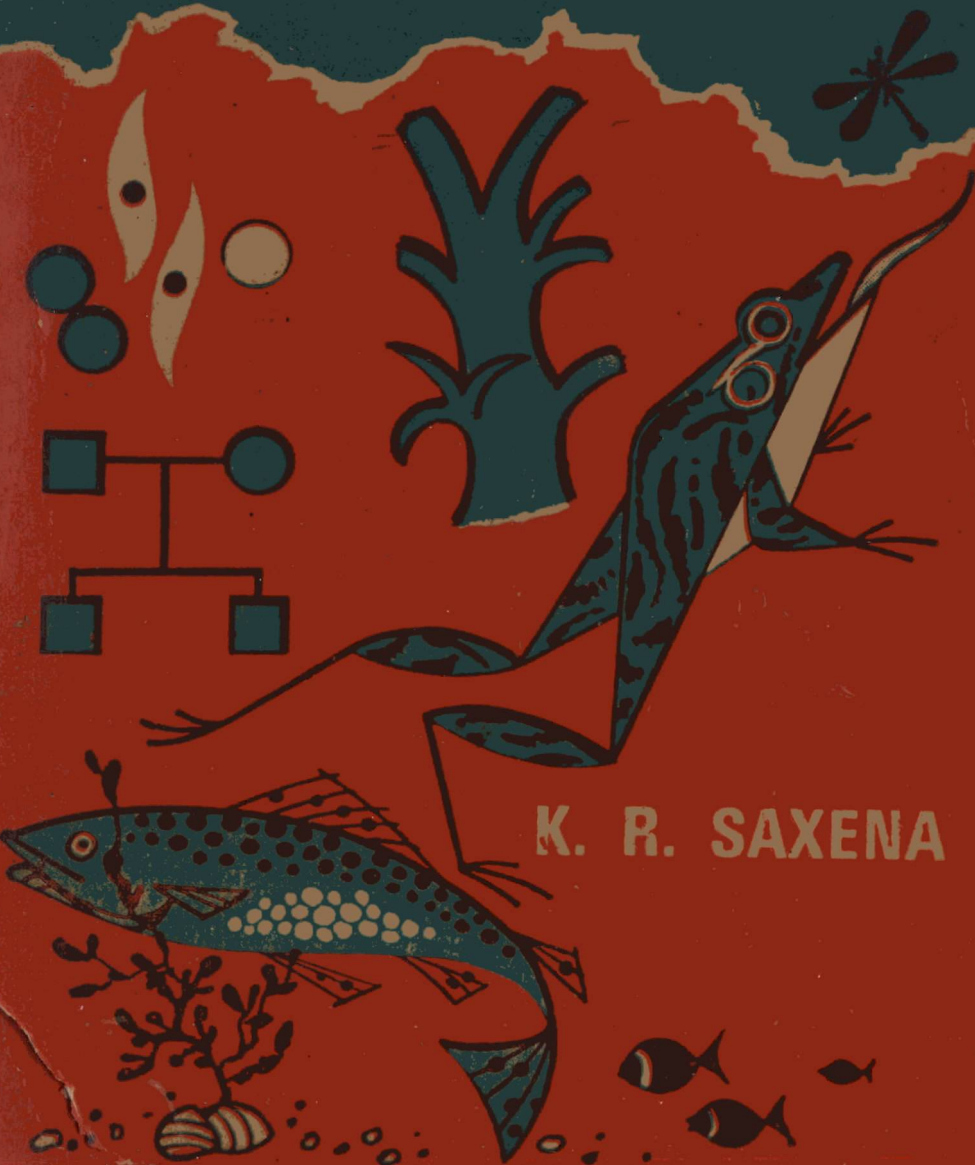
A TEXTBOOK OF ZOOLOGY

VOLUME TWO



K. R. SAXENA

A TEXTBOOK
OF
ZOOLOGY

(For the Second Year of the Intermediate Course)

VOLUME II

By

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PREFACE

On the basis of the year-wise distribution of the syllabus in zoology prescribed by the Government of Andhra Pradesh for the Intermediate Course, I was strongly feeling the necessity of re-arranging the entire matter into two volumes i. e., Vol. I and Vol. II based on the syllabi for I year and II year Intermediate Course. The Textbook of Zoology Volume I, covers up the I year syllabus and now this present Volume II is based on the entire syllabus of II year. The matter included in this book is a totally revised and condensed version of the matter earlier discussed in two volumes i e., Volumes II and III respectively.

The II year syllabus covered in this book is divided into three parts. Part I deals with the general characters of chordates and the functional anatomy of frog. Part II comprises chapters on the general survey of vertebrates. Part III is exclusively concerned with Heredity, Evolution and General Concepts of Ecology.

While condensing the matter of the earlier volumes II and III, every care is taken to deal the contents in depth so as to maintain the standard of a textbook. Further, every attempt is made to present the account with clarity and also in a manner easily understandable to a student of Intermediate Class. The information pertaining to various topics dealt with is made up-to date and suitable illustrations and self explanatory diagrams are given as and wherever felt necessary. Each chapter is followed by revision questions for the benefit of the students. The general form and format of the book are however kept the same. A few of the distinctive features of the revised edition are as follows.

In dealing with the functional anatomy of frog emphasis is laid equally on the structure and functions of the various organ systems of frog. The chapter dealing with the development of frog has thoroughly been revised with a view to lay stress on the fundamental aspects of development. The accounts on the *fate maps, embryonic inductions* and *inductive reactions* are explained precisely with the

help of suitable diagrams and likewise emphasis is laid on the *hormonal control of metamorphis* in amphibians. A clear understanding of these aspects of development, I feel, are all the more essential to keep pace with the recent knowledge in the field of developmental biology.

A detailed account on the snakes of India is given with emphasis on the diagnostic characteristics of the poisonous and non-poisonous snakes as well as their economic importance.

In a general survey of vertebrates e. g., fishes, birds and mammals, stress is laid on their natural history and behaviour of the animals belonging to the said groups. This will enable a student to have an idea of the wild life and the necessity to conserve the same for the benefit of mankind.

In a chapter on the Mendel's Principles of Inheritance the role of heredity with variations, in evolution is stressed.

The main theme of the origin of various forms of life *decended with modification* from ancestral stock has been conveyed while dealing with the theories and mechanism of organic evolution.

A brief account on the general concepts of ecology and ecosystem is written with a description of a pond as an ecosystem.

In writing this book I have referred to standard text and reference books on zoology.

I am thankful to all my colleagues for their valuable suggestions which enabled me to undertake the task of revising the book thoroughly.

I am highly grateful to Shri Lakshmi Narayana, N.C. partner, Messers Sri Saraswati Book Depot, for all his valuable suggestions and critical editing at every stage of writing this book. I record my deep sense of gratitude to him.

I also offer my thanks to the publishers and the staff of the press for their whole hearted cooperation in printing this book and also accepting last minute additions as well as deletions with apparent equanimity.

Every case has been taken to minimise the errors in printing. Inspite of this, some errors in printing or otherwise might have crept in for which I offer my apologies and hope to rectify them in future editions.

I strongly hope that the book will cater to the needs of the students and the teachers both. Valuable suggestions and constructive criticisms on this book if any are most welcome. This will enable me to improve this book in its future editions.

HYDERABAD
AUGUST, 1976

K. R. Saxena

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PART I

General Characters of Chordates and Functional Anatomy of Frog

CHAPTER I

CHORDATES

[Animals with a notochord]

The various examples of non-chordates discussed in the first volume gave us an idea about their structure and their remarkable diversity from a simple type of body plan to high degree of specialisations.

We shall now discuss about those animals that are included in the phylum **chordata**. Chordates, like many of the non-chordates e. g., annelids etc , are all triploblastic coelomate metazoans. Majority of the chordates like most of the non-chordates have a bilaterally symmetrical body.

There are, however, certain distinct features in which the chordates differ basically from all non-chordates. The general characters of chordates as such are discussed below.

Phylum chordata includes all those forms which possess a **notochord** or **chorda dorsalis**. From this structure the phylum takes its name as **chordata**. The **notochord** is found in the embryo of most chordates as a long, flexible cord of specialised vacuolated cells, running from head to tail along the dorsal mid-line. It lies immediately above the alimentary canal and below the dorsal cord of the central nervous system. In lower chordates e.g., **amphioxus**, the notochord is developed directly and unmistakably from the endoderm. In higher chordates i.e., craniates, it may originate from cells that are not obviously of endodermal derivation. The notochord is sometimes enclosed in a firm sheath. The notochord may be persistent throughout the life of the chordate or may appear at sometime or another during their life history or embryonic stages. The notochord in some is replaced either wholly or partially in the adult animal by a **backbone** or **vertebral column**. Such animals are called the **vertebrates** or **animals with backbones**. Animals **without backbones** are thus referred to as **invertebrates**. All the non-chordates as such and also the chordates with persistent notochords may be referred to as *invertebrates*.

The presence of **visceral clefts** in the lateral wall of the pharnyx (an anterior section of the alimentary canal) constitutes another almost universal feature of chordates. The visceral clefts arise as a series of perforations leading from the lateral wall of the pharynx to the lateral surface of the body. In the aquatic forms all

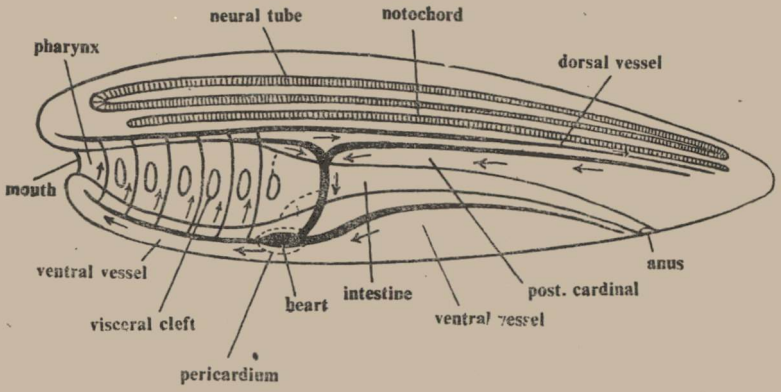


Fig 1.1 Diagram illustrating the basic arrangement of different organs in an idealised chordate.

these visceral clefts or some of them become modified to provide a respiratory surface in the form of **gills.** They are therefore called the **gill** or **branchial clefts.** In the creatures equipped with lungs, branchial clefts or grooves are always found in the embryo. In the adults of vertebrates, the branchial apparatus is sometimes converted to endocrine or other functions. In the more primitive members of the chordates the branchial apparatus is also used as a feeding mechanism.

The **central nervous system** of chordates is always dorsal in position. According to its mode of development it is hollow, tubular fluid-filled structure. In the advanced forms, the anterior part of the nervous system differentiates into a **brain.** In non-chordates as you have studied, the central nervous system is always ventral and consists of a solid double nerve cord.

In most of the chordates, the circulation of blood in the blood vessels is maintained by a central muscular propulsive organ called

the **heart.** The heart is always *ventral* in position and in the higher chordates it is contained within a modified part of the coelom called the **pericardial cavity**. This cavity is bounded by the **pericardium**. The **flow of blood** in the **dorsal blood vessel is from the anterior to the posterior end.** In non-chordates as you know, the heart wherever it is present, is usually a modification of the dorsal vessel. Further it is not enclosed in a pericardial cavity. The flow of blood in the dorsal blood vessels of non-chordates is always from the posterior to the anterior end of the body.

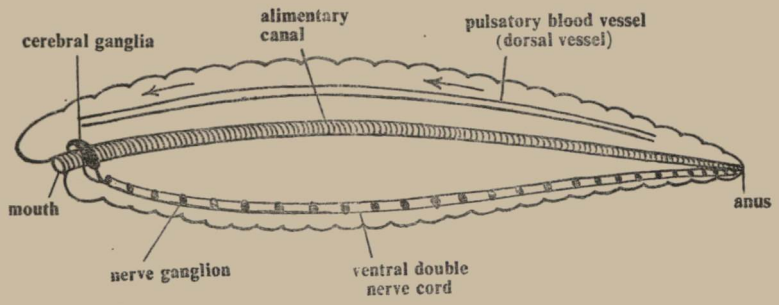


Fig. 1.2 Diagram showing the arrangement of various organs in an idealised non-chordate.

Metamerism in the chordates is found no doubt, but it is frequently masked externally. Each segment of the mesoderm in the chordates during development becomes divided into **somites** and the **lateral plate mesoderm.** The somites give rise to the body muscles (myotomes) and other structures. The lateral plate mesoderm is distinguished into the somatic and the splanchnic layers which bound the coelom and give rise to the bulk of unstriped muscles. The muscles of the body wall however never consist of circular and longitudinal muscle layers as seen in many non-chordates.

The posterior part of the body of chordates takes the form of a metamerically segmented **post anal tail.** It is quite different from the unsegmented condition of the terminal portion of the body found in non-chordates. This tail is highly flexible and muscular in

the aquatic forms. It constitutes the main propulsive organ. This structure in the terrestrial chordates takes various forms or may be reduced in the adult.

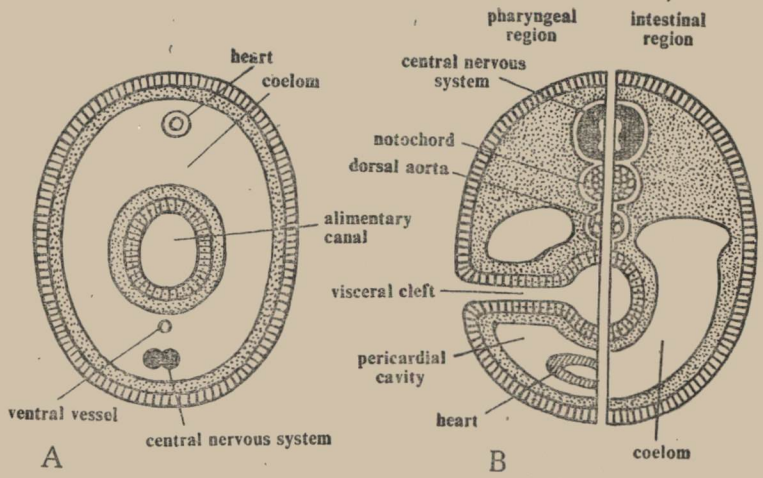


Fig. 1.3 Diagram to illustrate main differences between non-chordates and chordates (A) T.S. passing through the body of an idealised non-chordate (B) T.S. passing through the body of an idealised chordate.

We can summarise below the differences between the chordates and the non-chordates.

Chordates	Non-chordates
Notochord present.	Notochord absent.
Visceral clefts are present in pharynx.	Visceral clefts are absent.
The central nervous system is dorsal, tubular and hollow.	The central nervous system is ventral, solid and consists of double nerve cord.
Heart, ventral in position contained in a pericardial cavity which is surrounded by the pericardium.	Heart, dorsal in position in the form of a rhythmically contractile tube obtained as a modification of the dorsal blood vessel. No pericardial cavity and pericardium.
Post anal metamerically segmented tail is found.	The terminal portion of the body is unsegmented.

Protochordates

Certain members of the chordates are referred to as **protochordates** which lack the vertebral column. They are divided into three groups (1) **The Hemichordata** (Acorn worms) (2) **The Urochordata** (Tunicates-Sea squirts) and (3) **Cephalochordata** (Acraniates-lancelets) According to one view, these three groups of protochordates constitute three **sub-phyla** of the chordata. The fourth sub-phylum comprises the **vertebrata** (craniata). An alternative view is to regard **hemichordata** as an **independent phylum** on the basis that the animals of this group do not possess a notochord. The *urochordata* and the *cephalochordata* according to the above view are treated as protochordate members of the phylum chordata. In addition to the main chordate features, they also share certain characters with the vertebrates like the possession of an *endostyle, post anal muscular tail* and a recognisable uniform plan of early development.

Distinctive features of vertebrates

Vertebrates possess a **vertebral column** or **backbone.** In vertebrates a skeletal structure called the **cranium** develops around the brain and sense organs. They are therefore referred to as **craniates.** In some craniates the mouth is bordered with the jaws. Such craniates are called **gnathostomes** to distinguish them from those of the **agnatha** which do not possess jaws. The modern representatives of jawless vertebrates are the cyclostomes possessing round and suctorial mouths.

The gnathostomes invariably possess **limbs** with a **limb skeleton**, articulating with **limb girdles.**

The **brain** of craniates is a complex structure and at least *ten pairs of cranial nerves* arise from the brain.

The respiratory system always includes **gills** in aquatic forms and **lungs** in the terrestrial animals.

The excretory organs of craniates are **true kidneys** which are the collections of renal tubules of mesodermal origin.

The **gonads** (i. e., the testis and ovaries) are compact bodies and their ducts are closely associated with those of the kidneys.

The craniates possess a **muscular heart** of three or four chambers and almost always **red blood corpuscles.**

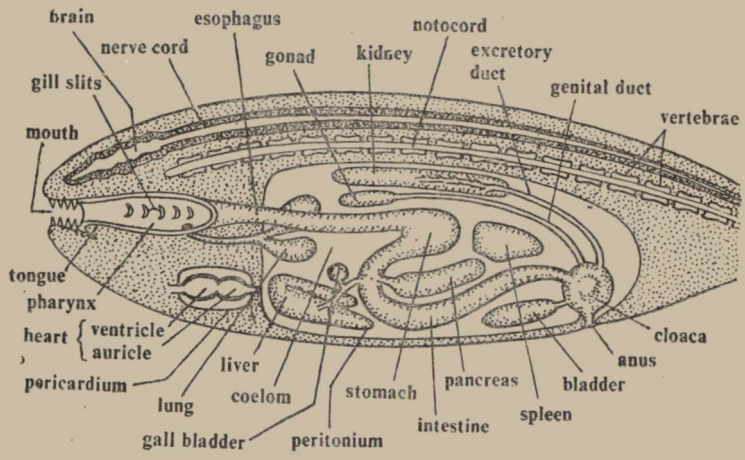


Fig. 1.4 Diagrammatic representation of the structures found in the body of an idealised vertebrate.

Outline Classification of Chordata

Phylum Chordata.

Sub-phylum **Hemichordata** (Balanoglossus).

Sub-phylum **Urochordata** (Ascidians).

Sub-phylum **Cephalochordata** (Amphioxus).

Sub-phylum **Craniata** (Vertebrata).

Super-class **Agnatha** (Jawless vertebrates).

Class 1. **Cyclostomata** (Petromyzon and Myxine).

Super-class **Gnathostomata** (Vertebrates with jaws).

Class 2. **Elasmobranchi** (Chondrichthyes-includes cartilaginous fishes).

Class 3. **Osteichthyes** (Includes bony fishes).

Class 4.	**Amphibia**	(Includes salamanders, frogs, toads and caecilians).
Class 5.	**Reptilia**	(Includes sphenodon, turtles, lizards, snakes, crocodiles, etc).
Class 6.	**Aves**	(Includes birds).
Class 7.	**Mammalia**	(Mammals, including man).

Revision questions

1. Describe the general characters of chordates.
2. What are craniates? Describe their distinctive features and outline classification.
3. Write notes on :
   (a) Visceral clefts.
   (b) Protochordates.
   (c) Notochord.

CHAPTER II

THE AMPHIBIANS

The first land vertebrates i. e., frogs and their relatives.

Frog can be studied as a good example of a vertebrate. Frog belongs to the class Amphibia. The members of this class have two phases in life. In the first phase of their life when they are young in **larval** or **tadpole stage**, they are fish-like creatures swimming in water. In the second phase or **adult phase** they are also well adapted for life on the land. The name of the class Amphibia (Gk. *amphi*: both or double; *bio*: life) thus indicates the mode of life of the amphibians. Amphibians include frogs, toads, salamanders and caecilians. They are regarded as the **first land vertebrates.**

The Common Indian Frog—Rana tigrina

Habitat: The Common Indian frog **Rana tigrina** like other frogs lives near water. It is found near a well, pond, lake, river or a stream. These places form the natural **habitat** of frog. The frog has to live in the neighbourhood of water on account of its particular mode of life. The frog, besides using its lungs, breathes mostly through its skin. For this purpose the skin has to be kept almost moist. The frogs thus take a jump now and then into water from the edge of the ponds or streams to keep their skin wet. Further the frogs do not drink water like us through the mouth but absorb the same through skin. This water is stored beneath the skin in the spaces called the sub-cutaneous lymph spaces. For this purpose also frogs have to live near water. The proximity with water in frogs is also necessary as the eggs are to be laid in water where only they can hatch them into larvae. The frogs however cannot stay long totally immersed in water. They have to come back to surface of the land to breathe air. The frogs are thus neither exclusively aquatic nor totally terrestrial forms. Their life is a good example of a *transition of vertebrates from water to land.*

External characters: The body of frog consists of **a head** and a **trunk**, there being no neck between the head and the trunk. The

tail also is absent in adult frog. Two pairs of limbs, the **fore-limbs** and the **hind-limbs** arise from the trunk.

The Head is the foremost part of the body. It is roughly triangular in outline. The extreme front end of the head is produced into a nearly semi-circular **snout**. Around the whole edge of the snout there extends the wide slit-like **mouth** guarded by the upper and the lower jaws.

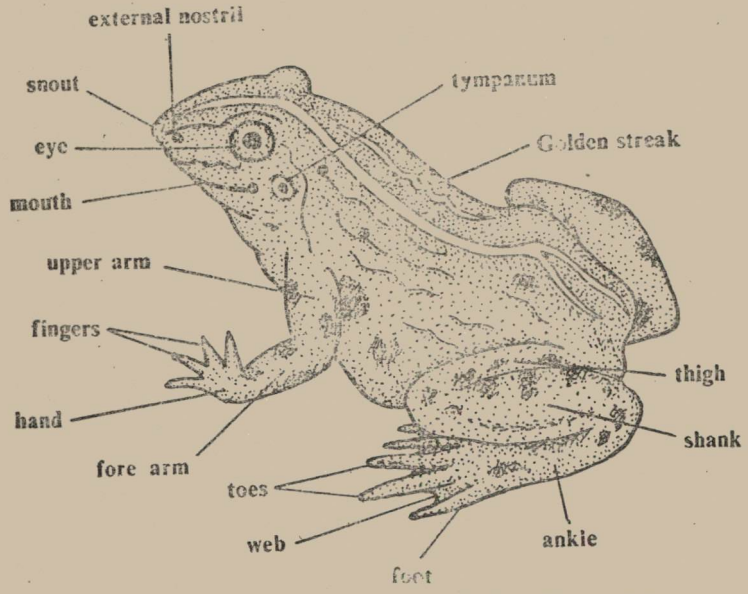


Fig. 2.1 The Common Indian Frog—Rana tigrina; External characters.

The fore-end of the snout at its top bears two small **external nostrils**, one on each side of the middle line of the body. Some distance behind the nostrils lie a pair of large prominent eyes. In the absence of a neck the frog cannot turn its head around. The frog's large prominent eyes however enable it to look in all directions even without a neck. In the centre of the eyes, as in our own, we can distinguish a coloured ring or **iris** which surrounds a roundish black space or **pupil**. The eye-lids are however different from our own. The **upper eye-lid** is fairly well developed but is only slightly movable. The **lower eye-lid** is in the form of a mere fold of skin which is incapable of covering the eye. The lower eye-lid is however

produced into a thin transparent sheath of skin called the **nictitating membrane.** The **nictitating** membrane can be drawn upwards over the eye. The nictitating membrane thus protects the eyes of the frog from the mud and other impurities in water. The frog can even see when the nictitating membrane is drawn over the eyes as it is a transparent structure.

