is a term which is used for any meat-eating organism. Carnivores are the most diverse in size. Carnivores have jaws that can only move vertically, or up and down and most of them have sharp, pointed canines and well-developed cheek teeth (premolars, and molars) that generally have cutting edges which help them tear meat. Most carnivores have strong, well-developed sharp claws, typically with five, but never fewer than four toes on each foot. Pinna may or may not be present in members of this order. This order includes both 1) terrestrial carnivores (Fig. 18.27 a i and ii) such as cats, dogs, dingos, wolves, cats, bears, weasels, and 2) the highly specialised group of marine, carnivores, called pinnipeds (Fig. 18.27 b i and ii) such as seals, sea lions, walruses seals and sea otters. The body of pinnipeds is usually insulated with a thick layer of fat called blubber and is typically covered with hair. The feet digits are not separate, in them but are connected by a thick web that forms flippers for swimming. Thus, the forelimbs and hindlimbs in pinnipeds are transformed into paddles which enable them to dive in the water at great depths.

Some carnivores, such as cats and pinnipeds, depend entirely on meat for their nutrition. Others, such as raccoons and bears, are more omnivorous, depending on the habitat. The giant panda is largely a herbivore, but also feeds on fish, eggs, insects and seals. Carnivores are distributed across the world in all oceans and on all major land masses except possibly in Australia, where the only terrestrial member dingos (*Canis lupus*), are present and which may have been brought in by humans. Order Carnivora has 280 species.

(i) (ii)

(a)

(i) (ii)

(b)

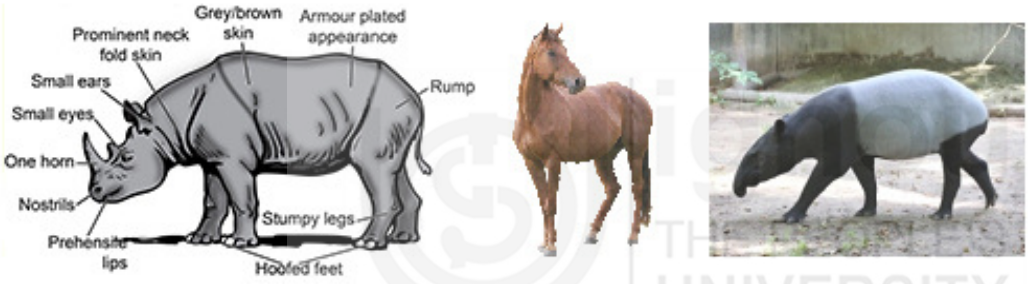
Fig. 18.27: Some members of Eutheria of Order Carnivora- a) terrestrial members: i) Brown Bear; ii) Tiger; and b) Marine members; i) A harbor seal; ii) A walrus with its long tusks which are actually elongated canines, and are present in both male and female walruses but are slightly longer and thicker among males.

18. Order Perissodactyla (^peris-so-dack-tile-aa) - Examples: horses, asses, zebras, tapirs, rhinoceroses.

Members of this order are herbivorous, odd-toed and hoofed mammals. The number of toes in each foot may be one or three and are covered by a keratinized hoof (Fig.18.28). Species of genus *Equus* consist of horses (Fig. 18.29 a), asses and zebras, all of which have only one functional toe, The rhinoceros (Fig. 18.29 b) has three toes and also has one or two horns which are not actually true horns as they are composed of keratin. The Rhinoceros also has a thick (1.5-5 cm) protective skin formed from layers of collagen (structural protein). There are five species of rhinoceros, two African and three Asian.

Fig.18.28: Foot of a horse, showing its one(odd number) functional toe which is in the form of a keratinized hoof.

The African species: 1) are the white; and 2) black rhinoceroses, and both species have two horns. The Asian rhinoceros are: 1) The great one-horned rhinoceros; and 2) the Java rhinoceros, both of which have one horn. The third Asian rhinocerose; 3) the Sumatran rhinoceros, has two horns and is also called hairy rhinoceros or Asian two horned rhinoceros. Tapirs (Fig. 18.29 c) are also placed in this order. There are 17 species in Order Perissodactyla.



(a) (b) (c)

Fig. 18:29: Some members of Eutheria of Order Perissodactyla a) A labelled diagram of a one horned Indian rhinoceros; b) A horse; and c) a Tapir.

19. Order Artiodactyla (^aartee-o-dak-tile) - Examples : Pigs (swines) Hippopotamus, Giraffes, Camels, Moose, Goats, Bison, Deer and their allies.

Members of order Artiodactyla are even-toed, with feet having two (Fig. 18.30), or four toes, each of which are sheathed in a keratinized hoof. Mammals of this order range in size from the 4000 kg like the hippopotamuses (Fig. 18.31 a), to the 2 kg "lesser Malay mouse deer". In artiodactyls incisors and canines are absent in upper jaw. Many artiodactyls, such as cattle (Fig. 18.31 b) and sheep, have horns while deer have antlers (Fig. 18.31 c), Many are ruminants. Most are strictly herbivores, but some species, such as pigs, are omnivorous. This order consists of 210 species, all of which are native to every continent, excluding Australia and Antarctica.

Fig. 18.30: Two toes of an Artiodactyl

20. Order Cetacea (^Seat-aa- See-aa) - Examples: Whales, Narwhals, Dolphins and Porpoises.

This Order consists of aquatic mammals (Figs.18:32 a and b) which have a fusiform, or streamlined body with a laterally flattened tail that ends in a

(a) (b) (c)

Fig.18:31: Some members of Eutheria of Order Artiodactyla: a) A Hippopotamus that has four toes; b) A cow which has two toes and a pair of horns; c) A white tailed, thus, male deer(called stag or buck) with antlers.

horizontal fluke. Thus, the end of the tail has two lobes separated by a deep notch. The anterior limbs of cetaceans are modified into paddle-shaped flippers while their hindlimbs are absent and vestigial, being located within the body. In these mammals the external nostrils or nares are present and are represented by a single or double blowhole on top of the head. Hairs are present in cetaceans but are limited to a few at the muzzle (snout). Like most mammals, cetaceans have mammary glands and females give birth to live young and feed them milk. All members of this order have a thick, subcutaneous, blubber layer filled with fat and oil. Cetaceans inhabit all of the world's oceans, as well as some freshwater lakes and rivers in South America, North America, and Asia. Other cetaceans live in brackish waters of estuaries and coastal marshes. There are 84 species in this order.

(a) (b)

Fig. 18.32: Representative members of Eutheria of Order Cetacea: a) A Dusky Dolphin; b) A Blue whale.

21. Order Primate (^pry-mates) - Examples: Lemurs, Aya-Aye, Lorises, Pottos, Bush Babies, monkeys, marmosets, apes, gibbons, gorillas, chimpanzees, orangutans and humans etc. (Fig. 18.33 a and b)

Members of order Primate are characterised by a large brain with well-developed cerebral cortex as compared to other mammals. The skull of primates are distinguishable from the skulls of other animals partly because their eye sockets are protected by a bony bar or the eye sockets are fully enclosed by bone. The sense of sight in primate species is the dominant sensory system. Primates have front facing, large eyes and well-developed vision that give them both binocular vision and stereoscopic vision as compared to mammals of other orders in which the sense of smell is the dominant sensory system. Among primates the brain and binocular vision are more developed in humans, monkeys and apes and noticeably less so in lorises and

lemurs. Most primate species are arboreal with grasping hands. Some primates including humans, a few great apes and baboons are primarily terrestrial rather than arboreal. However, all species possess adaptations for climbing trees. All primates except humans and apes have tails and most have opposable thumbs (thumbs that can be moved around to touch the other fingers) which thus enable them to grasp things. Primate adults may live in solitude or in mated pairs, or in groups of up to hundreds of members.