Just behind and slightly below the eye on each side is a large dark area in the centre of which is to be seen a tightly stretched membrane circular in outline. It is called the *drum membrane*, *tympanic membrane* or *tympanum*. This membrane is the outermost part of the ear of frog.

The Trunk : Head, in the absence of the neck, is directly in continuation with the trunk. The trunk is broad and somewhat flattened. The trunk at its posterior extremity on the dorsal side has an opening called the *cloacal aperture* situated between the two legs. Through this aperture the frog discharges its faeces, urine and genital products to the exterior.

The trunk bears two pairs of limbs, the fore-limbs and the hind-limbs. The fore-limbs are shorter than the hind-limbs.

The fore-limb can be distinguished into a proximal part (the part of the limb nearest to the trunk) called the **upper arm, the mid region** or the **fore-arm** and the distal part (i. e., part considerably away from the trunk) the **hand** or **manus.** The hand can further be distinguished into a *wrist*, *palm* and *fingers.* The fingers are four in number without nails. In the male frog during the breeding season, a pad like swelling develops on the first or index finger. This is called the **capulatory pad** or the **nuptial pad.** This helps the male frog to hold the female firmly during copulation or mating. The hind-limbs are much larger than the fore-limbs. Each hind-limb like the fore-limb is divided into three parts. The proximal part is the stout **thigh,** the middle, a long **shank** with a well marked 'calf' and the distal region the **foot** or **pes.** The foot comprises of an *ankle*, *instep* and the five *toes.* The ankle region is long—almost like a second shank without a heel. Out of the five toes, the first or innermost is short, the second of moderate length, the third longer, the fourth longer still, and the fifth of about the same length as the third. Between the toes there extends a thin, transparent web. The toes like the fingers have no nails. A common term *digit* is also used

and applied both to fingers and toes. The foot as compared to the other parts of the hind-limb is much longer. This is helpful in **leaping** or **hopping.** The adult frog as you might have observed hops about on land. The long and powerful hind-limbs enable the frog to jump and the smaller fore-limbs are used to break the fall when the frog alights on the ground. When the frog accasionally goes into the water, the powerful hind-limbs and the webbed toes enable it to swim.

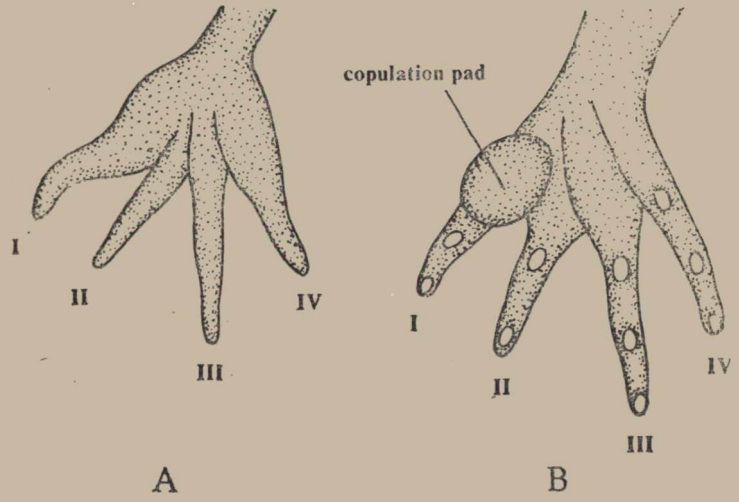


Fig. 2.2 (A) fingers of the hand of female frog. (B) fingers of the hand of male frog with a copulatory pad on the first or index finger during the breeding season.

Frog's body in a **squating posture** forms a characteristic hump on the dorsal surface of the trunk. The body of the frog in this posture is raised upon the arms which are kept slightly bent at the elbows. The fingers are spread out and directed forwards. The hind limb in this squatting posture is bent into a sort of Z, the knee being directed forwards and the ankle joint backwards. The toes are also directed forwards.

In the Common Indian frog, *Rana tigrina* which is also found in Sri Lanka, all the parts of the body, i.e., the head, trunk and limbs are covered with a soft slimy skin. The skin of frog is loosely attached to the underlying muscles. The dorsal or upper surface of the skin is green or olive in colour, irregularly mottled with dark spots of varying sizes. The under or ventral surface of the skin is

however whitish. There extends a median bright line on the dorsa surface of the body from the region of the snout to the extremity ofl the trunk. This is known as **Dorsal streak** or **Golden streak.** The colour of the skin is not always constant. If a frog is kept in darkness, the black spots increase to such an extent that the whole animal becomes almost black. If it is kept in full daylight then a corresponding brightening of the skin colours, takes place. The spots and the patches of brighter colour are always variable. The colour changing phenomenon of skin is a characteristic feature of frog and other animals also. The colour of the skin frequently changes in order to harmonise with the surroundings. By this, the frogs and other animals are capable of concealing themselves from their enemies. A thin outer transparent membrane from the surface of the skin is periodically cast off. This process is called **moulting.** The entire membrane is not shed at one time but casting takes place in small pieces.

Sexes : The male and female frogs can easily be distinguished by their external characters. The male frog as described above develops a **nuptial pad** or **copulatory pad** on the first or index finger during the breeding season (See Fig. 2·2B). Further, in the male frog there are found a pair of distensible sacs one on either side of the throat or little behind the articulation of the jaws. These are called the **vocal sacs.** These vocal sacs are expanded and help to intensify the noise produced by the frog. This is familiarly known as the **croaking** of frog. During croaking the mouth is kept closed and the air is passed to and fro between the lungs and the nostrils. The vocal sacs act as resonators to increase the sound and appear like little balloons during croaking. The croaking of frogs is a

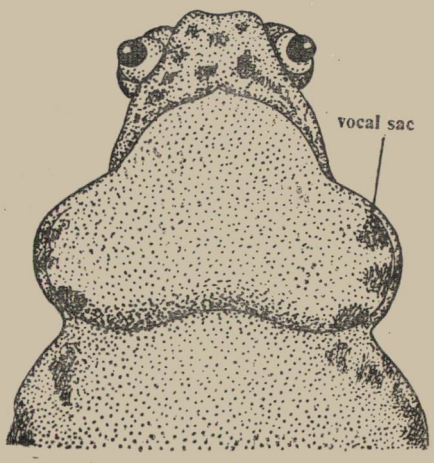


Fig. 2.3 The vocal sacs of a male frog in an inflated condition. With their help the frog produces the familiar croaking noise.

call for mating which generally takes place during the rainy season. The males amongst the commonest Indian type (Rana tigrina) are usually of a darker colour than the females.

Amplexus : The mating of male and female frogs occurs in water. During this process, the male frog mounts the back of the female, holding it firmly with the fore-limbs. The clasp is strengthened further by the copulatory pads on the index finger of the male. This sexual embracing is referred to as **amplexus.** The pairing continues till the female frog discharges its eggs over which the male pours the spermatic fluid. The eggs are thus fertilised in water.

The fertilised egg hatches into a **tadpole larva** which undergoes metamorphosis to become an **adult frog.**

Hibernation : Frog is a cold blooded vertebrate. The temperature of the body varies according to the surrounding medium. In severe cold it is incapable of bearing the frost. In order to protect itself from the adverse effects of cold, the frog usually buries itself underground in damp places. The frogs lie there, throughout the winter in dormant condition known as the **winter sleep** or **hibernation.** This is a period of suspended activity during which the frogs do not make any movement. The mouth remains closed and the feeding is stopped. Respiration is performed through the skin. The little energy required for this period of suspended activity is obtained from the store of glycogen in the liver and the fat in the fat bodies. When the spring approaches and conditions of the surroundings become favourable, the frogs wake up from their winter sleep and come out from their places of retreat to resume their normal active life.

Food and Mode of capturing the Prey:

Frog is a carnivorous animal. It feeds on the small creatures like insects, spiders and earthworms. Frogs also eat minnows tadpoles and even smaller frogs.

The mode of capturing the prey is characteristic and also an interesting sight. The tongue of frog plays a leading part in capturing the prey. The tongue of frog, quite contrary to our own, is attached to the floor of the mouth cavity in front. The hind end of the tongue is free and forked at its extremity. The tongue is always coated

with a copious sticky or adhesive substance. In its normal position the tongue lies in the floor of the mouth cavity.

When a frog sees a fly or any other small insect, then it throws out of its mouth the free hind-end of the tongue towards the prey with great rapidity. Once the prey is adhered to the sticky surface of the tongue, it is instantaneously withdrawn to its normal position in the mouth cavity. The prey so caught is thus swallowed. The small teeth along the margin of the upper jaw prevent the prey from being escaped.

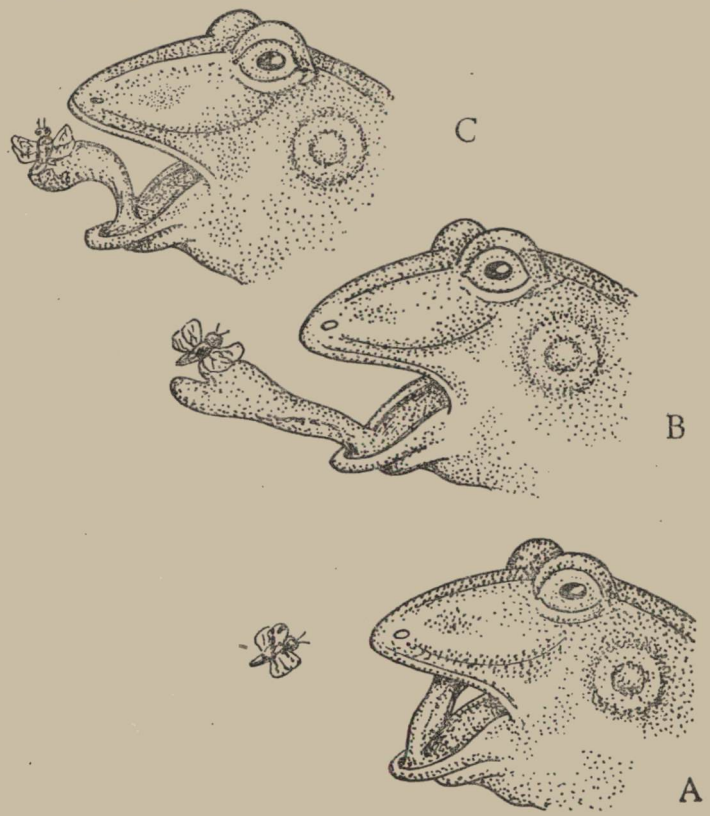


Fig. 2.4 The frog's tongue playing a leading part in capturing the prey. A) At the time of catching the prey the tongue is rapidly thrown out (B) The prey sticks to the slimy tongue (C) The tongue is then instantaneously withdrawn.

The General Internal Structure :

In order to understand the structure of the internal organs one has to dissect a frog. This will reveal the the structnre of various internal organs of the body.

The Mouth Cavity or Buccal Cavity : The mouth of frog leads internally into a spacious **mouth cavity** or **buccal cavity**. As stated earlier, the mouth is bordered above by the **upper jaw** and below by the **lower jaw**. If both the jaws, bordering the mouth are stretched apart one can observe the internal structure of the mouth cavity.

All round the edge of the upper jaw can be seen a row of small conical teeth called **the maxillary teeth**. The lower jaw however is devoid of teeth. On the roof of the mouth, a short distance behind the snout are seen two small patches of teeth called the **vomerine teeth.**

The teeth of frog are small, sharply pointed structures. Each tooth consists of a **base** and a **crown**. The major part of the crown is composed of **dentine** and the base is formed of **bone**. The exposed part of the crown is covered by a cap of very hard substance called the **enamel.** The tooth internally consists of a core of soft tissue called the **pulp.** The teeth are all alike and are fused to the surface of the bones that carry them. The teeth are now and then destroyed by use and thus fall out. They are however replaced one by one. The teeth are not suitable for mastication. They help in holding the captured prey and do not allow it to escape.

A pair of **internal nares** or **nostrils** in the form of small holes or apertures lie towards the outer sides of the upper jaw and slightly in front of the two patches of vomerine teeth. The external nostrils described earlier, communicate with the mouth cavity through these internal nostrils.

Behind the internal nostrils are two large **spherical bulgings.** These are formed due to the roof of the mouth cavity being bulged out by the huge eyes. Posteriorly, at each angle of the mouth is found a much larger hole or aperture called the **opening of the Eustachian tube** or **Eustachian recess**. There are thus a pair of

eustachian tubes opening one on each side of the angle of the mouth. Each aperture through an eustachian passage opens into a slightly dilated chamber—the **tympanic cavity** of its own side. The tympanic cavity is closed externally by the tympanic membrane already seen on the surface of the head.

The lower jaw as mentioned earlier forms a bony margin to the floor of the mouth. The rest of the floor is soft and fleshy but is slightly stiffened by a cartilaginous plate, the *body of the hyoid*, to be described later.

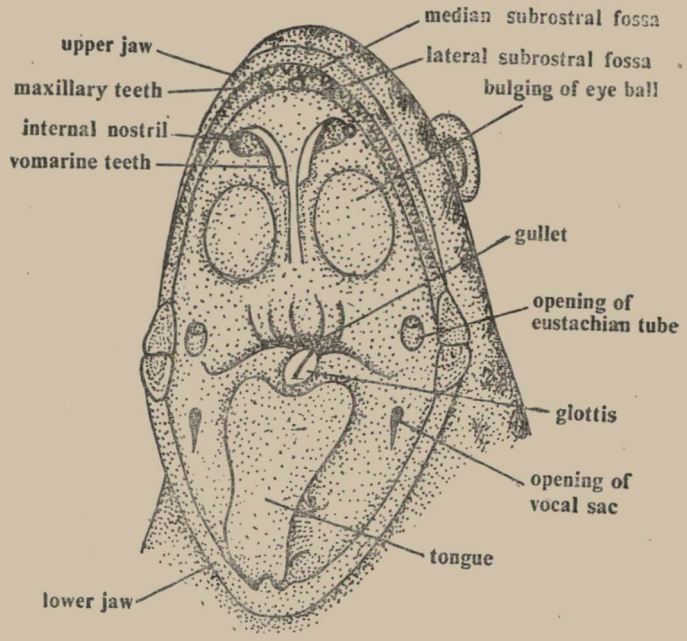


Fig. 2.5 The buccal cavity of frog. The two jaws have been stretched wide open to show the internal structure of the buccal cavity.

In the floor of the buccal cavity, a **protrusible tongue** covered with a sticky substance is present. The tongue is attached to the front part of the floor of the mouth. Its free bi-lobed or forked end lies in the floor of the mouth cavity directed backwards towards the pharynx or the throat. The tongue as described earlier takes a leading part in catching the prey.

The posterior narrow folded part of the buccal cavity is distinguished as the **pharynx** or **throat** which leads into a transverse slit called the **gullet.**

Just behind the backwardly turned forked tip of the tongue is found an oval elevation with a median longitudinal slit called the **glottis.** This leads into the lungs.

In some of the specimens under study one can notice the presence of a pair of openings one on each side immediately below the angle of the jaws. These are the **openings of the vocal sacs.**

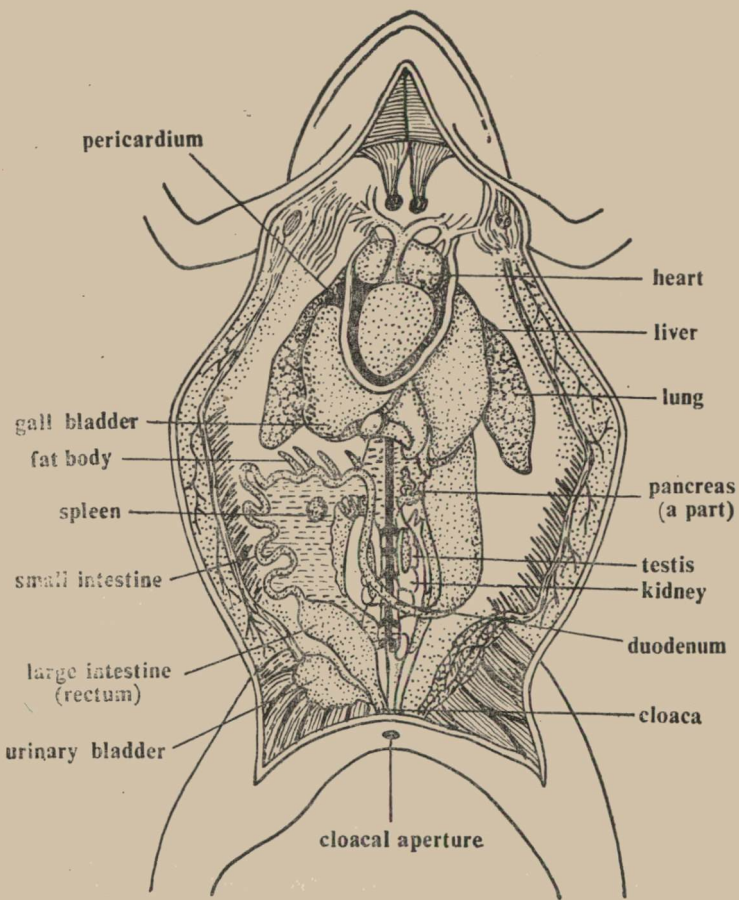
There are also to be seen behind the anterior border of the upper jaw three depressions. One **median sub-rostral fossa** and two **lateral sub-rostral fossae.** They help to shut the mouth firmly during respiration.

The Internal Organs :

If the body wall is cut open all along the ventral line one can see a large **trunk cavity.** It contains most of the soft organs of the body like *heart, stomach, intestine, liver, spleen, lungs, kidneys, testis* or *ovaries* etc.

All the soft organs found in the trunk cavity are collectively referred to as the **viscera.** The trunk cavity or the body cavity of the frog is a coelomic cavity as it is lined by the coelomic epithelium called the **peritoneum.** The body wall of frog thus consists of the skin, the muscles and the peritoneum. All the internal organs of the trunk cavity are also covered by a sheath of peritoneum. The internal organs thus apparently seen lying within the trunk cavity are in fact separated from it by their corresponding sheaths of peritoneum. The peritoneum from the two sides of each organ meets on the dorsal side to form a double fold. The double fold of peritoneum on the dorsal side of the digestive organs e. g., the intestine is known as the **mesentery.** The peritoneum which lines the trunk cavity is called the **parietal layer of peritoneum** and the peritoneum which lines the viscera may be recognised as the **visceral layer of peritoneum.**

It is evident from the cross section taken through the trunk of a frog that the peritoneum does not line the dorsal region of the body wall but comes down on the two sides so as to enclose a fairly large space called the **sub-vertebral lymph sinus** or **space.** Within this space lie, the kidneys and certain large blood vessels like the dorsal aorta and the post caval vein or the inferior vena cava. The kidneys and the above mentioned large blood vessels therefore, are lined by the peritoneum, only on the ventral side. The transverse section passing through the trunk of frog clearly shows the position of the



2.6 Disposition of the internal organs and the alimentary canal of frog cut open from the ventral side.

peritoneum relative to the body cavity and the internal organs or viscera.

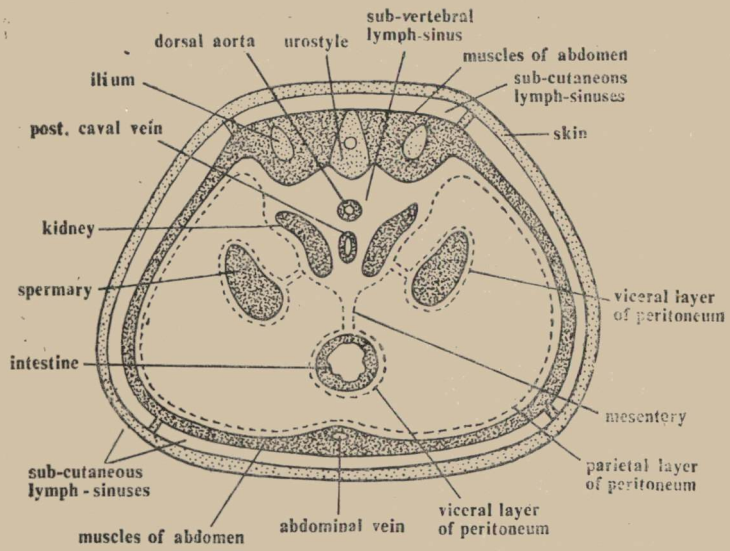


Fig. 2.7 Transverse section passing through the trunk of the frog (diagrammatic)

Revision questions

1. Describe the general characters and habitat of frog.
2. Write notes on the following :
   (a) Hibernation (b) Amplexus
   (c) Vocal sacs (d) Mesentery.
3. Give an account of the mode of capturing the prey by a frog.
4. Draw a well labelled diagram of the following :
   (a) Mouth cavity of frog.
   (b) Internal organs of frog as seen after opening the trunk and abdomen.

CHAPTER III

SKELETON, JOINTS AND MUSCLES

The Skeleton

The hard parts of the body giving support to the soft parts of it form the **skeleton** (Gr. *Skeletos*: hard). The skeleton forms a sort of frame-work which supports the body and gives it a proper shape. Since the skeleton, in all the vertebrates lies internally embedded in the muscles it is called an **endo-skeleton.**

The skeleton of an adult frog chiefly consists of bones and partly of cartilage. The skeleton of the tadpole i.e., the frog's larva is made up of cartilage only.

The skeleton of frog may conveniently be studied under two headings—1. The *axial skeleton*, which lies in the long axis of the body and 2. The *appendicular skeleton*, which comprises the skeleton of limbs and girdles.

The Axial Skeleton:

The axial skeleton consists of the **skull** and the **vertebral column** (**spinal column**) or the **backbone.**

The Skull:

The skull is composed of both bones and cartilages. It supports the various organs of the head like the eyes and the internal ear. The most prominent part is the central *brain case* or the **cranium** which protects the brain from injury. The **upper jaw** firmly attached to the skull forms a half circle around it. The **lower jaw** which is movable consists of two halves and supports the mouth. A **hyoid apparatus** lies in the floor of the mouth beneath the tongue.

The skull of a tadpole entirely consists of cartilage. It is called the *chondrocranium.*

The skull of an adult frog can now be studied.

For the sake of convenience, we may study the skull under seven regions which are as follows.

1. The cranium.
2. The olfactory capsule.
3. The auditory capsule.
4. The optic capsule.
5. The upper jaw.
6. The lower jaw.
7. The hyoid apparatus.

The Cranium or Brain Case :

The cranium or brain case, occupies the middle of the skull. It is roughly cylindrical in shape. On each side of the cranium is the **orbit**, a large gap to accommodate the eye.

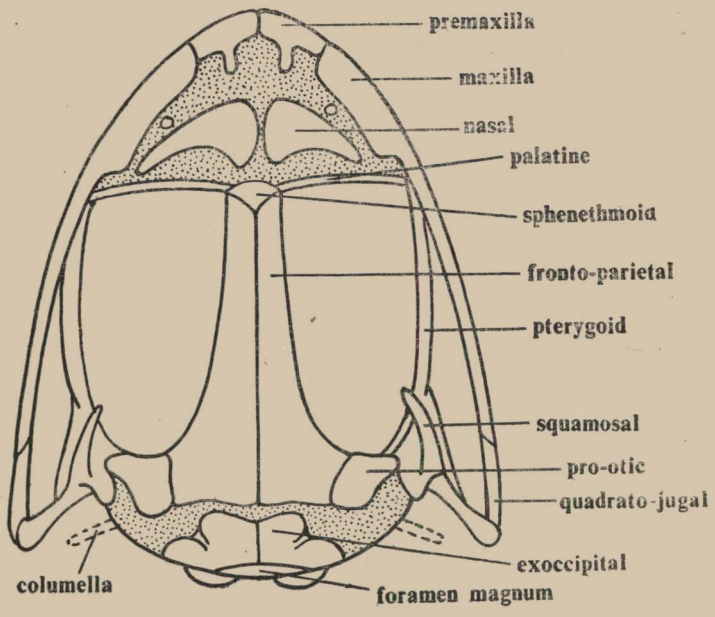


Fig. 3.1 Dorsal view of the skull of frog. The stippling indicates the cartilage.

The upper or dorsal side of the cranium is protected by a pair of bones, the **fronto-parietals**, which by widening out behind, also take a part in the protection of *auditory capsules*. At the front of the cranium, overlapped to some extent by the fronto-parietals, is the

sphenethmoid bone. It looks like a broad ring or girdle, and completely surrounds the cranium. Although it is visible from above it is best seen in a side view. It has a vertical wall infront which closes the cranial cavity. The vertical wall of sphenethmoid bone is pierced by two apertures through which the pair of olfactory nerves pass.

On the under side or the ventral surface of the cranium is a T-shaped bone called the **para sphenoid.** It is shaped like a dagger. The 'blade' and handle rest along the base of the cranium and the transverse bar extends across the auditory capsule. At the posterior end, the cranium is strengthened by the **exoccipital bones.** These bones almost completely surround a large hole, the **foramen magnum.** From this aperture the spinal cord emerges. The exoccipitals extend to the ventral wall of the auditory capsule where they meet the

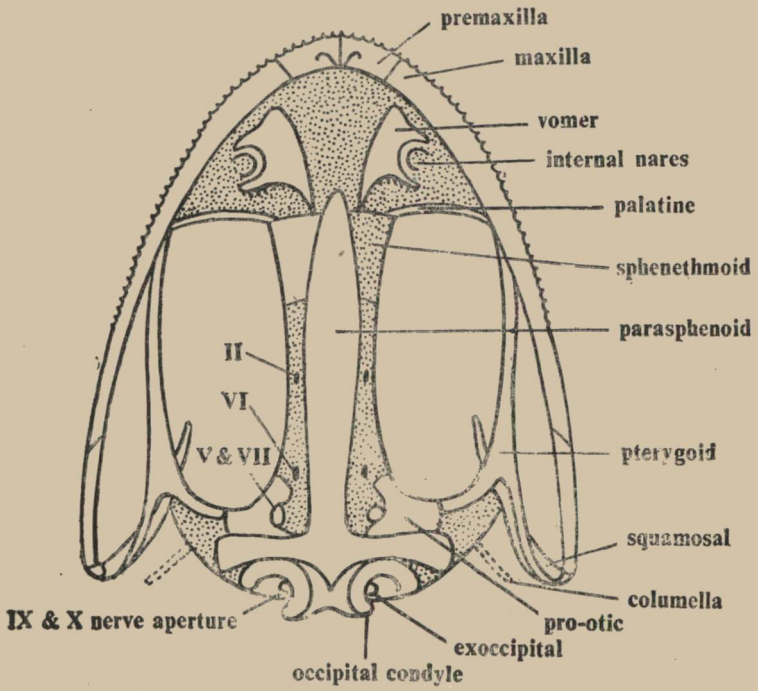


Fig. 3.2 Ventral view of the skull of frog. The stippling indicates the cartilage

transverse bar of the para-sphenoid. At the latero-ventral edge of the foramen magnum, each exoccipital forms a knob or condyle called the **occipital condyle** for articulation with the first vertebra. The two occipital condyles thus fit into the facets of the first vertebra.

The exoccipitals and sphenethmoid are *cartilage bones*, the fronto-parietals and para-sphenoid are *membrane bones*.

The **cartilage bones** are those which are formed in the place of pre-existing cartilage by ossification. These bones are also called **replacing bones**. **Membrane bones** or **investing bones** are those which develop independently of the pre-existing cartilage.

Membrane bones with rare exceptions are found only in the skull. The cartilage bones on the other hand are found all over the body.

Olfactory Capsule :

The olfactory or nasal capsules are found in front of the orbits and the cranium. They occupy the whole of the front of the skull. They lodge the olfactory or nasal organs.

The olfactory capsules are mostly cartilaginous. On the upper or dorsal side are the pair of **nasal bones.** This pair of bones are almost triangular and just touch each other in the middle line. At the front edge and towards the outer side of the nasal bones are the **external nostrils.** A pair of **septo-maxillary bones** along with the outer margins of nasals form the boundary of the external nostrils or nares. The under side of the nasal capsule is provided with a pair of bones called the **vomers**. The posterior edge of the vomers is roughened to form the **vomerine teeth.** The vomers like the nasals are triangular. They are surrounded by cartilage, but are completely separated from each other.

The Auditory Capsule :

The auditory capsule lodges the hearing apparatus. The auditory capsules are found in the form of a pair of projections on the sides of the posterior end of the cranium. The upper side of the auditory capsule is protected by the fronto-parietals and further it is also protected by a pair of **prootic bones.** Each prootic bone is saddle shaped and not only protects the dorsal side of the capsule but also forms a rim to the posterior face of the orbit. The part of the auditory capsule not protected by the bone is hardened by calcification. This capsule is therefore a much stronger chamber than

the nasal capsule. There lies at the side of the auditory capsule, the **squamosal bone.** It is a hammer shaped or T-shaped bone. The main stem or 'handle of the hammer' is attached by its end to the angle of the jaw. It leans obliquely forward, and in the posterior angle made by the cross-piece, the tympanic membrane of the ear is supported. The cross piece forms part of the circumference of the orbit.

The Optic Capsule :

The **optic capsule** is not fused with the skull. It is represented by the sclerotic coat of the eye-ball which contains a certain amount of cartilage. On each side of the cranium is the **orbit,** a large gap to accommodate the eye. The optic capsule is not attached to the skull.

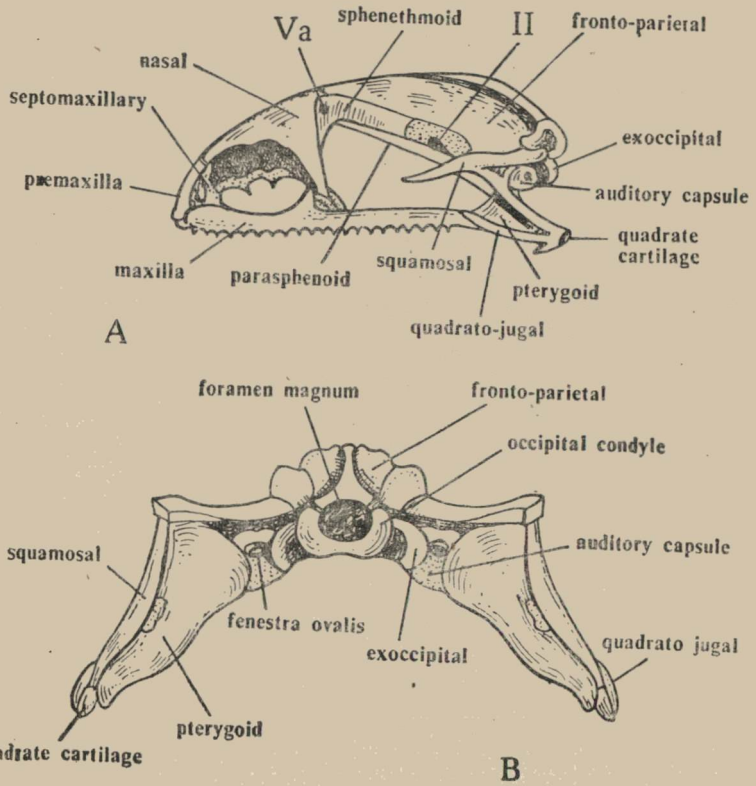
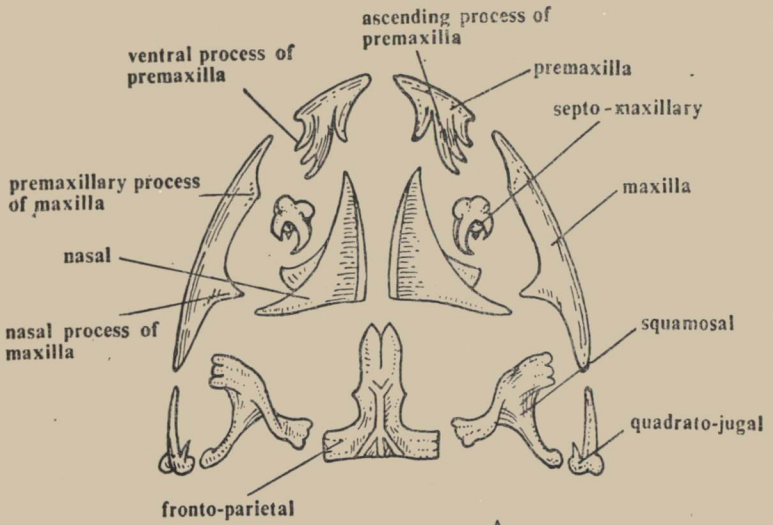


Fig. 3.3 The skull of frog (A) Lateral view (B) Posterior view.



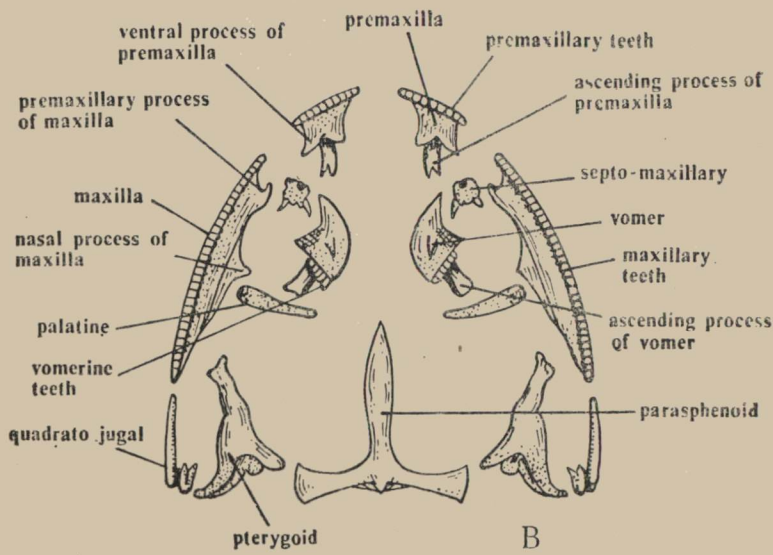


Fig. 3.4 The disarticulated bones of the skull of frog.
(A) Dorsal side (B) Ventral side.

In the complete skull, there projects from the outer wall of the auditory capsule a small rod-like bone of the middle ear, the **columella**. The outer end of the columella is applied to the inner surface of the tympanic membrane. The columella is however not always preserved in prepared specimens.

Apertures of the Cranial Nerves :

The aperture for the exit of the **IX** and **X cranial nerves** are seen in the hollow surrounded by the curvature of the exoccipital bone on each side. The aperture for the **V** and **VII nerves** lie at the posterior inner angle of the orbit between the prootic and the para-sphenoid. In the thin cartilage at the side of the cranium are two apertures. A very small one close to the prootic bone is the aperture for **VI nerve**. A large one for the **II nerve** (optic) is located at about the middle of the visible cartilage at the sides of the cranium. The internal nasal aperture is found at the outer edge of the vomer on each side.

The bones of the jaws will now be studied.

The Upper Jaw :

The upper jaw is attached to the nasal capsule or olfactory capsule in front and the auditory capsule behind. In the nasal region the small **premaxillae** give a firm support to the front of the nasal capsule. Each **premaxilla** sends out a backwardly directed process in the dorsal wall of the nasal capsule. The premaxillae are provided with teeth. Next to the premaxilla is found the toothed **maxilla**. Anterior part of the maxilla is broad and forms the side wall of the nasal capsule. Posteriorly, the maxilla tapers to a slender rod and articulates by an oblique contact with the **quadrato-jugal** bone. It has no teeth. At the posterior limit of the upper jaw the quadrato-jugal articulates with the squamosal bone.

If observed from the underside of the skull, the outer edge of the orbit is formed by the **pterygoid bone**. It is a tri-radiate bone which joins the maxilla in front and the auditory capsule behind. The posterior process of the pterygoid runs parallel with the stem of the squamosal and between the two is the **quadrate** cartilage, which is a part of the primitive cartilaginous upper jaw. The quadrate

cartilage will usually be seen only where it peeps out between the squamosals and the pterygoid bones.

The remaining upper jaw bone is the **palatine bone**. It is a very delicate bone which stretches from the anterior end of the pterygoid to the sphenethmoid thereby forms the anterior rim of the orbit on ventral side.

The Lower Jaw :

The lower jaw or the mandibular arch or the **mandible** is without teeth. It consists of two curved bars of cartilage or **rami** (each-half

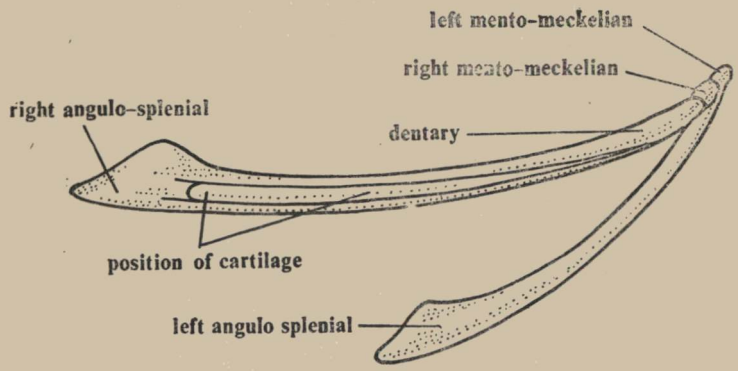


Fig. 3.5 Antero-lateral view of the lower jaw.

of the lower jaw is called a ramus) which are united in front by a ligament and partially invested by bones.

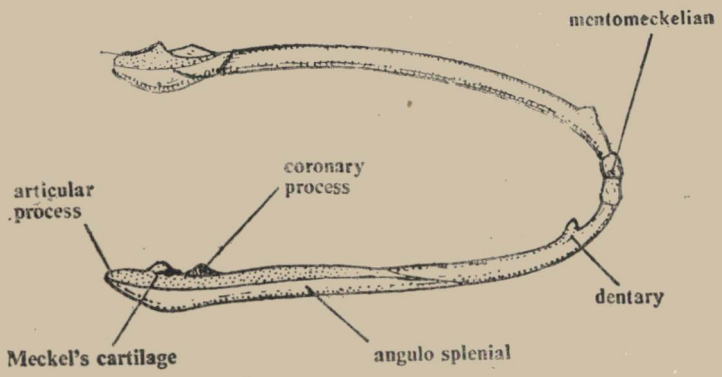


Fig. 3.6 The lower jaw of frog.

Each half of the lower jaw consists of a cartilaginous core, the **mandibular** or the **Meckel's cartilage.**

At the extreme anterior end of this cartilage where it is attached to its fellow of the opposite side, is a small bone, formed by the ossification of the cartilage itself called the **Mento-meckelian bone.** From this bone the **dentary bone** covers meckel's cartilage for nearly half way along the outer side of the jaw. On the inside of the jaw, along its whole length, is the **angulosplenial bone,** which extends also along the underside. As this bone approaches the articulation of the jaw, it is raised into a slight process called the **coronary process.** The quadrate cartilage along with the main limb of the outer arm of the pterygoid forms the suspensorium by means of which the lower jaw is suspended from the skull.

The Hyoid Apparatus:

The hyoid apparatus is a cartilaginous structure lying in the floor of the mouth. It is the remnant of the gill arches which support the gills of the larva or tadpole.

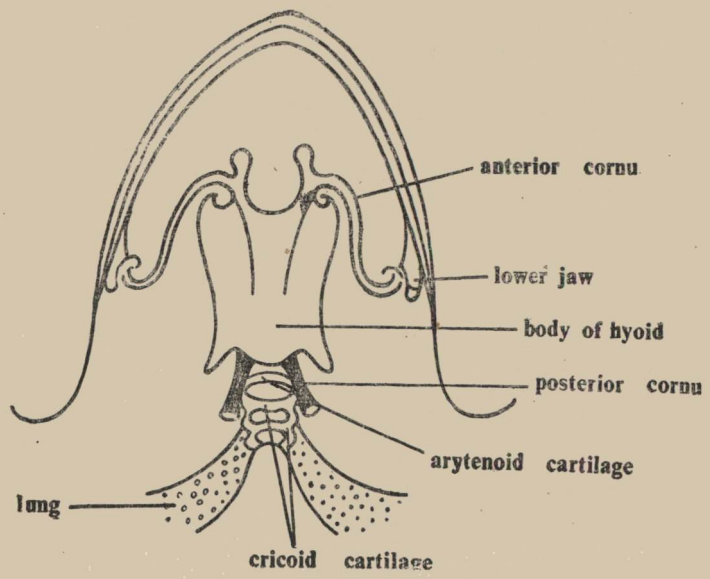


Fig. 3.7 The hyoid apparatus of frog in situ.

The hyoid apparatus consists of a roughly rectangular plate of cartilage called the **body of the hyoid** lying in the middle of the floor of the buccal cavity. Certain processes like the **anterior cornu** and others arise from the angles of this plate. The anterior cornu and the smaller processes at the anterior angle of the 'body' are frequently of red colour and are thus comparatively easily located. The **posterior cornu** of the 'body' lies at the sides of the larynx. The posterior cornu of the hyoid are bony. Each anterior cornu, recurves, from the anterior angle of the 'body' parallel with the jaw, round the angle of the mouth to the auditory capsule.

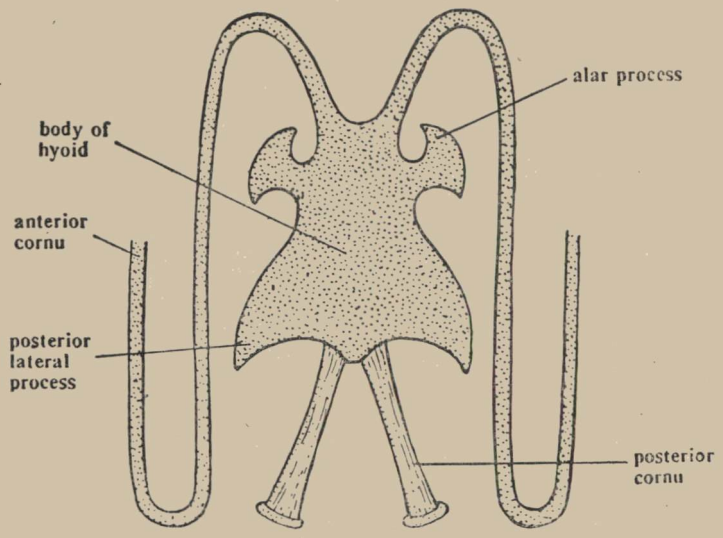


Fig. 3.8 The hyoid apparatus of frog.

The vertebral column or backbone or spinal column consists of nine movably united ring-like pieces called the **vertebrae** (singular : vertebra) and articulated with the last vertebra is found a long bony rod, the **urostyle.**

The *second*, *third*, *fourth*, *fifth*, *sixth* and *seventh* vertebrae are almost similar. They are referred to as **typical vertebrae.** The *first*, *eighth* and *ninth* vertebrae have some peculiarities and differ as such from the typical vertebrae;

A typical vertebra has somewhat the form of a signet ring, with its sides produced into two outstanding projections. The part of the vertebra, comparable to the stone of the ring is called the **body of the vertebra** or **centrum**. It is ventral in position. The form of this centrum is **procoelous**. Procoelous type of centrum is one with an anterior concave surface and posterior convex face. Both the faces of the centrum are covered with a thin layer of cartilage. The part corresponding to the circle of the ring is called the **neural arch** which forms a complete ring around the spinal cord. It is situated

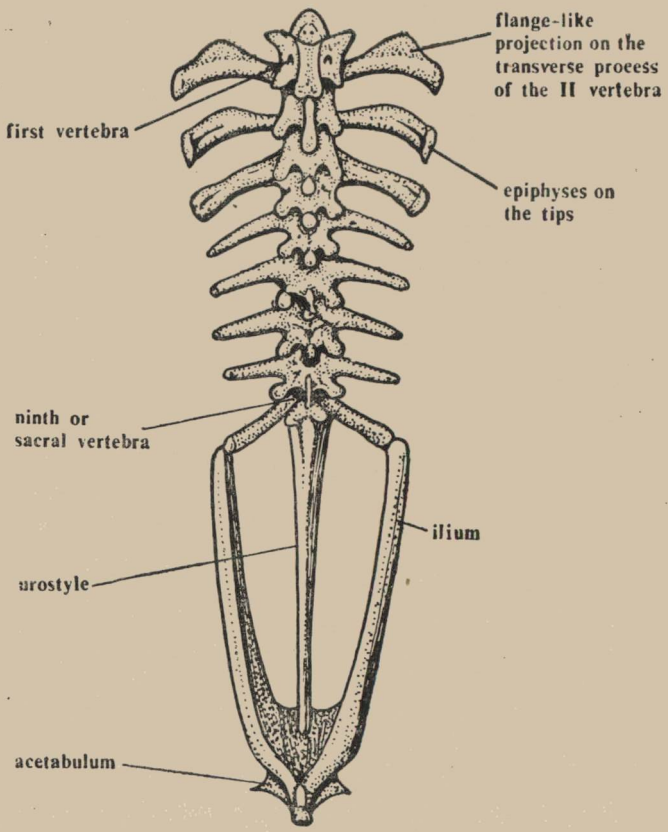


Fig. 3.9 The vertebral column, urostyle and the pelvic girdle of frog.

dorsally. The neural arch is produced in the middle line above into a blunt projection called the **neural spine**. The neural arch further on either side gives off a large outstanding projection (already referred to) called the **transverse process**. It is tipped with cartilage. These cartilaginous epiphyses that are found upon the distal ends of the transverse processes are well distinguished in *Rana tigrina*. The epiphyses upon the third vertebra are very prominent and backwardly directed.

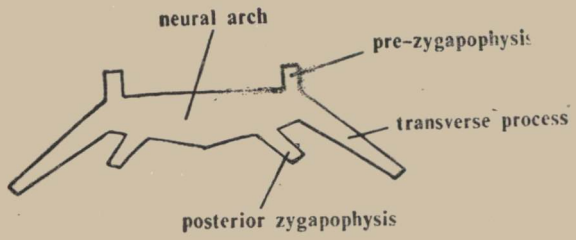


Fig.3.10 The diagrammatic representation of the structure of a vertebra from the dorsal side.