The Order Primate, according to cladists is a monophyletic clade and has 376 species. It is divided into two distinct suborders (Fig.18.33 and 18.34).

22) **Suborder Strepsirrhini (older term-Prosimii) (Fig. 18.33 (a) and Fig. 18.34)**. In this suborder the comma-shaped nostrils of the primates are surrounded by a wet, naked region called the rhinarium. Members of this suborder have a long, non-prehensile tail, and their second toe is provided with a claw. Lemurs, aye-aye, lorises, pottos and bush babies belong to this suborder. Strepsirrhini primates tend to have a more pointed, almost dog-like snout rather than the flatter faces of their Haplorrhini cousins, and are thought to be most similar in appearance to the first primates. Cladists have recently proposed that the suborder Strepsirrhini, split off from the primitive primate line about 63 mya.

(a) (b)

Fig.18.33: Distinguishing features of skulls between Suborders: a) Strepsirrhini; and b) Haplorhini and some representative members of each suborder.

23) **Suborder Haplorhini (older term-Anthropoidea) (Fig. 18.33 b and 18.34)**. In this suborder the primates have dry, hairy noses and ringed nostrils. Primates of this suborder also differ in skull morphology from suborder strepsirhini. This suborder contains the tarsiers, marmosets, New and Old World monkeys, gibbons, gorilla, chimpanzees, orangutan and humans etc. New World Monkeys are sometimes called platyrrhine monkeys because their nostrils are widely separated.

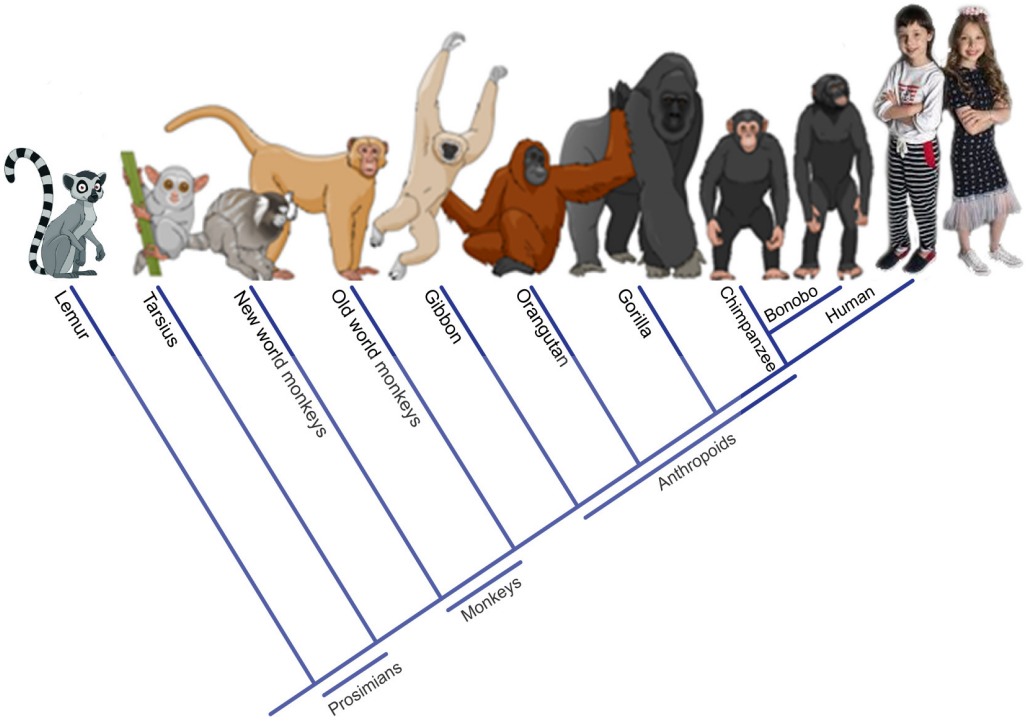


Fig 18.34: Showing the tree of life of Order Primates which are separated into two Suborders: 1) The Strepsirrhini or Strepsirhini, or wet nose primates, which includes lemurs, aye-ayes, lorises etc.; and 2) The Haplorhini or dry nose primates, which include monkeys, apes, humans, and tarsiers etc.

SAQ 3

1. Which of the following animals belongs to the order Perissodactyla?

   i) Zebra

   ii) Horse

   iii) Rhino

   iv) All of the above

2. Match the name of the animal given in Column A with its area of occurrence given in Column B:

	Column A		Column B
i)	Hairy two horned rhinoceros	a)	Africa
ii)	Zebra	b)	Deserts of Western Australia
iii)	Marsupial mole	c)	North America
iv)	Virginia opossum	d)	South America
v)	Monitos del monte	e)	Sumatra

3. Identify and write the name of the suborder/orders on the basis of defining features given in the following statements:

   i) Primates which have dry, hairy noses, ringed nostrils belong to

Suborder…….. .

ii) Horses which are herbivorous, odd-toed and hoofed mammals, belong to the order…….. .

iii) Aquatic mammals with fusiform body, anterior limbs modified into paddle-shaped flippers. Hindlimbs externally absent and vestigial being located within the body. A laterally flattened tail present that ends in a horizontal fluke as the end of the tail has two lobes separated by a deep notch such mammals belong to order……

iv) Mammals which are even-toed with two or four toes, each sheathed in a keratinized hoof; lack incisiors and canines in the upper jaw and some of them have horns or antlers all belong to the order…….... .

v) Mammals that may be terrestrial or aquatic and have jaws that can only move vertically, or up and down. Most members with sharp, pointed canines and well-developed cheek teeth (premolars, and molars) that generally have cutting edges which help them tear meat. Most of them have strong, well developed sharp claws, typically with five, but never fewer than four, toes on each foot. Such mammals are placed in the order …….. .

vi) True flying mammals which mostly rely on echolocation for locating and identifying objects and in which wings are formed by the modification of their forelimbs, in which the second to fifth digits are elongated to support a thin membrane of skin that enables them to fly. Such mammals belong to the order…….. .

18.7 SUMMARY

1. Mammals have evolved from various ancestries and share various characteristics with their ancestors.
2. Mammals have several features similar, to Classes Reptilia and Aves but have several features which are unique only to them.
3. It is believed that mammals have evolved from reptiles, along with aves. Scientists believe on the basis of several evidences that mammalians have a reptilian ancestry. This view gets a stronger support from the fact that monotremes which are primitive mammals and extant reptiles have close resemblances in their anatomical features, including soft as well as hard parts.
4. Long before the arrival of the true mammals, a group of reptiles called Synapsida acquired many mammalian characteristics and lived through the Permian and Triassic periods.
5. The first major non-mammalian synapsid group consisted of pelycosaurs which were the most common amniotes in the Permian period and were both carnivores and herbivores and looked like lizards but were not closely related to them as they had a synapsids skull while lizards have a diapsid skull. Pelycosaurs were thus synapsids and not reptiles.