In addition to the transverse processes, the neural arch gives off from its anterior face on either side and just above the origin of the transverse processes, a small shelf-like projection called the **anterior articular process** or the **anterior zygapophysis** or the **pre-zygapophysis** (Pl. Zygapophyses). The upper surface of each anterior zygapophysis is flat and smooth and covered with a thin layer of cartilage. A similar pair of processes called the **posterior zygapophyses** or **post zygapophyses** arise from the posterior face of the neural arch. These are directed backwards and outwards.

In their normal position it will be noticed that the convex posterior face of the foremost centrum fits into the concave anterior face of its successor like a cup and ball. At the same time the posterior zygapophyses of the first fit over the anterior zygapophyses of the second. All the neural arches of the vertebrae are joined together to form a continuous long canal, the neural canal which encloses the

spinal cord. The vertebrae can be moved upon one another either up and down or from side to side.

When the vertebrae are seen in their natural position it will be noticed that the centra and the articular processes are the parts of the vertebrae which are in contact. Certain gaps are to be seen between the side of the arches. These gaps are bounded by the articular processes above and the centra below. These spaces so formed are referred to as the **inter vertebral foramina** and through them the nerves emerge from the spinal cord.

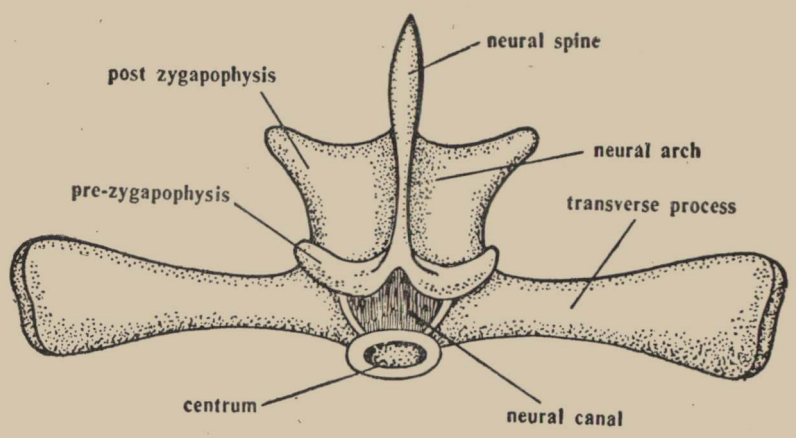
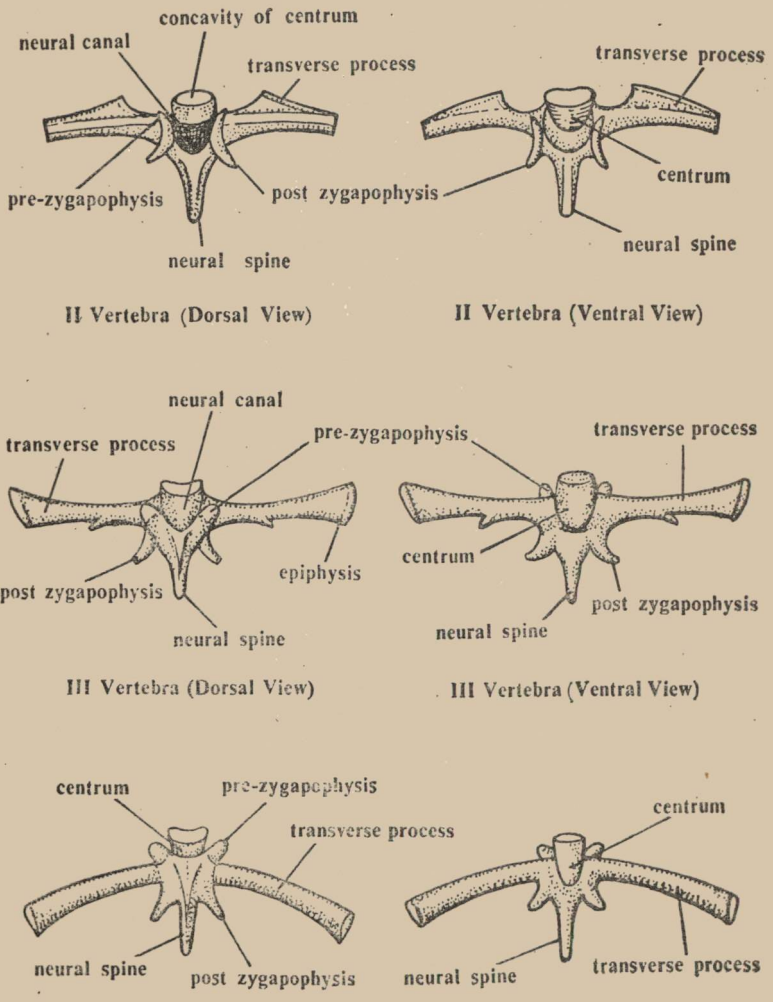


Fig. 3.11 A typical vertebra of frog.

The second to the seventh vertebrae exhibit in all essential details, the structure mentioned above. These typical vertebrae can however be further distinguished with each other by the form and direction of their transverse processes. For example, the transverse processes of the **second vertebra** are directed slightly forward. The transverse processes of the **third vertebra** are strong and directed outwards at right angles to the vertebral column. The transverse processes of the **4th, 5th, 6th** and **7th vertebrae** are directed backwards.

The structure of the first, eighth and the ninth vertebrae is as follows :

Typical Vertebrae (II to VII)



II Vertebra (Dorsal View) II Vertebra (Ventral View)

III Vertebra (Dorsal View) III Vertebra (Ventral View)

IV to VII Vertebrae (Dorsal View) IV to VII Vertebrae (Ventral View)

Fig. 3.12 Typical vertebrae of frog. (A) II vertebra, dorsal and ventral views. (B) III vertebra dorsal and ventral aspects. (C) IV to VII vertebrae dorsal and ventral views.

I Vertebra or Atlas : The first vertebra is found immediately behind the posterior region of the skull. The first vertebra of all vertebrates is commonly called the **atlas** vertebra. (Derived from (Gk.) *atlao* : I endure or sustain). Atlas was the name of a Greek God who was supposed to bear the weight of the earth on his shoulders. As mentioned above, the first vertebra bears the burden of the entire skull and hence is referred to as the atlas.

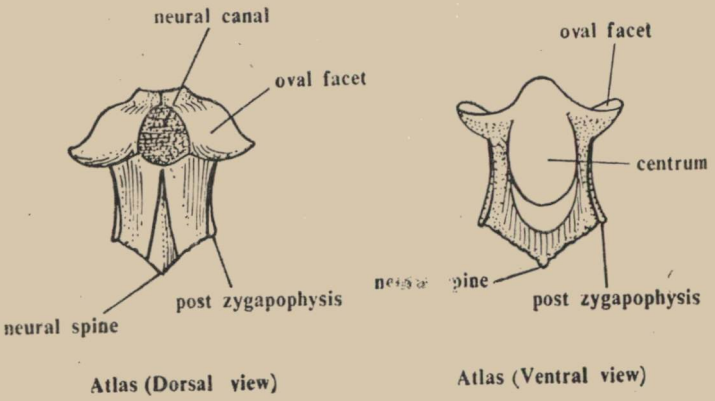


Fig. 3.13 Atlas—First vertebra, dorsal and ventral views.

The first vertebra is very small and ring-like. It is devoid of the transverse processes and the anterior zygapophysis. It has however a slightly developed posterior zygapophysis. The neural spine

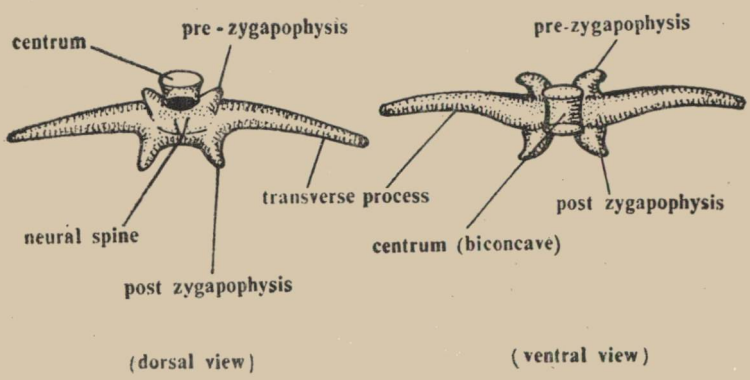


Fig. 3.14 The eighth (VIII) vertebra—Dorsal and ventral aspects.

is present. It has a small centrum which on its anterior face bears two large **oval shaped** or **cup-like facets** into which the occipital condyles of the skull fit.

The eighth vertebra: The anterior and the posterior faces of the centrum of the eighth vertebra are concave. Such a type of centrum having biconcave faces is called an **amphicoelous centrum**. The transverse processes of the eighth vertebra lie at right angles to the spinal column.

The ninth vertebra: The centrum of the ninth or the sacral vertebra has a convex anterior face which fits into the concave posterior face of the eighth vertebra. The posterior face of the centrum of the ninth vertebra bears two **convex projections** or **condyles** which fit into similar depressions found at the anterior end of the urostyle. A centrum which is convex at its either end is called

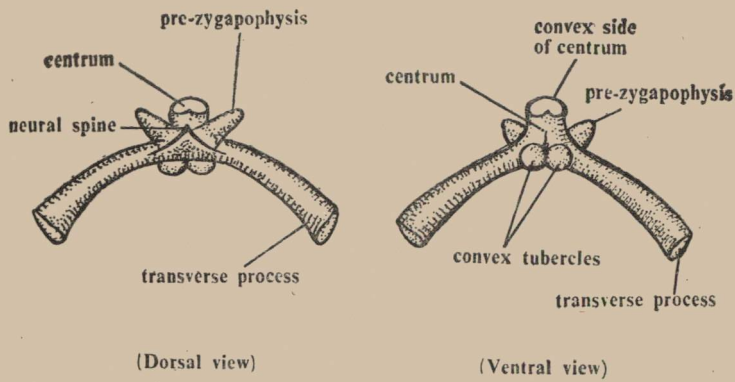


Fig. 3.15 The ninth (IX) Vertebra—Dorsal and ventral views.

acoelus. The anterior zygapophyses are present and articulate with the posterior zygapophyses of the eighth. Posterior zygapophyses are absent for the obvious reason that there are no anterior zygapophyses of a succeeding vertebra to articulate with. The transverse processes are thick and strong. They are directed backward at an angle of about 45°. These transverse processes articulate with the ilia of the hip girdle or the pelvic girdle.

Urostyle: The urostyle is a structure formed by the fusion of vertebrae. The urostyle is in the form of a long bone with a gradually diminishing **ridge** or **crest** along its dorsal surface. At the anterior

end of the urostyle, two concavities or depressions are found which fit into the posterior double condyles of the ninth vertebra. Above these depressions there is found a narrow deep cavity into which the terminal part of the spinal cord runs. Some distance behind the

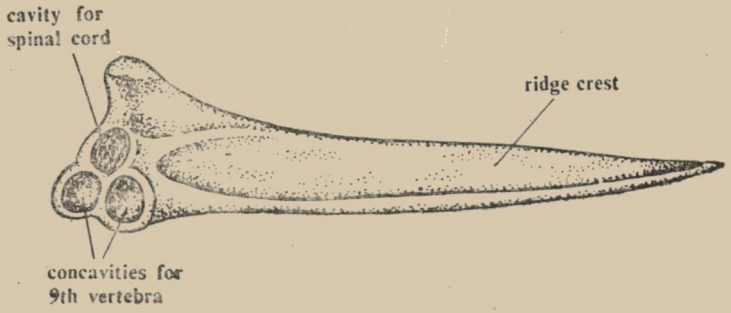


Fig. 3.16 The urostyle of frog.

anterior end of the urostyle there is on each side, a small aperture for the exit of the last spinal nerve (X spinal nerve). These apertures are however very imperfectly developed or sometimes absent on one or both sides of the urostyle in *Rana tigrina*. The posterior narrow end of the urostyle rests on the middle region of the pelvic girdle i.e., in the depression found at the site where the two halves of the pelvic girdle meet.

The Appendicular Skeleton:

The appendicular skeleton of the frog consists of the **pectoral** (or **shoulder**) and **pelvic** (or **hip**) **girdles** and the bones of the **fore** and **hind-limbs**.

The Pectoral Girdle: The pectoral or shoulder girdle of frog is in the form of an incomplete hoop and encircles the region of the trunk. The pectoral girdle primarily supports the fore-limbs but it should also be remembered that it protects the heart which lies immediately beneath it and also the lungs.

The pectoral girdle consists of two symmetrical halves which meet in the mid-ventral line but open in the mid-dorsal region. It will be noted that on each side the fore-limb is articulated to the pectoral girdle through a socket called the **glenoid cavity**. The

glenoid cavity found on each side of the pectoral girdle is formed at the junction of the following skeletal pieces.

The bone radiating upwards from the glenoid cavity is the **scapula**, which forms the bend of the pectoral girdle on the ventral side. At the anterior end of the scapula is found a projection called the **acromion process**. On the dorsal side of the scapula is a large flat plate of cartilage called the **supra scapula**. It is partially calcified.

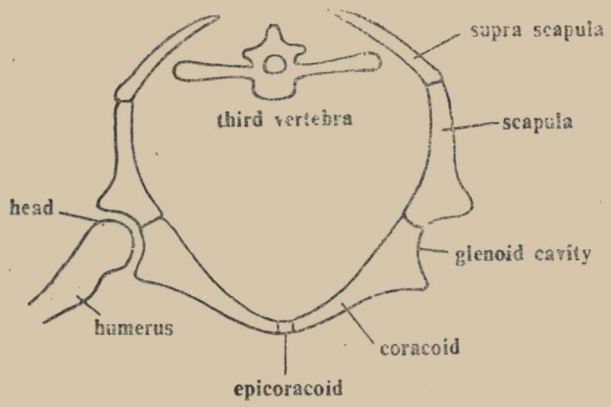


Fig. 3.17 Diagrammatic transverse section passing through the pectoral girdle of frog.

The skeletal piece along the posterior margin of the glenoid cavity, which radiates inwards and downwards is called the **coracoid**. In the mid-ventral line between the coracoids of the two sides are found two narrow strips of cartilage called the **epicoracoids**. In *Rana tigrina*, however, the inner ends of the coracoids overlap each other; hence the epicoracoids are not distinctly visible. A narrow bar of cartilage called the **pre-coracoid** arises from the anterior corner of the glenoid cavity or from the inner end of the scapula. It runs inwards toward the middle-line, not quite meeting its fellow from the opposite side. Actually only a narrow strip of pre-coracoid is visible, because a thin bone clavicle is wrapped round it. Further it will not be distinct in a dried specimen. The **clavicle** is a small membrane bone which lies one on each side of the pectoral

girdle. One end of the clavicle is closely applied to the antero-ventral side of the coracoid and the other end of it towards the scapula is bent almost at right angles and is found attached to the acromion process of the scapula. Between each clavicle, precoracoid and the coracoid is found a large vacuity or fenestra called the **caracoid foramen** or **fontanelle.**

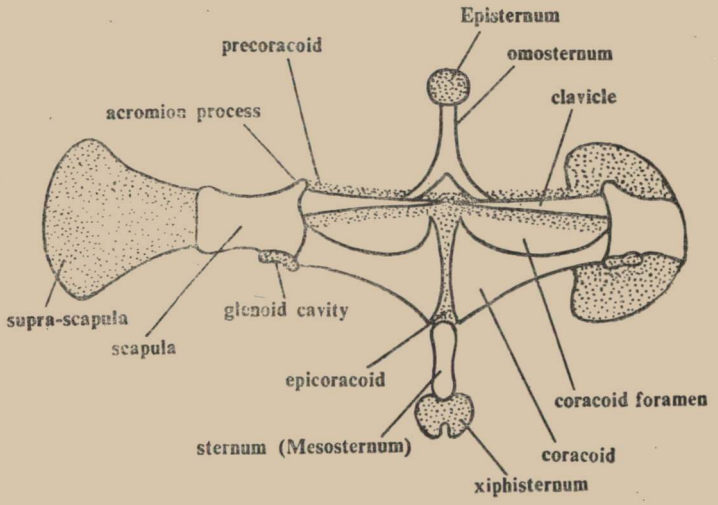


Fig. 3.18 Pectoral girdle of frog.

The mid-ventral region of the pectoral girdle forms the sternal portion or the **sternum.** The sternal region consists of a series of two bones and cartilage. Attached to the inner ends of the clavicles and projecting forward is a small λ shaped bone called the **omosternum.** It is capped by the circular cartilaginous **episternum.** At the posterior ends of the coracoids and projecting backwards is the bone variously called the **sternum, mesosternum** or **xiphisternum.** This also is tipped with an expanded bi-lobed cartilage called the **xiphisternum** or **xiphoid cartilage.** The terminology is confusing as regards the xiphisternum which may either refer to the bone or its terminal cartilaginous tip. It is however more appropriate to call the bone, the **sternum** or **mesosternum** and the cartilage, **xiphisternum.**

The Pelvic Girdle :

The pelvic (or hip) girdle, like the pectoral is an incomplete hoop around the posterior part of the body intermediate between a U and V, made of two similar halves that are united at a *symphysis*. The pelvic girdle in frog has been modified in accordance with the jumping habits of the animal. It is dorsal in position and lies almost in line with the backbone. The conspicuous hump on the back of the frog marks the point of attachment of the pelvic girdle to the backbone.

On either side of the body of the girdle is a concave depression called the **acetabulum** by means of which the hind limbs articulate with the girdle. Like the glenoid cavity, this socket is found at the junction of three skeletal pieces, two bones and one cartilage.

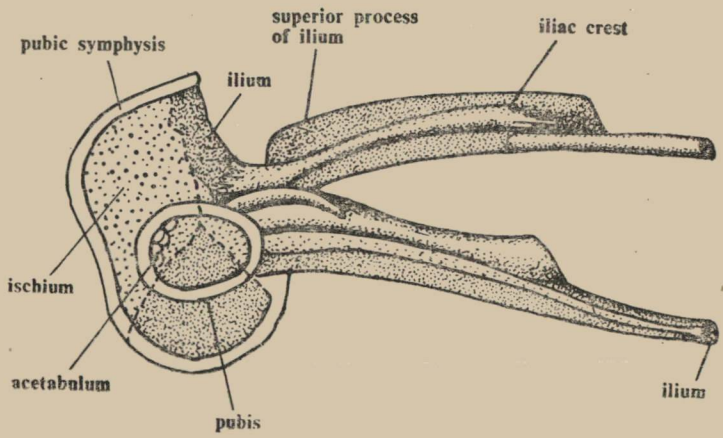


Fig. 3.19 Complete view of the pelvic girdle of frog.

Of these, the anterior and upper one is called the **ilium**. It is a long bone in the form of a shaft, attached in front to the transverse process of the ninth or sacral vertebra of the same side; behind, it spreads out to share in the formation of the circular portion of the girdle. The arm of the ilium has along its upper edge a vertical ridge called the **iliac crest**. The posterior skeletal element of the acetabulum is called the **ischium** and on the ventral side of the acetabulum is found the **pubis** (Pl. Pubes.) It is a calcified cartilage.

The ilia, ischia and pubis of the two sides become united in the median plane to form a strong **symphysis.** The arms of the ilia only remain separate, thereby the figure of the pelvic girdle appears like a U or V.

The Limbs :

The fore and the hind-limbs of frog belong to the type known as **pentadactyle** or five-digited, as distinct from the **fin type** of fishes. Pentadactyle limbs need not always have five digits. The reduction in the number of digits may occur but that the limbs are built on the five digit plan.

The limbs of frog have the usual parts met with in other vertebrates. The fore-limb consists of an **upper arm, fore arm, wrist** (**carpus**) and **hand** (**manus**). The hind-limb consists of **thigh, leg** (**crus** or **shank**), **ankle** (**tarsus**) and **foot** (**pes**).

The Generalised Structure of a Pentadactyle Limb :

The general arrangement of the skeleton of the pentadactyle limb in the vertebrates is as follows :

As regards the fore-limb, the skeleton of the **upper arm** consists of a single long bone, the **humerus.**

The fore-arm consists of two bones—the **radius** and **ulna.** The wrist or carpus is composed of **nine small bones** called the **carpal bones.** These are arranged in three rows. In the proximal row, there are three bones, the **radiale** (next to the radius), the **intermedium** in the middle, and the **ulnare** (next to the ulna). The middle row consists of a single **centrale.** The distal row is formed of five bones referred to as **carpale one to five.** In the **hand** (or **manus**) the bones are arranged in two series. First, a series of five **metacarpals** forming the palm of the hand, are found. The metacarpals are followed by a series of **phalanges** which are arranged in rows and form the skeleton of separate digits or fingers. The number of phalanges varies. The **first** or **pollex** has two phalanges whereas the other digits are of three phalanges each.

The hind-limb skeleton consists of precisely the same arrangement of bones but receive different names.

The first part of the hind-limb, the **thigh** consists of a single bone, the **femur**. The **leg** (shank or crus), is composed of two bones, the **tibia** and the **fibula**. The **ankle** (tarsus) consists of nine small bones, the **tarsal bones** arranged in three rows. The proximal row of tarsals consists of **tibiale**, **intermedium** and **fibulare**. The distal row comprises **tarsale one to five**. The bones of the **foot** or **pes** are called the **metatarsals** and that of the digits or toes, the **phalanges**. The first digit is called the **hallux**. On the various bones of the limbs projections may be found. The projections found on the humerus are called **tuberosities** and those present on the femur are called the **trochanters**.

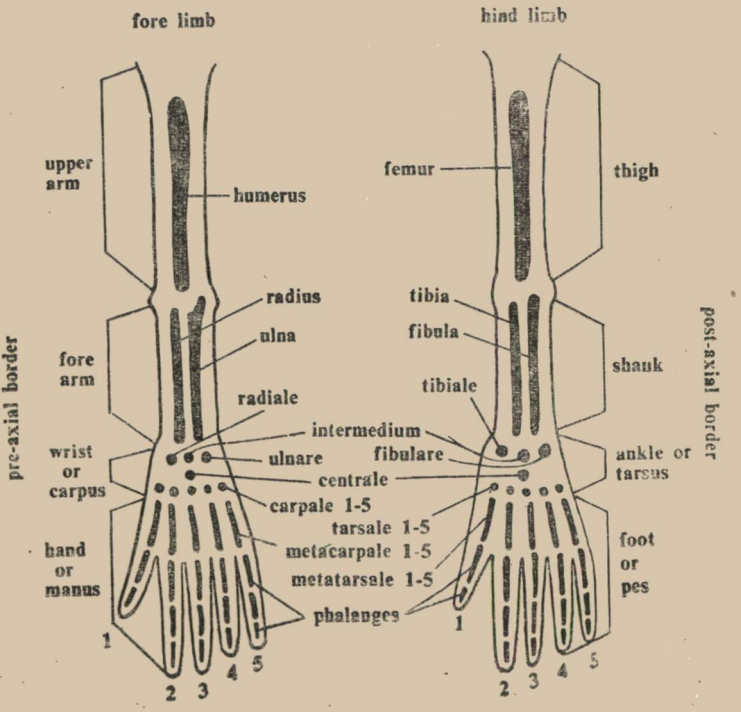


Fig. 3.20 The generalised structure of pentadactyle (fore and hind) limbs.

In the case of both the limbs, the side of the limb which bears the first digits (pollex in fore-limb and hallux in the hind-limb) is spoken of as the **pre-axial** side or border and the other as the **post-axial.** The skeleton of the fore-limb and the hind-limb of frog will now be described.

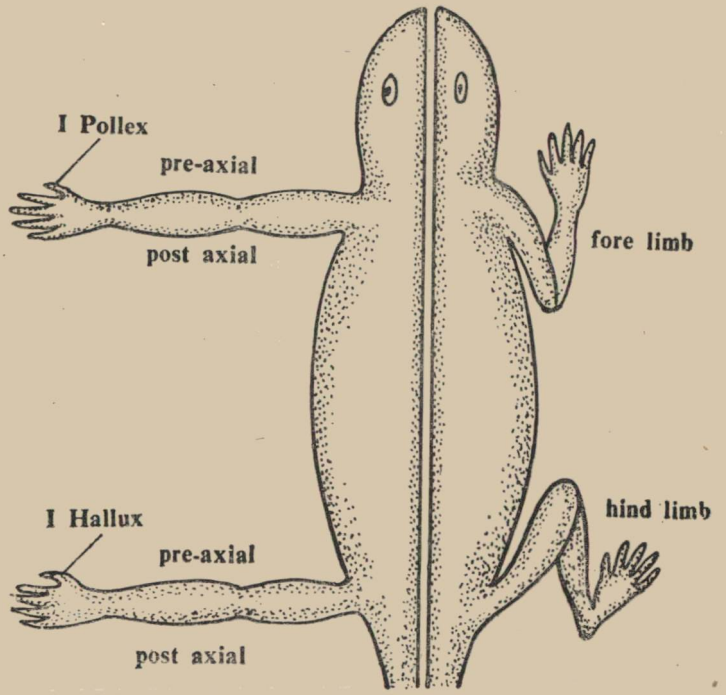


Fig. 3.21 The pre-axial and post-axial sides or borders of the limbs shown diagrammatically.

The Fore-limb of Frog :

The upper arm bone of the frog is the **humerus.** It is in the form of a simple slightly curved shaft swollen at each end. The proximal end (nearest to the body) is called the **head** which fits into the glenoid cavity of the pectoral girdle. The distal end (away from the body) is referred to as the **trochlea.** The trochlea articulates with the bone of the fore-arm. Along the proximal half and on the anterior side (pre-axial) is a prominent ridge on the shaft of humerus. It

is called the **deltoid ridge** to which the strong deltoid muscle from the scapula is attached. The contraction of this muscle obviously raises the arm. The fore arm consists of a single bone formed by the fusion of two bones—radius and ulna ; hence the name **radio ulna** is given to it. This indicates that the two bones are concerned in its make up i.e., radius and ulna. Although fused, it looks like two bones united because of the deep groove present on the back and front, especially at the distal end. In such a short limb of frog it may be noted that one strong fused bone radio-ulna is better than two

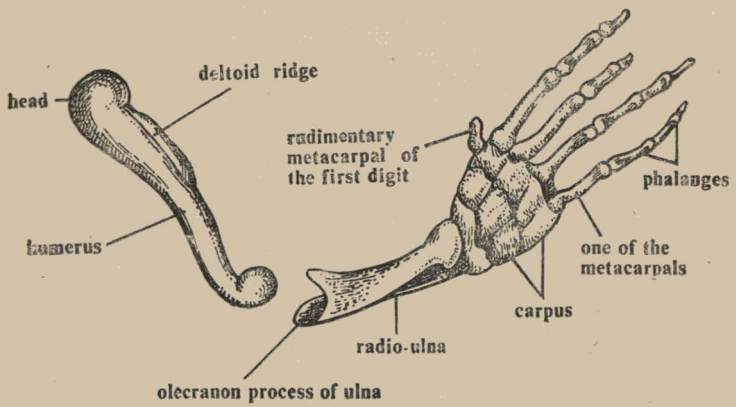


Fig. 3.22 The fore-limb of frog.

slender ones where the shock in alighting from a jump must be met. The radial half of the bone is pre-axial and the ulnar half post axial. The proximal end of the radio-ulna bears a depression called the **olecranon notch.** The trochlea of the humerus articulates with this notch to form the **elbow joint.** The ulnar region behind the olecranon notch is produced into a small **olecranon process.** The olecranon process and the proximal end of the ulnar portion are rather rough for muscle attachment. Muscles (triceps of the arm), coming from the scapula and the humerus round the elbow are attached here. The effect of contraction of these muscles will of course be to straighten the arm.

The wrist bones or carpals will hardly be distinguishable in a dried preparation as the fragments of ligaments hide them. The

carpal bones in frog's wrist are **six in number** arranged in two rows of three. Proximal carpals consist of a **radiale** (towards the radius), **intermedium** in the middle and ulnare (towards the ulnar part) and the distal carpals are 1, 2, and (3+4+5). The proximal row of carpals articulates with the distal end of the radio-ulna and the distal row with the first row of bones of the hand region or the metacarpals.

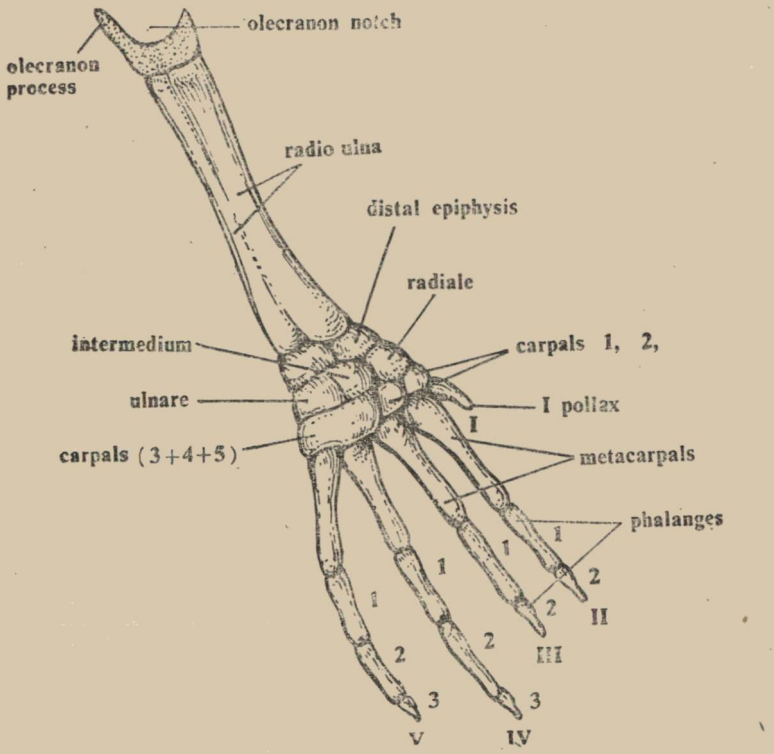


Fig. 3.23 Radio-ulna, carpals, metacarpals and phalanges of the fore-limb.

The palm of the hand consists of five **metacarpals**. No digit bone or phalanx is attached to the first metacarpal. The first digit or **pollex** in frog as such is quite rudimentary. The fore-limb of frog as such consists of four digits only (i.e., 2—5). The second, third, fourth and fifth digits have respectively 2, 2, 3, and 3 phalanges. The proximal phalanx of each digit articulates with the corresponding

metacarpal. The number of phalanges in a digit are expressed usually in the form of a **digital formula**, which in the case of frog is as follows. 0, 2, 2, 3, 3, in which the figures give the number of phalanges respectively of digits, *I*, *II*, *III*, *IV* and *V*.

Digital formula of the fore-limb of frog		*I*	*II*	*III*	*IV*	*V*
=	digits					
	phalanges	0	2	2	3	3

The Hind-limb of Frog :

The hind-limb of frog is distinct in being larger than the fore-limb. The hind-limb is about three times the length of the fore-limb. The relative length of it is a distinct advantage in frog's swimming movements which are chiefly those of the hind-limbs. The length of the limb is also associated with the mode of progression i. e., hopping.

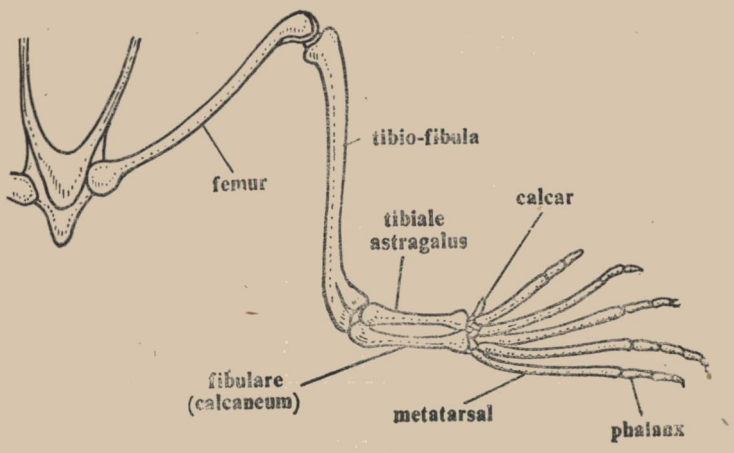


Fig. 3.24 The hind-limb of frog.

The **femur** or thigh bone is in the form of a slightly sinuous (sigmoid) shaft with each end of it being rounded. The proximal end or the **head** articulates with the acetabulum. The distal end of femur is somewhat broader and less globular than the head. This end articulates with the shank bone or tibio-fibula.

The leg or shank bone like the radio-ulna of the fore-limb is a compound bone formed by the fusion of tibia and fibula and

is therefore called the **tibio-fibula.** It's compound nature is evident from a groove seen on its surface. The groove however is less pronounced than in the case of the radio-ulna. The tibio-fibula is expanded towards the ends. The joint between the femur

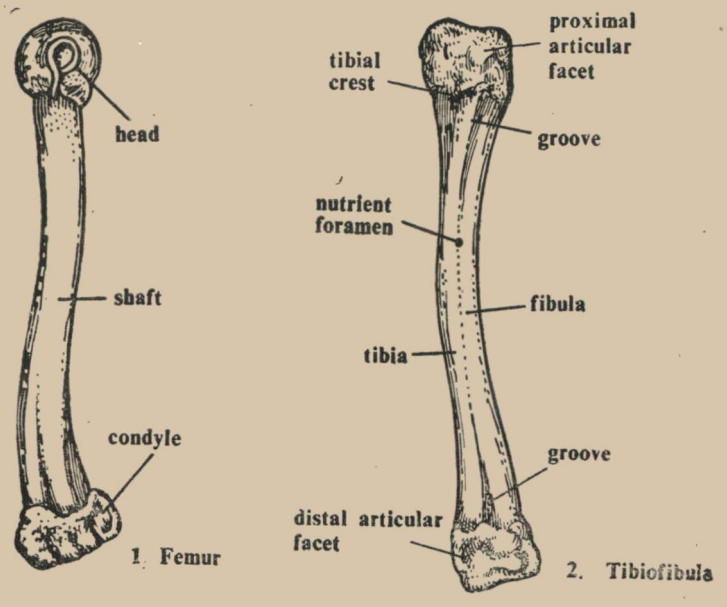


Fig. 3.25 The femur and tibio-fibula of frog.

and tibio-fibula is effected by two globular surfaces. The two surfaces are held together by a 'cap' of ligament which practically restricts movements to the lateral plane allowing the knee to be bent outwards only.

The ankle bones or tarsals, just as in the case of wrist consists of two rows; in each row are two bones. The proximal row of tarsals consists of two bones called the **tibiale** or **astragalus** and the **fibulare** or **calcaneum.** They are greatly elongated adding thereby to the length of the hind-limb and also enhance the leaping capacity of frog. The astragalus and calcaneum are united together at the two ends by common epiphyses, with a space in the middle. The astragalus is on the pre-axial or tibial side and the calcaneum on the

post-axial or fibular side. The distal row of tarsals consists of two very small bones and can be best seen on the upper side of the skeleton of the ankle. They lie next to the first three digits, i. e., on the pre-axial side.

The foot consists of five toes and also an extra toe called the **calcar** or **pre-hallux**. The pre-hallux consists of a very small metatarsal to the end of which, sometime one and at times two bones are attached. The calcar or the pre-hallux, does not however, appear externally.

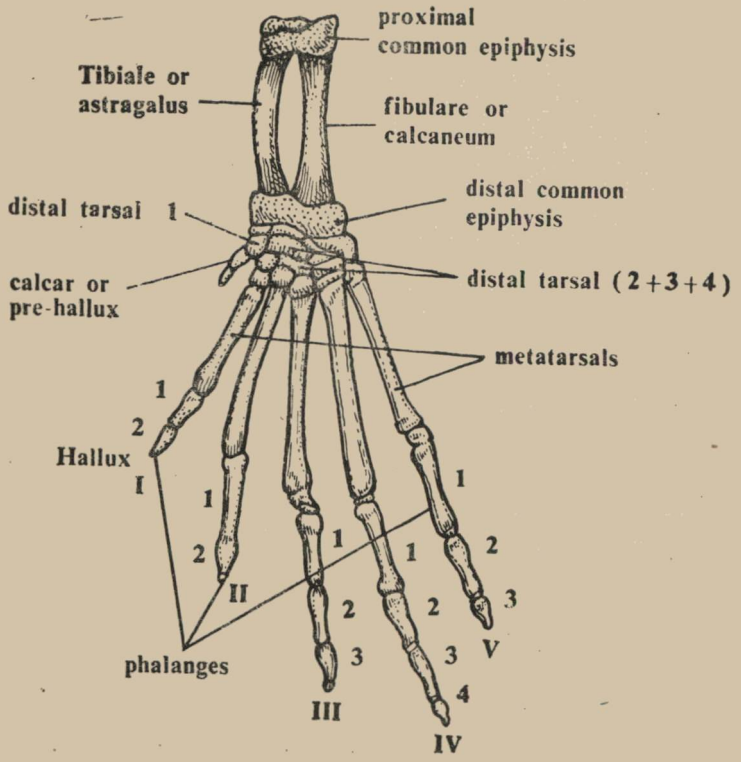


Fig. 3.26 Tarsals, metatarsals and phalanges of the hind-limb of frog.

There are five **metatarsals** in the foot, the five digits or the toes articulate with their corresponding metatarsals. The first toe is

called the **hallux** and is pre-axial. A number of phalanges are found in the digits. The number of phalanges in each digit is as follows :

The first (hallux), two, the second, two, the third, three; the fourth, four and the fifth, three.

		I	II	III	IV	V
Digital formula of the hind-limb of frog	digits					
	phalanges	2	2	3	4	3

JOINTS AND MUSCLES

Joints : You have studied the details about the skeletal system of frog. It has been noted that many parts of the skeletal system fit into or fit against one another in certain ways. A **joint** is formed by the fitting together of two or more bones. Three different types of joints are recognised i. e., **perfect**; **imperfect** and **immovable.**

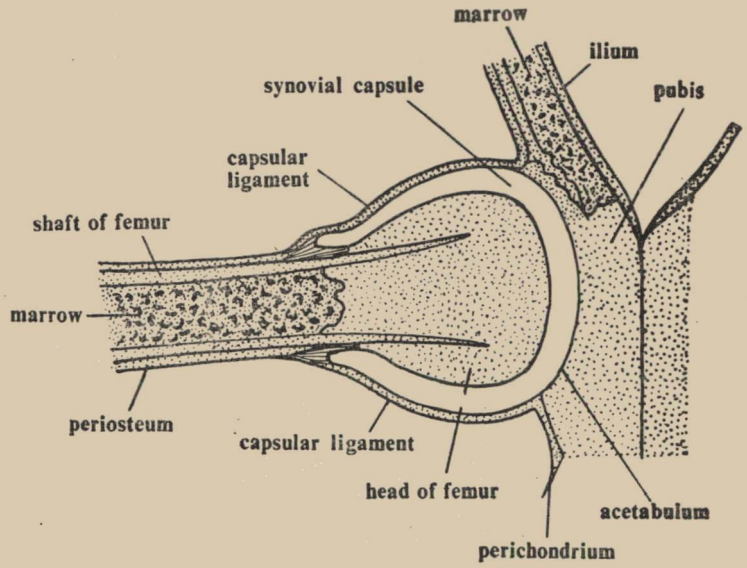


Fig. 3.27 Horizontal section of a frog's hip joint (Ball and socket joint).

A **perfect joint** is one which permits free movement at the point of the union between the bones. The hip joint is a good example of a perfect joint.

It was mentioned that the hip girdle or the pelvic girdle has on either side, a cup-shaped depression called the acetabulum. The round head of the femur fits into the depression of the acetabulum accurately but rather loosely. The acetabulum is lined by a thin layer of connective tissue, the perichondrium. Likewise, the head of the femur too is covered by the perichondrium. The perichondrium is further continued on the adjacent bone where it is referred to as the periosteum.

The covering of the perichondrium on the head of the femur and lining of the same in the acetabulum helps in the smooth working of the joint. Attached to the round rim of the acetabulum is found a strong sheet of connective tissue called the **capsular ligament.** It forms a sort of short fibrous tube. The other end of the capsular ligament is fixed to the femur just below the head. The capsular ligament, further, is continuous in each case with the perichondrium also. A space is left all round between the head of the femur on the inside and the ligament and the acetabulum on the outside. This space is called the **synovial capsule.** The synovial capsule is filled with a watery fluid called the **synovia** which plays the role of a cushion between the bones forming the joint. The synovia thus protects the bones from friction by keeping them apart and the capsular ligament holds the bones together and as such prevents their dislocation. The example of hip joint is a type of joint in which the rounded head of the femur fits into a cup or socket of the acetabulum. It is called a *ball and socket joint.* This type of joint allows the upward, downwards and side movements of the femur and also the femur is capable of certain amount of rotation. The ball-and-socket joints as such permit movement in any plane. A similar but less perfect type of ball-and-socket joint is that of the shoulder joint. The glenoid cavity is the socket into which the round head of the humerus fits.

The shallow type of ball-and-socket joint is also furnished by the vertebrae. As was mentioned, the convex posterior end of one centrum fits into the anterior concave surface of the centrum of adjacent vertebra and further the two centra are bound together by a ligament. This offers a shallow ball-and-socket joint which provides a very limited range of movement.

The other types of perfect joints seen in frog are the **hinge joints** and the **gliding joints**. The general plan in both these types of joints is the same as noticed in the ball-and-socket joints. The bones are covered with a cartilage and remain separated by a synovial capsule. They are further held together by the capsular ligaments. The example of the hinge joints are the **elbow** and the **knee** joints. These joints however are capable of movement in one plane only—that is up and down, but not from side to side. This restricted movement is partly due to the form of adjacent surfaces and partly to the mode of attachment of the ligaments.

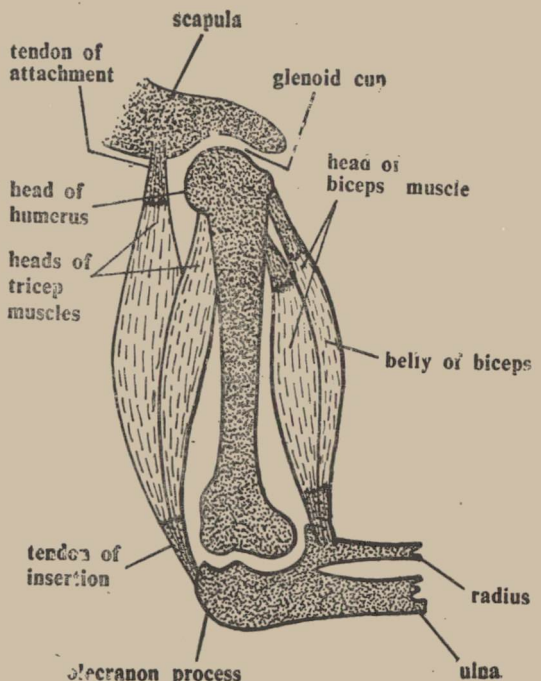


Fig. 3.28 The shoulder joint in man.

The example of gliding joint is furnished by the articulating processes or zygapophyses of the vertebrae. There are synovial capsules between the articulating processes and the ligaments holding them together. These zygapophyses are capable to glide on each other either up and down or from side to side to a limited extent. Strong ligaments connect the neural arches with one another and the first vertebra is joined to the skull through the ligaments.

In all the cases where free movement is essential, joints are formed in the manner described above. In these joints, the bones are held together by ligaments and a synovial capsule is interposed between their adjacent cartilage-covered surfaces.

Imperfect Joints:

In the regions where little or no movement is requited such as between the bones of the shoulder and hip girdles **imperfect joints** are found. In the imperfect joints, the two adjacent bones are united by cartilage or ligament only. The synovial capsule is absent.

Immovable Joints:

In the case of immovable joints no movement at all is permitted. Such joints are referred to as **sutures.** The bones in this case are directly and firmly united with one another and no intervening material is found. The joints between the bones of the skull are the examples of **immovable joints.**

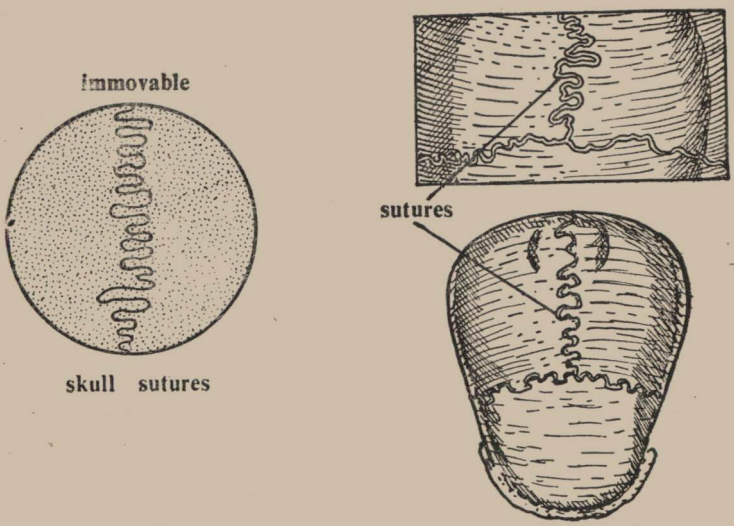


Fig. 3.29 Immovable joints—(Sutures).

Muscles:

When the skin of frog is removed, it will be noticed that under it and separated from it by the lymph spaces, is a nearly colourless, semi-transparent fibrous substance called the **flesh.** It is superficially covered by a thin transparent sheath called the **fascia.** The flesh underlying the fascia consists of a number of separate bands. **The**

separate bands are the **muscles.** The various muscular bands are separated from one another by a kind of packing substance known as the connective tissue. It is delicate and transparent. Thus, it will be clear that whole of the flesh is made up of distinct muscles readily separated from one another.

The muscular tissue consists of fine threads or fibres arranged in bundles. The muscles perform contraction. The co-ordination in the working of muscles is directed by the nervous system. On each muscular fibre or group of fibres are found the end plates of the nerves that convey the impulses to stimulate the muscles to act. The contraction of the muscles also takes place when a mechanical, chemical, thermal or an electrical stimulus is applied to it.

Muscles can be distinguished as the **voluntary** and the **involuntary** types. The **voluntary muscles** are those which are under the control of the 'will' of the animal e.g., the muscles of the limbs etc. The frog can swim or jump according to its desire or will with the help of the voluntary muscles. The **involuntary muscles** are not governed by the 'will' of the animal. They work without the 'will' and even the knowledge of the animal. The involuntary muscles usually form a part of the wall of some internal organs such as the intestine, stomach, bladder, etc.