6. A group of carnivorous pelycosaurs gave rise to the therapsids which were the only synapsids that survived beyond the Paleozoic era.
7. Therapsids had a more erect gait (way of walking) and their limbs were positioned below the body rather, than at the sides. As a result, their body was raised from the ground. The raised body of this group of synapsids required better coordination of their muscles in order to maintain their gait. Maintenance of gait was achieved by the evolution of a larger cerebellum which is the region of the brain that is responsible for coordination.
8. A group of synapsid therapsids called the cynodonts, survived into the Mesozoic era and evolved several new features, which were mammal-like.
9. The cynodonts diversified in the Triassic and Jurassic periods and out of them one small carnivorous group, called trithelodontids though not true mammals resembled the mammals especially with reference to features of the skull and teeth.
10. The therapsids gave rise to the first mammals, in the late Triassic period which were contemporaries of Mesozoic reptiles such as pterosaurs, crocodiles and dinosaurs.
11. The first mammals were small; almost shrews sized and had a large brain case and diphyodont dentition (the teeth are replaced only once).
12. The first small mammals evolved over 220 million years ago from a therapsid ancestor.
13. Fossil remains mainly teeth and jaws, reveal very little about the first true mammals.
14. Early mammals were mostly tiny creatures no bigger than rats and mice, and insignificant. But they could still manage to survive by exploiting different ways of life from those practiced by contemporary gigantic reptilian enemies.
15. Early mammals were nocturnal and so avoided direct conflict and competition with the dominant, mostly diurnal reptiles. These early mammals were ground dwellers and lived in burrows or hid under vegetation. They were and herbivorous or carnivorous and had regulated high body temperature that is they were endothermic.
16. The early mammals had larger brain and superior sense of smell, compared to other groups of animals and had the ability to gain entry into nocturnal niches which helped them to be less exposed to predators. These mammals because of their larger brains and greater intelligence in comparison to all other groups of vertebrate developed the capacity to think, understand, analyse and most importantly reason each and every action of theirs and to learn from the previous experiences.
17. By the end of the Cretaceous period i.e. The Mesozoic Age, the vast majority of dominant reptiles became extinct. Many ecological niches were now left open to the mammals enabled them as a result to diversify and occupy diverse habitats. Present day mammals are widely distributed

and are found in all the continents and all the seas.

18. Class Mammalia has been divided into three Subclasses: i) Allotheria (multituberculates (extinct group); ii) Prototheria (extant group); and iii) Theria (extant group).

19. Members of Class Mammalia (**^mae-millia)** are characterised on the basis of the presence of hair, mammary glands, three ossicles in the middle ear and single dentary bone in the lower jaw.

20. Majority of the mammals except for monotremes are **viviparous**, meaning they produce live young instead of laying eggs. Monotremes lay eggs and so are oviparous.

21. Monotremes are placed in Subclass Prototheria and include the platypus and echidna which are extant mammals**.** The rest of the extant mammals are placed in the Subclass Theria which are divided into two Infraclasses: 1) **Infraclass Metatheria**, which includes both extant and extinct marsupial mammals. Marsupial mammals give birth to underdeveloped embryos, which post birth climb from the birth canal into a pouch on the front of the mother's body, where they feed and continue to grow. This group of mammals includes the kangaroos, wallabies, koalas and possums. 2) **Infraclass Eutheria,** which includes both extant and extinct placental mammals. These mammals give birth to fully developed embryos which develop in the mother's uterus, receiving nutrients across the placenta. Most mammals belong to this group and include humans, rabbits, squirrels, whales, elephants, shrews, armadillos, dogs cats, sheep, cattle and horses etc.

22. **Subclass Prototheria contains a single Order** Monotremata in which are placed the oviparous monotreme mammals, the duck-billed mole or platypus and echidnas.

23. **Subclass Metatheria contains 7 Orders** which are: 1) Didelphimorphia, 2) Paucituberculata, 3) Microbiotheria, 4) Dasyuromorphia, 5) Peramelemorphia, 6) Notoryctemorphia, 7) Diprotodontia.

24. **Subclass Eutheria contains 21 orders** which are as follows: 1) Afrosoricida 2) Macroscelidea 3) Tubulidentata, 4) Proboscidea, 5) Hyracoidea, 6) Sirenia, 7) Cingulata, 8) Pilosa, 9) Dermoptera 10) Scandentia, 11) Lagomorpha 12) Rodentia, 13) Soricomorpha, 14) Erinaceomorpha, 15) Chiroptera, 16) Pholidota 17) Carnivora, 18) Perissodactyla, 19) Artiodactyla, 20) Order Cetacea, 21) Order Primate.