Most of the muscles of the body are attached by both ends to bones by means of a dense, white, strong and inelastic band of a connective tissue called the **tendon.** Each skeletal or voluntary muscle has an **origin,** and an **insertion.** The part of the muscle with its tendon, attached to a relatively immovable or less frequently movable part (e.g., any bone), is called the **tendon of origin** or simply **origin.** Likewise, the distal end of this muscle attached to a more frequently movable part (i. e., any bone) is called the **tendon of insertion** or simply **insertion.**

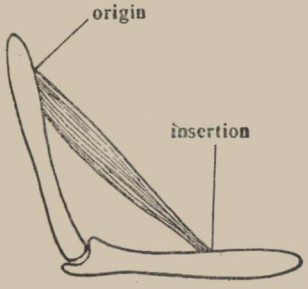


Fig. 3.30 Diagram showing the **origin** and **insertion** of a muscle.

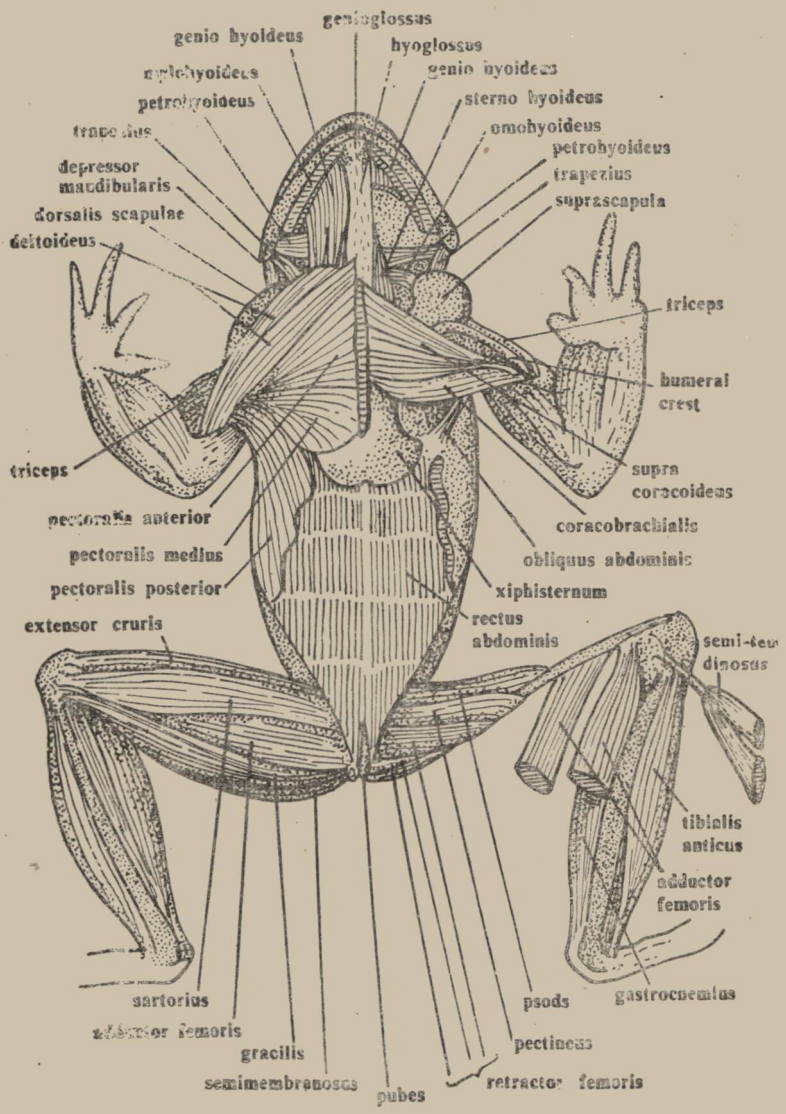


Fig. 3.31 The muscles of the frog on the ventral side (abdomen). The superficial muscles are shown on the animal's right and deeper muscles on the left.

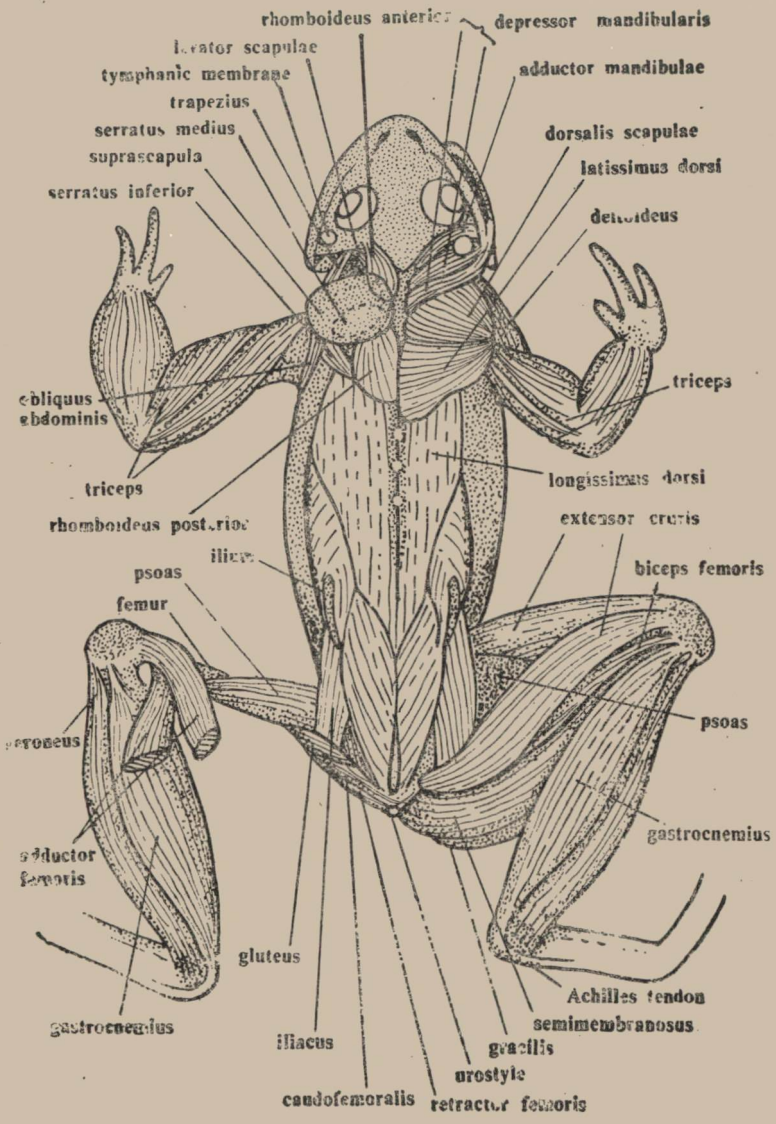


Fig. 3.32 The muscles of the frog on the dorsal side (back). The superficial muscles are shown on the right and deeper muscles on the left.

The following types of muscles are recognised on the basis of the various types of movements they produce.

1. *Extensor* is a muscle which extends or straightens a part e. g., triceps are the muscles which extend the fore-arm or the upper arm.

2. *Flexor* is a muscle which bends (flexes) one part upon another. The muscles that bend the knees or fingers belong to this type. Likewise, bicep muscle flexes fore-arm towards the upper arm.

3. *Adductor* is a muscle which draws or pulls a part towards the axis of body (or of a limb) e. g., *Lattissimus dorsi* draws back the arm.

4. *Abductor* is a muscle which is opposite in action to the adductor. It draws or pulls a part away from the axis of the body (or of a limb) e. g., *deltoid muscle.*

5. *Levator* is a muscle which elevates or raises a part. The *masseter muscle* raises the lower jaw to close the mouth.

6. *Depressor* is a type of muscle which lowers or depresses a part. The *depressor mandibulae* moves the lower jaw down to open the mouth.

7. *Rotator* is a muscle which causes a part to rotate upon another e. g., *pyriformes.*

8. *Sphincter* is a circular muscle which constricts an opening e. g., *pyloric sphincter* and *sphincter ani.*

9. *Supinators* are the muscles which turn an appendage upside down or in the supine position.

10. *Pronotors* are the muscles which turn an appendage back again so that the normal lower surface is down or in the prone position.

11. *Protractor* is a muscle which brings about the forward movement of the limb.

12. *Retractor* muscle brings about the backward movement of the limb.

The majority of muscles act in *antagonistic groups* or pairs. For example, if one set of muscles bends or flexes a portion, there will be its corresponding antagonistic pair of muscles to extend or straighten that portion. The general arrangement of muscles in frog are shown in figures 3·31 and 3·32. On the basis of their general

structure voluntary muscles are of three forms—(i) Broad thin sheet muscles, such as the *external oblique* or *transversus* that form a flexible wall for the abdomen. (ii) Slender ribbon-like muscles, usually with restricted origin and insertion, such as the *biceps* or *deltoidaeus*. (iii) Sphincter muscles where the fibres are arranged circularly as in the *sphincter ani* which constricts to close the anus.

Revision questions

1. Describe the structure of the skull of frog as revealed by its dorsal and ventral sides with the help of well labelled diagrams.
2. Describe in detail with the help of labelled diagrams the structure of the lower jaw and the hyoid apparatus of frog.
3. Explain the terms 'Investing' or 'Membrane bones' and the 'Replacing or Cartilage bones.'
4. Describe the basic structure of a typical vertebra of frog with the help of a labelled diagram.
5. What are the salient features of the 1st, 8th and the 9th vertebrae of frog?
6. Explain the terms 'Procoelous', 'Amphicoelous' and 'Acoelous centra' with suitable examples.
7. Describe the structure of a Urostyle.
8. What is an 'appendicular skeleton' – Describe the structure of the pectoral girdle.
9. Describe the structure of the pelvic girdle of frog and state how its structure is adapted to the leaping mode of progression of frog.
10. Mention in detail the general structure of a pentadactyl limb with the help of diagrams.
11. Describe the fore-limb bones of frog.
12. Describe the hind-limb bones of frog and state how its structure is adapted to hopping.
13. Describe the various types of joints and their function.
14. Enumerate the muscles with their functions on the basis of various types of movements they produce.

CHAPTER IV

TISSUES

Tissues are composed of cells and some of them also contain intercellular substances. The tissues may be in the form of a liquid as in the case of *blood*, hard and stony as *bone*, soft but fibrous as an *areolar connective tissue*.

The study of tissues and their structure is called *histology*.

Tissues can be defined as an organised assemblage of cells and intercellular materials so integrated with other parts of the body that a particular function is performed. Each cell of the tissue cooperates with the other cells of its groups in the performance of a particular function. The tissues are aggregated to form **organs** and the organs are combined to form the **organ system.**

There are four types of tissue

I. Epithelial tissue – derived from all three germ layers.
II. Connective tissue – derived from the mesoderm.
III. Muscular tissue – derived from the mesoderm.
IV. Nervous tissue – derived from the ectoderm.

The various types of vertebrate tissues are discussed below.

I. The Epithelial Tissues :

An epithelium is a sheet of cells that covers an external surface or lines an internal surface.

Directly beneath an epithelium, and attached to it, is a (usually thin) **basement membrane.** This is a sheet of non-cellular material which serves to support and bind down the epithelium.

The chief function of the epithelial tissues is protection, such as preventing the loss of body fluids or the invasion of foreign material. Some epithelia have secretory activity particularly those lining the glands are primarily secretory. The epithelia are further intimately concerned in the processes involved, in respiration, assimilation of nutrient

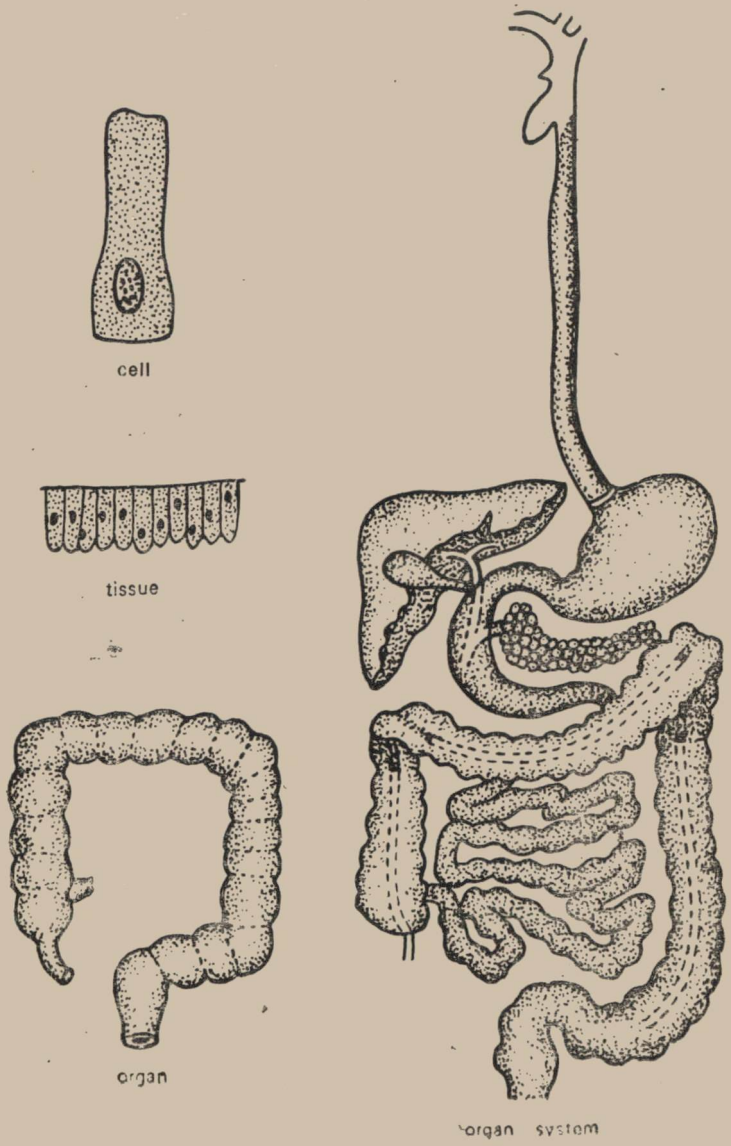


Fig. 4.1 Diagrams showing the relations between cells, tissues, organs and organ system.

materials, eliminatian of wastes, reception of stimuli and reproduction.

Kinds of Epithelial Tissues :

The epithelial tissues are classified on the basis of the form and arrangement of the cells. Further, on the basis of the presence of one or more than one layer of cells, two types of epithelial tissues are established. The type of tissue which consists of a single layer of cells is called a **simple epithelium**. The tissue which consists of more than a single layer of cells is referred to as **stratified epithelium.**

The form and structure of the various types of simple epithelia are as follows.

Simple epithelia, are the tissues consisting of a single layer of cells. On the basis of the shape of the cells, they are distinguished into **simple columnar, simple squamous** and **simple cuboidal epithelia.**

Simple Columnar Epithelium :

Simple columnar epithelium consists of cells which are distinctly taller than they are wide. They are placed side by side like columns with their long axes perpendicular to the surface.

In certain single cells of a simple columnar epithelium, mucinogen droplets are accumulated due to which the free or distal end of such cells is much distended. Such distended columnar cells are called the **goblet cells.** Goblet cells occur abundantly in the lining of the intestine where they liberate their secretion as mucin which together with water forms a layer of mucus, covering the lining of the gut.

The columnar epithelium is found lining the digestive tract and many small glands in the wall of the stomach and intestine of vertebrates.

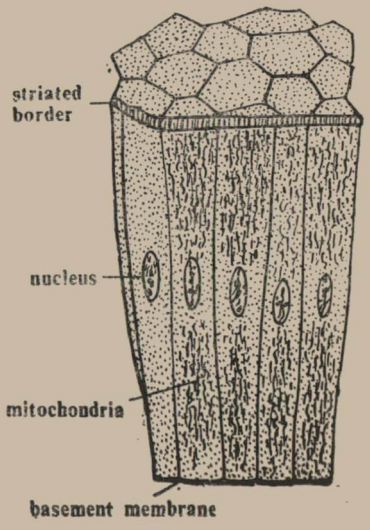


Fig. 4.2 Simple columnar epithelium.

Pseudo-stratified Columnar Epithelium :

The term **pseudo-stratified columnar epithelium** is commonly applied to a single layer of columnar cells which apparently resemble a stratified type. All the columnar cells giving such a type of stratified

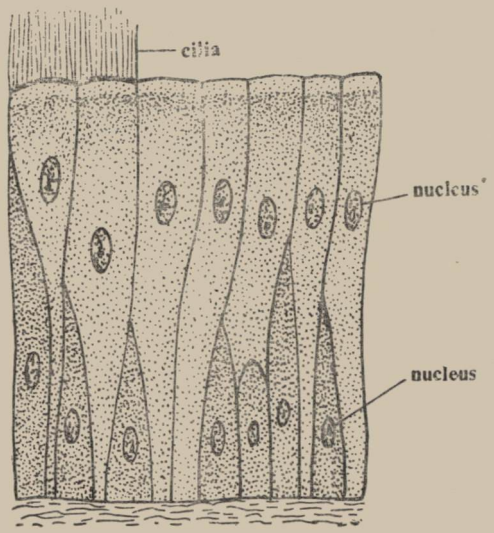


Fig. 4.3 Vertical section passing through a pseudo-stratified columnar epithelium. On the left are seen two ciliated cells which commonly occur in epithelia of this type.

appearance rest upon a common basement membrane. The apparently superficial cells which are elongated have a long tapering proximal portions. The polyhedral or fusiform smaller cells of various sizes fill in the gap amongst the long tapering proximal portions of the elongated cells. This type of arrangement of the columnar cells gives the false appearance of many layers of cells hence such type of columnar epithelium is known as **pseudo-stratified columnar epithelium**.

Pseudo-stratified columnar epithelium forms the lining of the trachea and bronchi of mammals.

Simple Squamous or Pavement Epithelium:

The term squamous means scaly. The **simple squamous epithelium** is composed of flattened, plate-like cells joined edge to edge like the paving stones of a foot-path. In the cells of a squamous epithelium, the cytoplasm is so scanty that the nucleus which is centrally placed, causes a slight bulge.

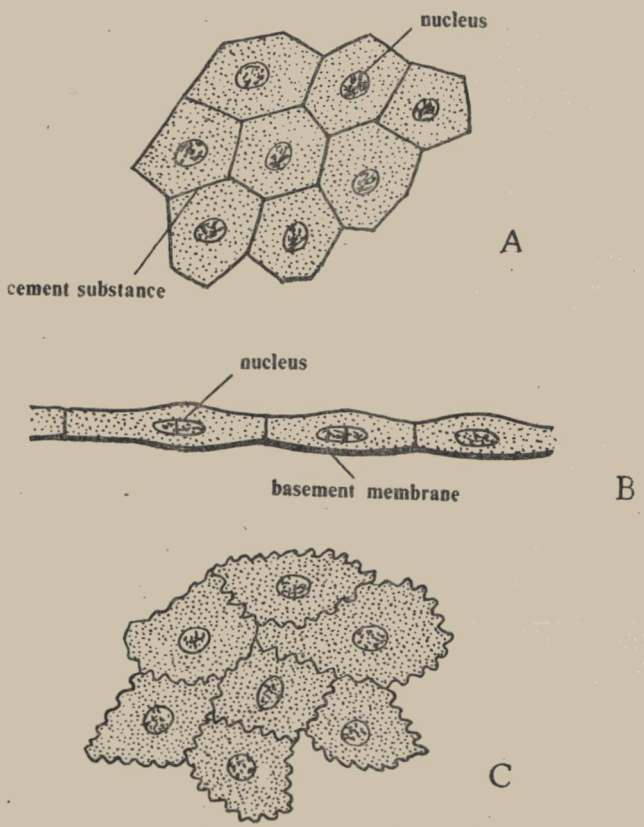


Fig. 4.4 Simple squamous epithelium
(A) Surface view (B) Vertical section (C) Tessellated type.

In some cases, the boundaries of the cells are irregular with wavy outlines which interlock with the corresponding irregularities

in the adjacent cells. Such squamous epithelium is said to be **tessellated.**

A simple squamous epithelium is found forming Bowman's capsule and the thin loop portions of the uriniferous tubules of the kidney. Simple squamous epithelium is also seen forming portions of the respiratory surfaces of the lungs and gills.

Simple Cuboidal Epithelium :

Simple cuboidal epithelium resembles a simple columnar epithelium except that the cells are of lesser height and their height almost equals their width. The cells in section appear as rough squares.

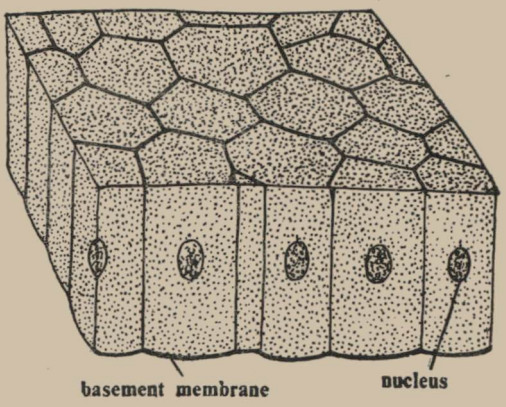


Fig. 4.5 Simple cuboidal epithelium.

Some of the portions of the excretory ducts of many glands and the uriniferous tubules of the kidney consist of cuboidal epithelium. Cuboidal cells lining various ducts may have a **striated** or **brush border** distally. or the cilia may also extend from the free surfaces of the cells.

Stratified Epithelia or Compound Epithelia :

The cells in the stratified or compound epithelia are several layers deep. The stratified epithelia are classified on the basis of

the shape and arrangement of the cells, with the emphasis on the type of cells forming the superficial layer.

The stratified epithelia are classified into the following types.

Startified Squamous Epithelium :

This type of stratified epithelium serves as a protective membrane. At the superficial surface the cells become very much flattened like those of a simple squamous epithelium. The squamous cells of the superficial layer are constantly being worn away and replaced by the underlying cells. The cells of the basal layers divide constantly and after each division one daughter cell remains in the same position as the mother cell while the other is pushed upward into the next layer. The newly formed cells so pushed upwards, undergo chemical alterations and as they move closer to the surface of the membrane, they finally die and become part of the surface layers, which continually wear away. The deepest layer of cells, forming the basal layer is referred to as the **Malpighian** or **germinative** layer and the cells of this layer as described undergo continuous division.

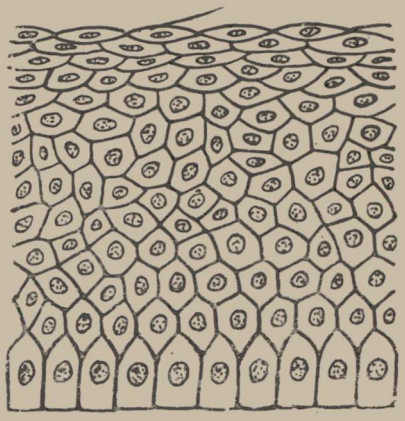


Fig. 4.6 Stratified (compound) squamous epithelium.

This type of tissue is found in skin, mouth, oesophagus, etc.

Stratified Cuboidal Epithelium :

In this type of epithelium the basal layer of cells are cuboidal or low columnar in shape. The intermediate region of several cell layers has irregular polygonal cells. The superficial layer of cells is roughly cuboidal with a rounded outer margin. This type is commonly found forming the epidermis of urodeles and lining the cloaca and cloacal bladder of amphibia generally.

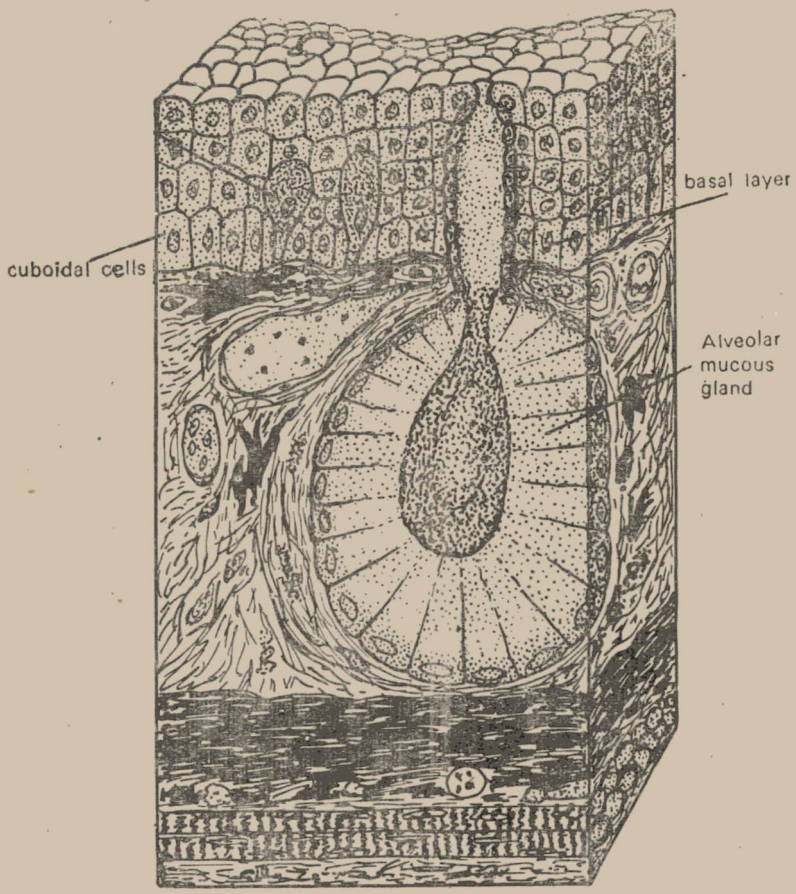


Fig. 4.7 Stratified cuboidal epithelium with an alveolar mucous gland.

Stratified Columnar Epithelium :

The basal layer consists of cuboidal or low columnar cells. The intermediate cell layers have irregularly polygonal or polyhedral cells. In the superficial layer of cells, the cells are elongated prisms which appear columnar in sections. It may be found lining the vas deferens and some of the larger excretory ducts of the compound glands of mammals. In some cases e. g., vas deferens, the columnar cells are ciliated.

Transitional Epithelium: The superficial layer cells in this type of epithelium consists of very large cells, convex on the distal

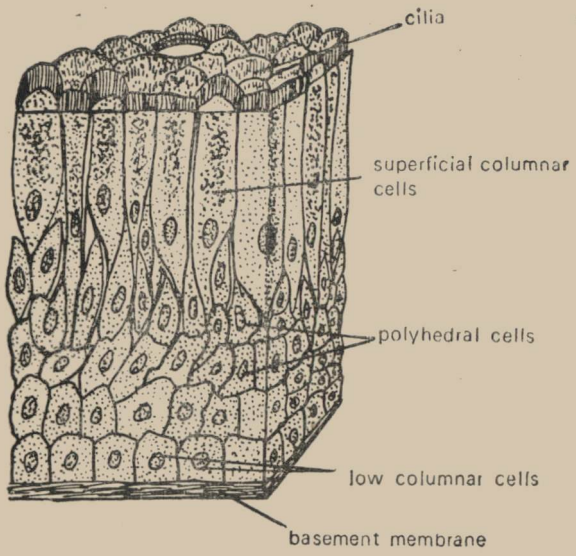


Fig. 4 8 Stratified columnar epithelium.

boundary (i.e., cells of the surface away from the basal layer) and with the concavities at their proximal (nearer to basal layer) ends. Into

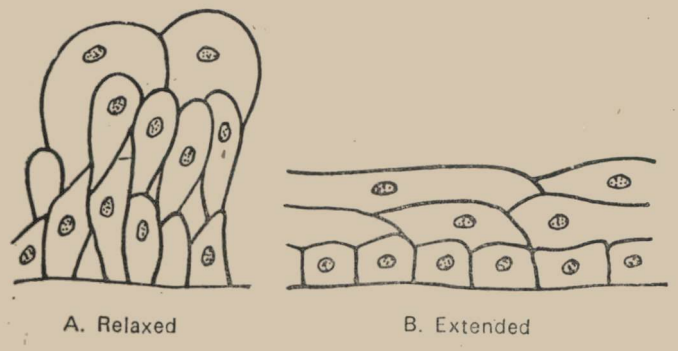


Fig. 4.9 Transitional epithelium from the wall of the urinary bladder. (A) Relaxed (B) Stretched or extended.

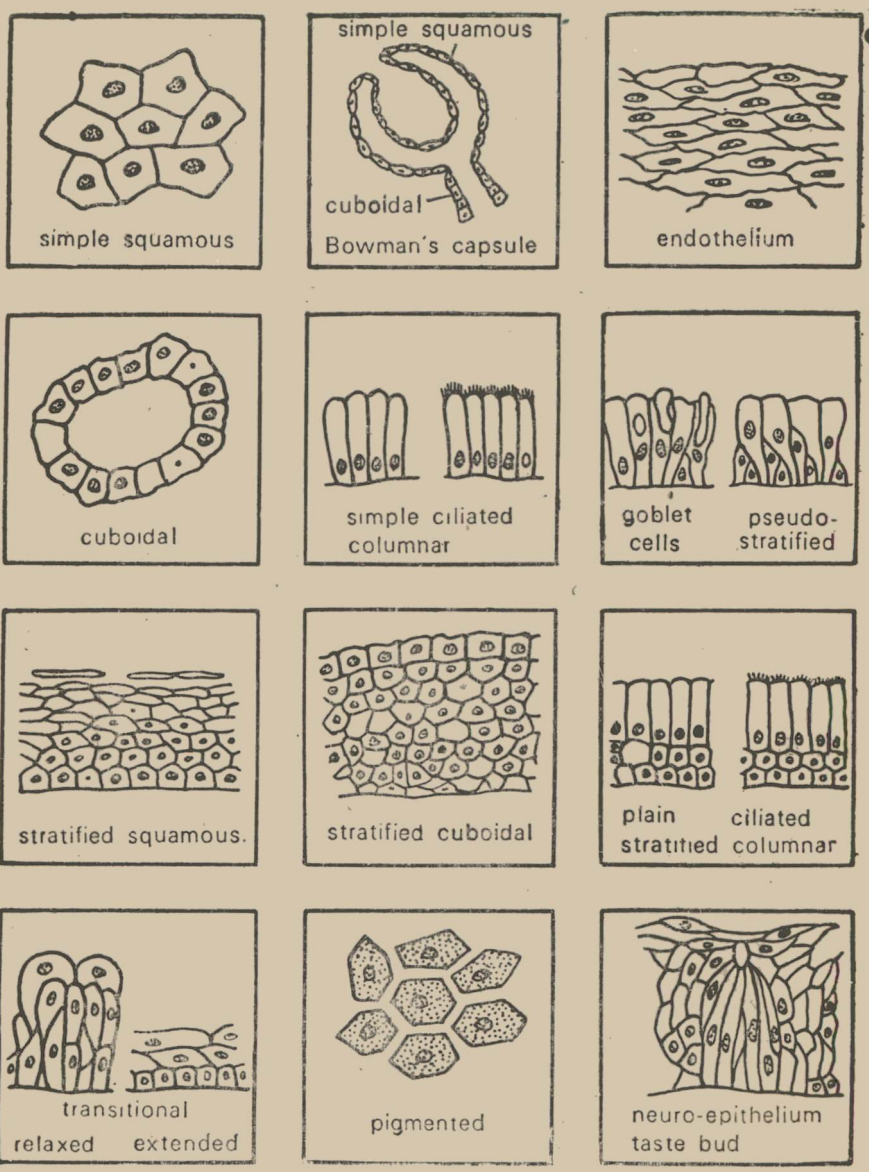


Fig. 4.10 Schematic summary of the epithelial tissues.

the proximal concavities of these cells, the distal parts of underlying cells fit. The basal layer of cells appears cuboidal or low columnar in section. In the top and middle layers, the cells are commonly binucleated. The pelvis of the kidney, the ureters, the bladder and part of the urethra in mammals, have a lining of the transitional epithelium. The transitional epithelium appears to be limited to the class mammalia. It is known as the transitional epithelium because the cells of such a membrane are capable of considerable displacement under tension. When such a membrane is distended (or extended) as found in a full bladder, there appear to be only two or three layers of cells. In a distended state the surface cells stretch most and the underlying cells are drawn out into thin layers. As the tension is released, the cells slide back into position so that the thickness and marked stratification of the transitional epithelium is apparent.

II. Connective Tissues :

The connective tissues are those in which a greater part usually consists of intercellular materials of various kinds. The cells of the connective tissues are partially or completely separated from each other by the various types of intercellular materials. All the connective tissues except a special tissue (Neuroglia) in the central nervous system, are of mesodermal origin.

The connective tissues, in general, act as packing and supporting elements for the body. The connective tissue is also referred to as the *supporting tissue*. The cellular components of the connective tissues in addition to playing a part in the formation of intercellular substances, are also equally active in storage and phagocytosis.

The connective tissues contain characteristic constituents with distinctive qualities. These structures include the connective tissue cells; the connective tissue fibres and the intercellular substances.

A reference here will be made to the connective tissue fibres which form a part of cartilage and bone to be discussed later.

Two kinds of connective tissue fibres—*Collagenous* and *Elastic* are described below. They are wholly different both physically and chemically.

1. Collagenous Fibres :

Collagenous fibre is also called *white fibre* as it is colourless. It is notable for being a compound fibre which consists of still finer fibrils.

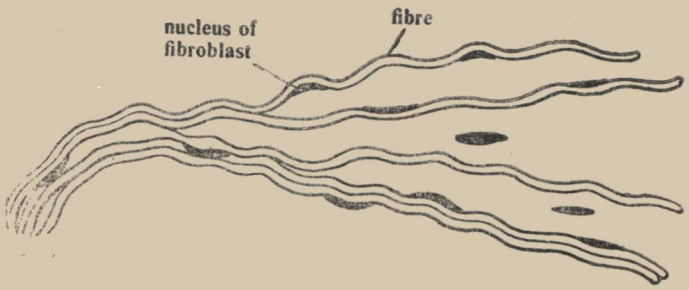


Fig. 4.11 White or collagen fibres.

A collagenous fibre is a bundle composed of a variable number of fibrils which are held together by a cementing substance. A fresh collagen fibre is opaque with a dull pearly appearance. Electron micrographs prove that fibrils are composed of still finer microfibrils. Collagenous fibres consist of an albuminoid, *collagen* hence the name collagen fibre.

2. Elastic Fibres :

Elastic fibres are always solitary and never occur in bundles. They branch and anastomose abundantly, thereby forming a network. The fibre is composed of *elastin*, an albuminoid. With aging, elastin degenerates into elacin. Fresh massed fibres have a yellowish colour hence they are also called *yellow fibres*.

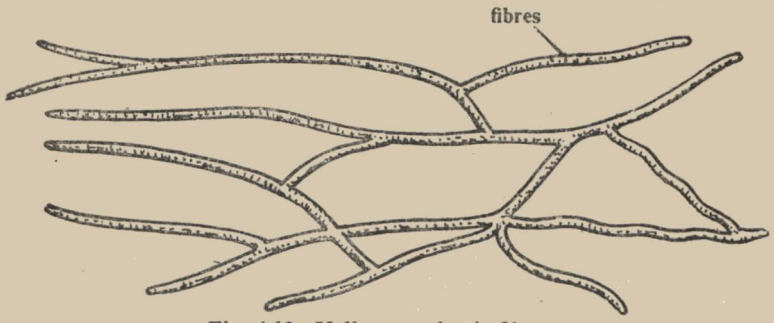


Fig. 4.12 Yellow or elastic fibres

The histological structure of cartilage and bone are now discussed.

Cartilage, also referred to as the 'gristle' of the body, is a specialised type of supporting tissue. It consists of *cells*, *fibres* and *ground substance*. The ground substance and fibres, together, constitute the *matrix* of cartilage.

Three distinct types of cartilages are commonly distinguished. They are the (i) **hyaline** (ii) **elastic** and (iii) **fibro-cartilage.**

Hyaline Cartilage :

The hyaline cartilage occurs on the ventral ends of the ribs, articular ends of the long bones; nose, larynx, trachea, bronchi, external acoustic meatus and the foetal skeleton.

This cartilage occurs in plates, columns or irregular masses. It is solid but is somewhat flexible and elastic. It is transluscent with a bluish to pearly tint. Hyaline means glassy which is the property of its matrix. It is enclosed in a fibrous envelope, except on articular surfaces.

Microscopic structure : The whole cartilage slice is bordered by a fibrous strip, the *perichondrium*. The perichondrium is composed of coarse, firm connective tissue. The connective tissue consists mostly of densely interwoven collagenous fibres.

Next to the region of perichondrium, the cartilage tends to be more cellular. The cells are found to be embedded in a clear stainable *matrix*. The cells called the chondrocytes are large i. e., upto 40μ and tend toward a spherical shape. The mutual pressure often distorts them. Near the perichondrium the cells are relatively young and flattened. In young cartilage, cells occur singly. They remain single near the perichondrium. In somewhat older cartilage, the cells usually occur in groups called the *cells nests*. They are arranged in rounded groups or in rows.

The matrix of the cartilage appears to be homogeneous. There are spaces in the matrix called the *lacunae*. The lacunae are occupied by cartilage cells. The matrix though appears to be amorphous and

homogeneous is actually stiff and gelatinous, permeated by a felt work of fine collagenous fibrils.

The chemical composition of the matrix is complex. One component is collagen belonging to collagenous fibres. The ground substances consist of chondrotin sulphate; chondromucoid and albumoid There is a high content of water i.e., almost 70 percent.

In general, the cartilage is devoid of blood vessels, lymphatics and nerves. In large cartilages, however, there are blind channels containing blood vessels (e.g , epiphyes of foetus and adult). There are no canaliculi in the matrix along which the fluids might pass. The nutrients, oxygen and cell wastes thus only seep through the matrix. The articular cartilage derives its nutrition from the synovial fluid that bathes it.

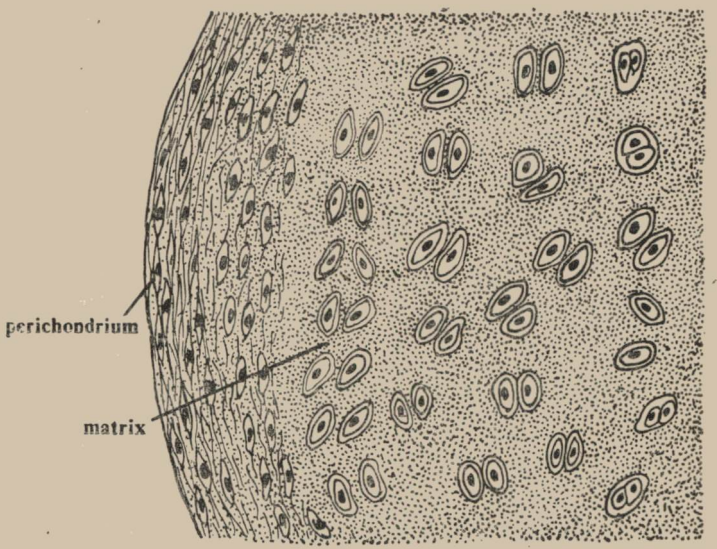


Fig. 4.13 Hyaline cartilage in section.

Calcified cartilage : The hyaline cartilage which forms the skeleton of some elasmobranchs, becomes impregnated with calcium salts which are deposited in the matrix. Such a cartilage is called

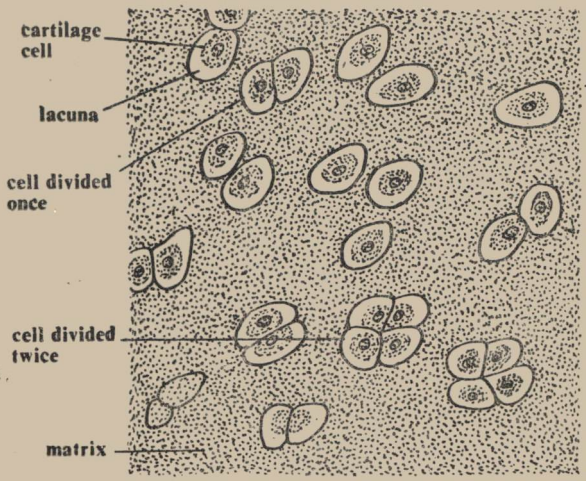


Fig. 4.14 Hyaline cartilage of the frog.

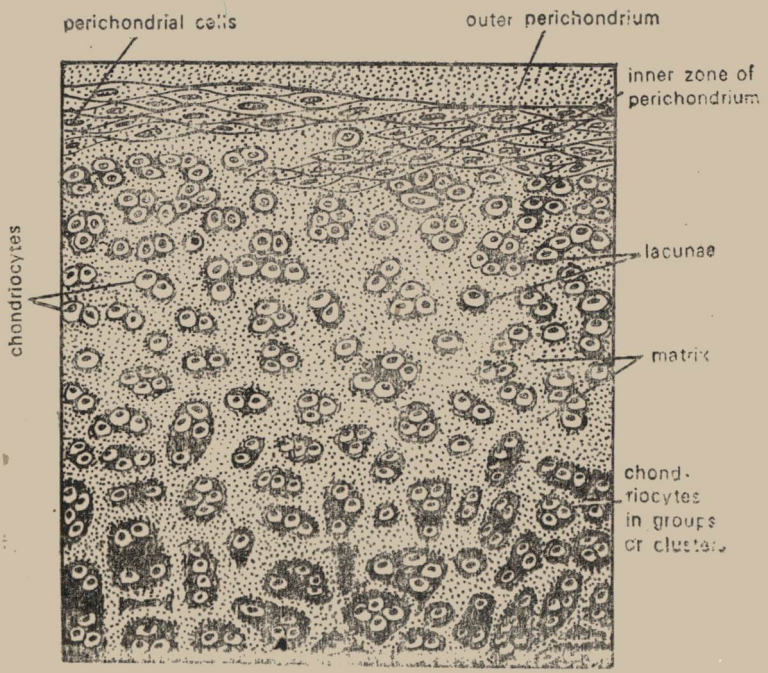


Fig. 4.15 A section passing through a hyaline cartilage from a sternal rib of a guinea pig.

calcified cartilage. The impregnation of calcium salts makes the cartilage harder and more rigid support than does the hyaline cartilage. A similar deposit of calcium also occurs in the epiphyses of amphibian bones. In mammals, calcification occurs in the hyaline cartilage just before it is destroyed and replaced by bone.

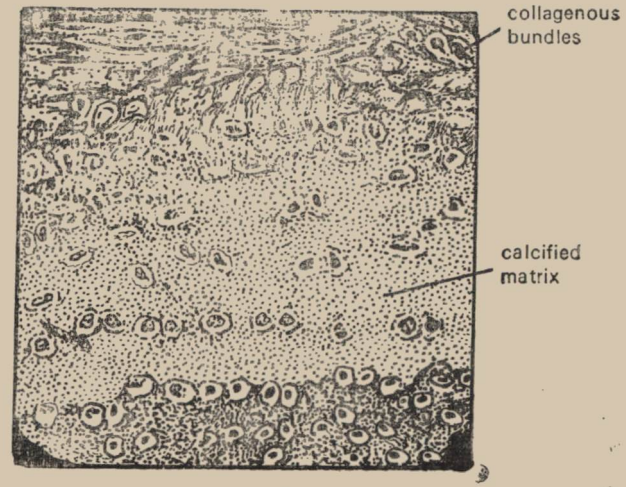


Fig. 4.16 Calcified cartilage.

Elastic Cartilage :

The elastic cartilage occurs in locations where support with flexibility is required. It occurs, for example, in the external ear (auricle), auditory tube, and certain cartilages of larynx.

Elastic cartilage is yellow because of elastic fibres and more opaque than hyaline cartilage. It is also more flexible and elastic. It consists of an ensheathing perichondrium.

Microscopic structure : It is fundamentally similar to the hyaline type. The cells are found singly or in groups within the capsules. The general matrix also contains ground substance and masked collagenous fibres. *It contains, in addition, a mesh work* of branching elastic fibres.

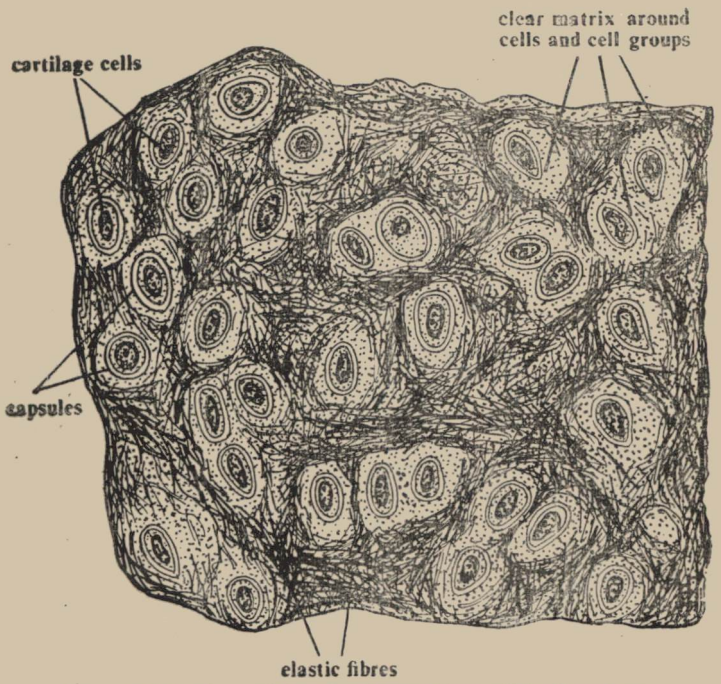


Fig. 4.17 Section of the elastic cartilage of the human ear.

Fibro-Cartilage :

The fibro-cartilage occurs in those regions where a tough support or tensile strength is required. It occurs in intervertebral and articular discs. Pubic symphysis, some articular cartilages and rims of some sockets are composed of the fibro cartilage. It should

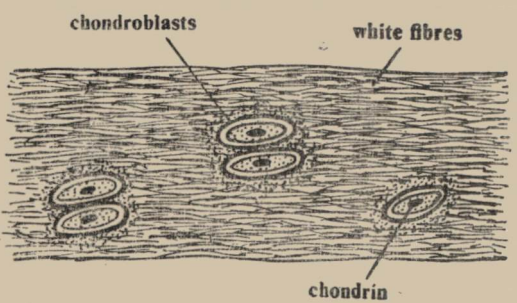


Fig. 4.18 Fibro cartilage.

however be remembered that fibro cartilage never occurs wholly alone, but merges insensibly with the neighbouring hyaline cartilage or with the fibrous tissue.