18.8 TERMINAL QUESTIONS

1. What is the probable reptilian group from which mammals have evolved? Select the correct one from the names given in the brackets. (Crocodilia/ Lacertilia/Synapsida)

2. Which order among the three group of extant mammals are considered the primitive group of mammals?
3. Describe the main features of the therapsids.
4. What are the defining features of cynodonts?
5. Differentiate between Artiodactyla and Perissodactyla.
6. Give two distinguishing morphological features of the following orders:
   i) Cingulata
   ii) Sirenia
   iii) Primate

18.9 ANSWERS

Self-Assessment Questions

1. 1. i) e; ii) d; iii) a; iv) b; v) c
   2. i) heterodont; ii) single; iii) synapsid; iv) heterodont; v) reptiles; vi) non mammalian
   3. (i)
   4. i) Infraclass; ii) Marsupials; iii) Marsupials; iv) oviparous; v) 2
2. 1. i) e; ii) h; iii) d; iv) c; v) a; vi) f; vii) b; viii) g
   2. (ii)
3. 1. (iv)
   2. i) e; ii) a; iii) b; iv) c; v) d
   3. i) Haplorhini; ii) Perissodactyla; iii) Cetacea; iv) Artiodactyla; v) Carnivora; vi) Chiroptera

Terminal Questions

1. Synapsida
2. Order- Monotremata
3. Refer to Sub-section 18.2.1
4. Refer to Sub-section 18.2.2
5. Members of order Artiodactyla have even toed feet. Each feet would either have 2 or 4 toes that are covered in a keratinized hoof. Many artiodactyles like cattle have true horns. Most artiodactyles are herbivores except for pigs which are omnivores while. Deer have antlers. In comparison members of order perissodactyla are odd toed hoofed mammals with the feet having one or three toes covered by a keratinized hoof. Horses, assess and zebras are one toed while rhinoceros are three toed. Members in this order do not have antlers or true horns and the horn

present in rhinoceros is not a true horn. All members of order Perissodactyla are herbivorous.

6. i) Order Cingulata contains the insectivorous armadillos .1) They are odd looking, armoured creatures as the dorsal surface of their body is covered by armour, formed of osteodermal plates that form bands. The number of bands is often a useful character in distinguishing between different armadillo species, 2) Armadillos have small peg-like teeth and generally eat termites and ants.

   ii) Order Sirenia contains fully aquatic, herbivorous mammals that are well-adapted to their aquatic environment and may be marine in nature or may live in fresh waters. 1) Sirenians include the dugongs and manatee which have a large head, two nostrils located on the top or at the front of a thick muzzle and they lack ear pinna. 2) The forelimbs of sirenians are modified into flippers and the hindlimbs are absent in them. The tail of sirenians is horizontally flattened.

   iii) Members of order Primate are characterised by 1) a large brain, with well-developed cerebral cortex as compared to other mammals. 2) The skull of primates is distinguishable from the skulls of other mammals, partly because their eye sockets which are protected by a bony bar or are fully enclosed by bone 2) Primates have front facing large eyes and have wel-developed binocular and stereoscopic vision, as the sense of sight is the dominant sensory system in them.

GLOSSARY

Alveolus (plural, alveoli) : a small cavity such as the tiny air sac in the lung or sac of a compound gland, or the socket for a tooth.

Allantois : one of the extra embryonic membranes of the amniotes that functions in respiration and excretion in birds and reptiles and plays an important role in the development of placenta in most mammals. In most mommals it plays s important role in the development of the ante.

Amnion : the innermost extra embryonic membrane that forms a fluid filled sac around the embryo in amniotes.

Anus : the terminal opening of the gut.

Atrium : any main chamber; the principal receiving chamber of the heart; the large cavity containing the pharynx in tunicates and cephalochordates.

Canine : a pointed tooth located between incisors and premolars.

Chorion : outer layer of the double membrane that surrounds the embryo of reptiles, birds and mammals. In mammals it contributes to the formation of placenta.

Cloaca : the common chamber into which the gut, excretory tubes and reproductive tubes empty their contents.

Diaphragm : the domelike muscular partition between the abdominal and thoracic cavities in mammals which functions in inspiration and in defeacation.

Diastema (plural, diastemata) : a gap which is a the toothless region between the canine and premolar teeth in some mammals.

Eocene : the second epoch of the Tertiary period of the cenozoic era.

Fenestra (plural fenestral) : large opening usually in a bone or between bones.

Homeotherms : warm blooded animals which maintain a constant body temperature that is not influenced by the surrounding temperture.

Gestation : the period of time from fertilization to birth in embryos that develop within the body of a parent.

Genealogy : account of descent from the ancestor; investigation of pedigree; plants or animal's line of development from earlier forms.

Incisor : any tooth of a mammal that is located anterior to the canine tooth and is used for cutting.

Larynx : a complex of cartilaginous elements, muscles, and fibers at the pharyngeal openings of the trachea that functions to protect the phayngeal opening and in some forms permits vocalization by forming a voice box especially in humans.

Mammal : any animal belonging to the class Mammalia. Mammals have mammary glands, hair, warm bodies and three ear ossicles i.e, incus, malleus and stapes in the middle ear cavity.

Marsupial : any individual of the mammalian order Marsupialia which includes opossums, kangaroos, and wallabies.

Marsupium : an abdominal brood pouch present on most marsupials in which the young ones develop.

Monophyletic : group of species having all been derived from a common ancestor or single parent stock.

Nocturnal : of pertaining to the night.

Occipital condyle : one of the joint surfaces present on the occipital region of the skull that articulates with the first verlebra called atlas.

Oesophagus : the part of the gut tube that lies between pharynx and stomach.

Ossification : deposition of mineral salts, calcium phosphate and calcium carbonate around collagen fibres present in tissues so that the tissue becomes hardened or ossified.

Polyphyletic : derived from more than one ancestral source; opposed to monophyletic.

Taxonomic clade : a taxon or a group consisting of a single species and all of its descendents that forming a distinct branch on a phylogenetic tree.

Viviparity : the condition in which the young undergo considerable development within the body of the maternal adult.

Wing : any appendage which serves as a major aerofoil, especially the forelimbs of birds, bats and pterosaurs.

FURTHER READINGS

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Appendix-1

GEOLOGICAL TIME TABLE

Era	Period	Epoch	Bilogic Events	Years before present (B.P.)
CENOZOIC	**Quaternary**	Recent	Modern humans	11 thousand
		Piestocene	Early humans	1.7 million
	Tertiary	Piliocene	Large carnivores	5 million
		Miocene	Abundant grazing mammals	23 million
		Oligocene	Apes, monkeys, whales	38 million
		Eocene	Radiation of placentals	54 million
		Peleocene	Fist placental mammals	56 million
MESOZOIC	**Cretaceous**		Climax of giant land and marine reptiles, followed by extinction; flowering plantts; decline of gymnosperms	135 million
	Jurasic		First birds; first mammals; dinousours abu	192 million
	Triassic		First dinosaurs; mammal like reptiles; Conifers dominate plants	230 million
PALEZOIC	**Permian**		Radiation of reptiles; displacement of amphibians; extinction of many marine invertebrates	280 million
	Carboniferous	Pennsylvanias	First reptiles; giant insects;s great conifer forests	320 million
		Mississippain	Radiation of amphibians; abudant sharks; scale trees and seed ferns	345 million
	Devonian		First amphibians freshwater fishes abundant; bryozoans and corals	405 million
	Silurian		First jawed fishes	430 million
	Ordovician		Ostracoderms (first vertebrates): abundant marine invertebrates; first land plants	500 million
	Cambrian		Origina of many invertebrate phyla and classes; trilobites dominant; marine algae	570-600 million
PRECAMBRIAN	**Precambrian**		Fossial algae; other fossils extremely rare; evidence of sponges and worm burrows	

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ISBN : 978-93-89668-04-9