The fibro cartilage has an opaque appearance and a firm fibrous texture. It lacks a perichondrium.

Microscopic structure: The cartilage cells are of ordinary type but are relatively sparse. They occur singly, in groups or in rows. The visible matrix is limited to the near vicinity of the cartilage cells.

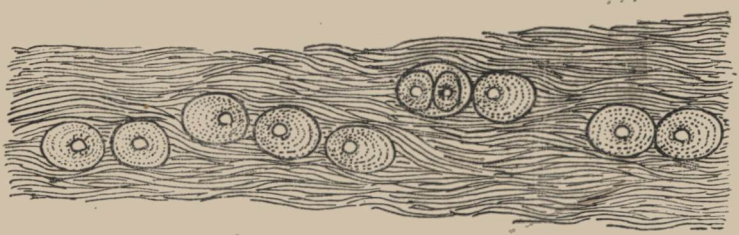


Fig. 4.19 White fibro cartilage from an inter-vertebral disc. Human.

Masses of coarse collagenous fibre are preponderant. These fibre bundles usually take a common direction, yet they may be interwoven. During development, such bundles largely displace the ground substance.

Bone, like other supporting tissues, consists of cells, fibres and a ground substance. The ground substance and fibres together, constitute the matrix of the bone.

In the formation of a bone, the mesenchyme gives rise to **osteoblasts** which are specialised connective tissue cells. The osteoblasts are associated with the development of the bone matrix. The bone matrix so obtained consists of small bundles of **osteo-collagenous fibres**. These fibres become rigid by impregnation with calcium salts. As the deposit of collagen accumulates and becomes impregnated with calcium, the osteoblasts gradually become embedded in it. The spaces occupied by the osteoblasts in the matrix are called **lacunae**. The osteoblasts, once they are embedded in the

matrix are called the **osteocytes.** The osteocytes are surrounded by lacunae. Each lacuna gives off a number of extremely fine branching tubules called **canaliculi,** which extend in all directions, those from the neighbouring lacunae opening into one another.

The osteocytes give off branching cytoplasmic processes which lie in the canalicules and doubtless come into contact with those of the neighbouring osteocytes. There thus extends throughout the tissue, a system of communicating cells.

Bone may be **compact** or **spongy.** Compact bone is hard and dense. It is the outside layer of all bones. Spongy bone is internal and is generally covered by the compact bone. The spongy bone is also called the *cancellous bone* or the *trabecular bone*.

Microscopic Structure of Bone in Mammals:

In most of the larger mammals and in man, the characteristic feature of the adult bone tissue is its **lamellar structure.** The fibres

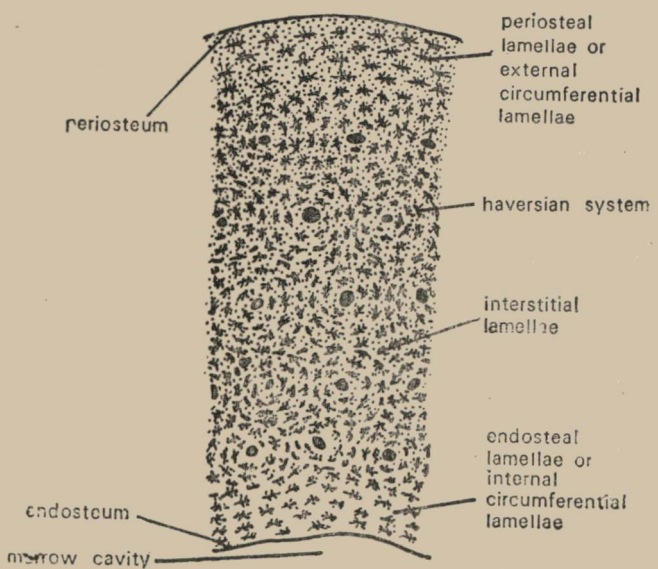


Fig. 4.20 Diagram of a cross-section passing through the shaft of a long bone.

and the calcified matrix of the bone is organised into layers or **lamellae.**

The major part of the *compact bone* is composed of several groups of concentrically arranged lamellae. Each such group of concentrically arranged lamellae have, at the centre, a space or canal called the **Haversian canal.** Each group of concentrically disposed lamellae with bone cells in lacunae around a central Haversian canal forms the **'Haversian system'** or **'osteone.'** The major part of the compact bone as such is composed of several Haversian systems. The irregular angular spaces between the Haversian systems are filled with **interstitial** or **ground lamellae.**

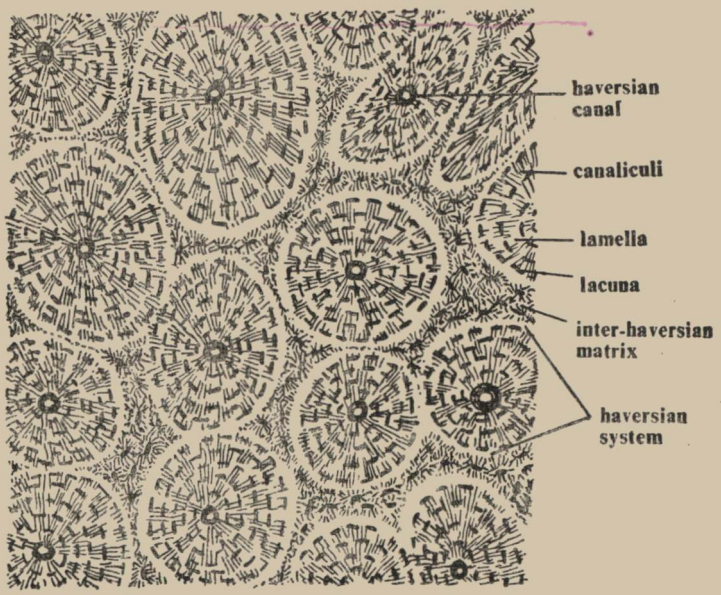


Fig. 4.21 A transverse section passing through a compact bone showing the Haverian system.

The **Haversian canals** that are found at the centre of the concentric lamellae are longitudinal channels. All the Haversian canals further anastomose with each other by oblique and transverse communications. They are also communicated with the periosteum and the endosteum through narrower channels called the **Volkman's**

canals. The Haversian canals thus establish a continuous and elaborate canal system which lodges the blood vessels and nerves of the bone.

The bone is covered by the **periosteum** which is a special dense connective tissue layer. The periosteum contains blood, lymphatic vessels and nerves. The blood vessels pass into the bone substance from the periosteum by way of Volkman's canals.

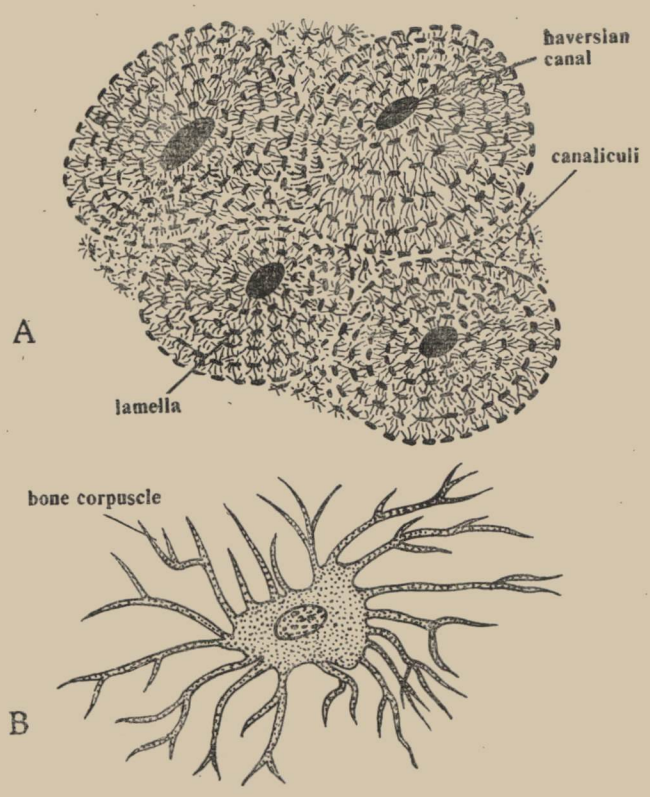


Fig. 4.22 Bone (A) Transverse section of a dried material showing Haversian systems. (B) A bone corpuscle or osteocyte.

Beneath the periosteum are found **periosteal lamellae**, or **outer contour lamellae** or **external circumferential lamellae**. They vary in number and are arranged parallel to the surface of the bone.

The **endosteum** is a thin connective tissue layer lining the walls of the larger cavities of the bone which are usually filled with bone marrow. The endosteum, gives rise to, **endosteal lamellae** or **internal circumferential lamellae.** These, like the periosteal lamellae, are concentrically arranged round the endosteum and internal to the mass of Haversian systems.

Bone marrow is the substance which occupies the central cavity of the shaft of the bone or the spaces in the cancellous bone. **Yellow bone marrow** is found in the *marrow cavities* of long bones. It consists principally of fat cells. **Red bone marrow** is found in the spongy bone at the ends of most long bones and in flat bones of the cranium, sternum, ribs and bodies of vertebrae. It consists of a stroma (frame work) and free cells within the mesh of stroma. Red bone marrow is concerned with the formation of blood cells.

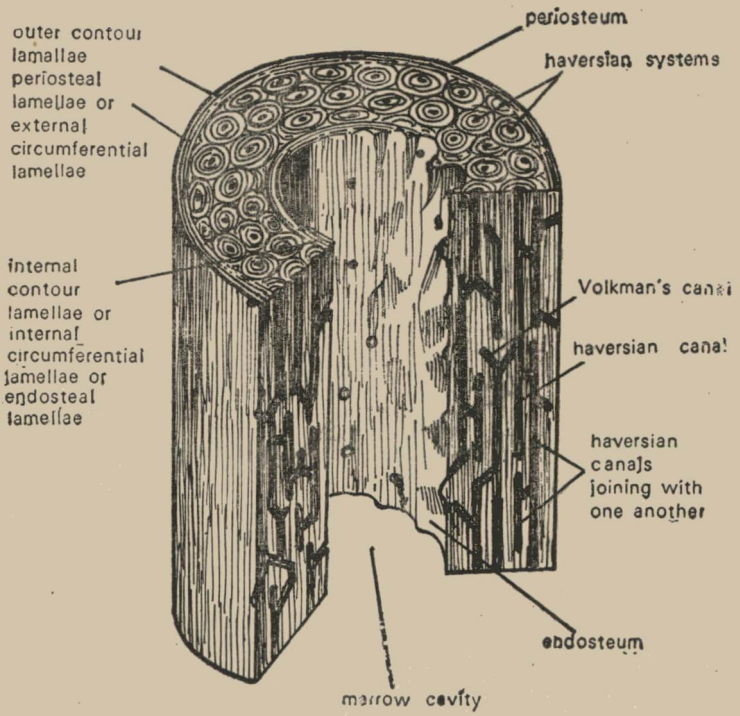


Fig. 4.23 A diagram of the structure of the shaft (diaphysis) in a long bone of a mammal.

A spongy bone shows the same lamellar structure but differs from a compact bone in the more irregular arrangements of its lamellae and the relatively few Haversian systems.

The Structure of the Bone of Frog :

A transverse section passing through a dried bone such as the femur of frog reveals the structure of bone. It is made up of a large number of concentric lamellae found around the central marrow cavity. The lamellae possess numerous spaces or lacunae from which are given off fine branching tubes, the canaliculi. The canaliculi of the adjacent lacunae anastomose with one another. Within the lacunae are found the osteocytes. The concentric lamellae

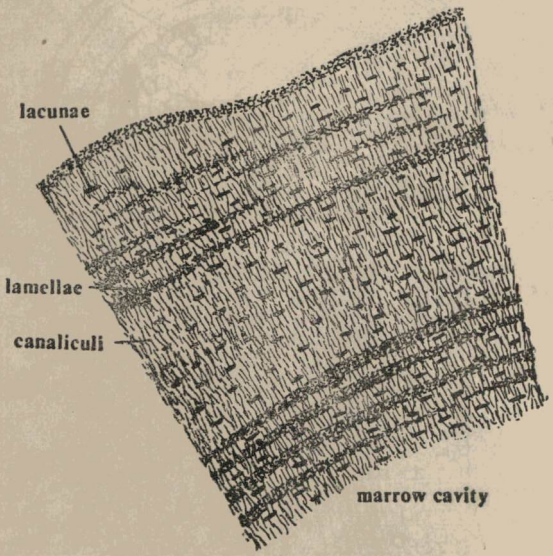


Fig 4.24 Transverse section of dry femur of frog.

surround the marrow cavity, like the external and internal circumferential lamellae found in mammalian bones. A section of decalcified bone reveals that the marrow cavity is filled up with bone marrow containing largely adipose tissue and blood vessels. The marrow is encircled by a fibrous substance disposed off into two layers. In both these layers, cell spaces corresponding to the lacunae of the

dried bone are seen. Each cell space locates within it a bone cell or an osteocyte which sends off delicate branching processes into the canaliculi. The adjoining osteocytes are as such connected with one another through these processes of the osteocytes. The superficial covering of the bone is a tough fibrous sheath called the periosteum.

The bone tissue is formed by the activity of the osteoblasts which are found in two layers. One layer of these bone forming osteoblasts lies just outside the marrow and another layer just beneath the periosteum.

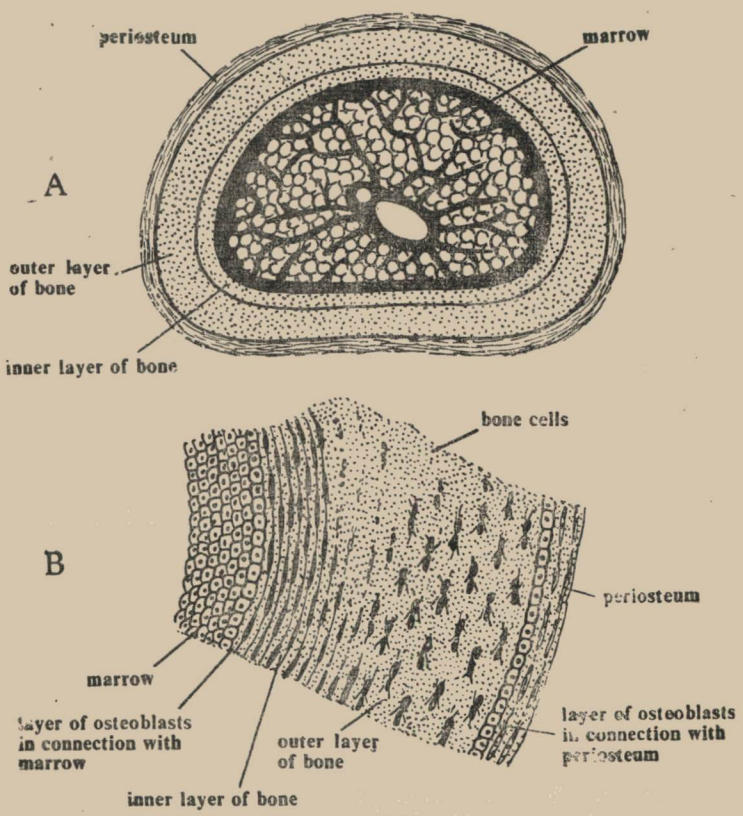


Fig. 4.25 The transverse section passing through a decalcified frog's femur. (A) Under low power. (B) Under high magnification.

III. Muscular Tissue :

The muscular tissue is derived from the mesoderm. It is specialised for contraction. The muscular tissue is made up of elongated units, the muscle fibres bound in a frame-work of vascular connective tissue. The unit of muscle tissue is a cell that is usually called a *muscle fibre.* This usage (i. e., an entire cell is a fibre) is unique for the muscle. The living substance of a muscle cell is given a special name, *sarcoplasm.* The muscle comprises the 'flesh' of the body and much of the walls of hallow organs.

Three categories of muscles on the basis of their function and structure are distinguished. They are as follows :

1. *Smooth involuntary muscle* : This is a smooth muscle mostly occuring in hallow organs.

2. *Striated involuntary muscle* : This is the cardiac muscle of the heart wall.

3. *Striated voluntary muscle* : This is the skeletal muscle, attached to the various bones.

The muscular tissue enters into the composition of many organs as building material.

Smooth Muscles :

Smooth muscles consist of fusiform or spindle shaped cells with abundant cytoplasm. These cells are thickened in the middle

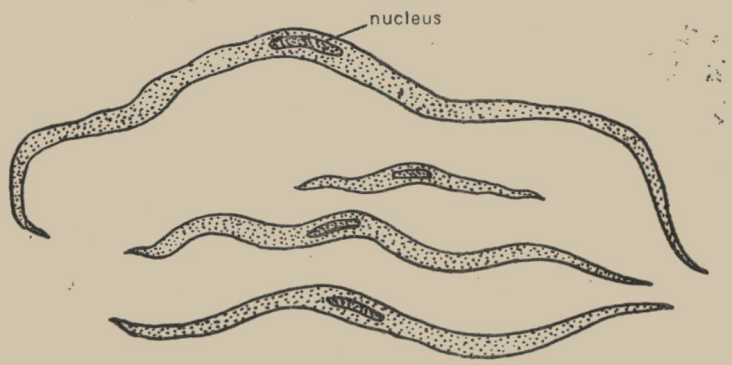


Fig. 4.26 The isolated smooth muscle cells.

and become narrower toward both the ends which are pointed. The nucleus lies in the central thickened portion of the cell. It is oval shaped. The muscle cells, as a rule, are gathered into dense **sheets** or **bands**. Within the **muscular bands**, the muscle cells lie roughly parallel to each other but are irregularly and densely packed together in such a manner that the narrower portion of one cell lies against the wider portions of its neighbours. The muscle cells may however occur as isolated units scattered among the connective tissue fibres.

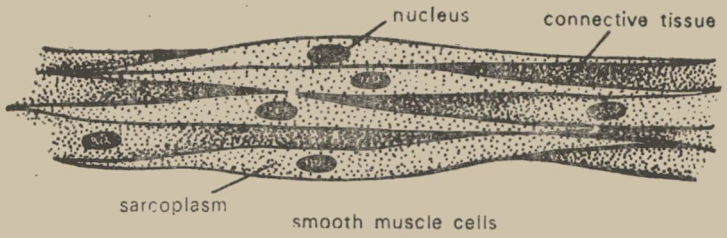


Fig. 4.27 Smooth muscle cells.

The smooth muscle cells vary much in their length. They may reach a length of 0·5 mm (500 microns) in the pregnant human uterus, while their average length in the intestine of man is 0·2 mm with a thinckness of 6μ. The smallest smooth muscle cells occur in the small blood vessels where they are 15 to 20μ in length. The smooth muscles are found in the wall of the alimentary canal from the middle of the oesophagus to the anus. They are also found in the ducts of the glands connected with the intestine. They also occur in the dorsal wall of trachea, whole bronchial tree (alveolar ducts), ureter, bladder, testes and their ducts, prostate and cowper's glands, broad ligament, oviducts, uterus, vagina, blood vessels, larger lymphatics and spleen. They are also to be seen scattered in varying amounts in the connective tissue of the skin. In the eye, the smooth muscles are found in the iris and the ciliary body.

The plasma membrane of the muscle cells is seen in high resolution electron micrographs as a 'Unit membrane.' The cytoplasm of smooth muscle cells contains the usual cell organelles, mitochondria, golgi complex, centrioles, endoplasmic reticulum and ribosomes (Cf. ultra-structure of a cell, Vol. I). It also contains some glycogen and occasional fat droplets,

The cytoplasm also contains longitudinally arranged intracellular fibrils called the **myofibrils.** The myofibrils are concerned with contraction. The myofibrils apparently represent aggregates of the myofilaments which can be seen in electron micrograph. It is assumed that the myofibrils contain the contractile elements (myosin and actin). The substance between the myofibrils is called the *sarcoplasm.* It usually accumulates in small amounts at both ends of the nucleus. Most of the cell body is occupied by fibrils which are so closely associated that the sarcoplasm cannot be noticed between them.

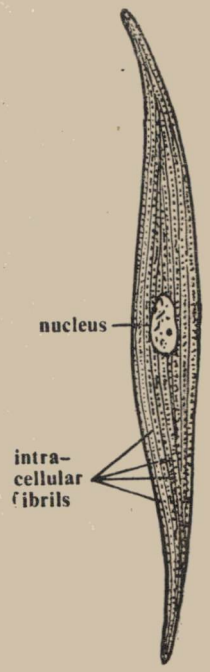


Fig. 4.28 A smooth muscle cell with intracellular fibrils or myofibrils.

The contraction of smooth muscles is slow and sustained. The skeletal muscles on the other hand contract rapidly and soon get fatigued.

The contractions of the smooth muscles are carried out independently of the 'Will.' These muscles as such are also referred to as the **"Involuntary muscles."**

The vertebrate smooth muscles have a double innervation of the autonomic nervous system, one set coming from the sympathetic and the other from the para-sympathetic nerves. This nerve supply from the autonomic nervous system controls the involuntary action of the smooth muscles.

Striped Muscles :

Striped, striated, skeletal or **somatic muscles** make up the musculature of the skeleton. These muscles, in contrast with smooth muscles are usually under the control of the 'Will'; hence are also known as **voluntary muscles fibres.**

Each muscle consists of many long cylindrical muscle cells or muscle fibres. The muscle fibres vary in length from 1–40 mm and in thickness from 50—100 μ or more. The muscle fibres of a muscle are united in **muscle bundles** or **sheets** or **fasiculi.**

The muscle fibres are clearly limited by a continuous thin transparent membrane called the **sarcolemma.** Within the sarcolemma, the muscle fibres are composed of a mass of special cytoplasm called the **sarcoplasm.** In this are found embedded a number of **nuclei** which are elongate or oval in shape. Thus, the muscle fibre is a *multinucleate structure.* Most of the substance of the muscle fibre is occupied by a number of myofibrils. The myofibrils are the essential contractile elements. The myofibrils run throughout the length of the fibre closely side by side without anastomosing. In the course of development of a muscle fibre as the number of myofibrilae increases, the sarcoplasm is reduced to a small amount.

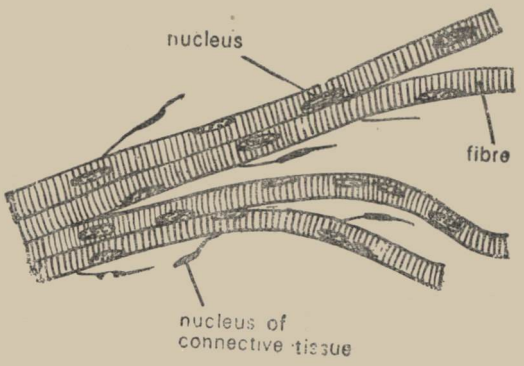


Fig. 4.29 Striated muscle fibres.

The muscle fibres present a banded appearance, hence the name *striped* or *striated* muscles. Not only the muscle fibres but also their components, the myofibrils too are striated. They are so arranged that the corresponding points of their striation pattern (light or dark) lie at the same level giving the appearance of **discs** or **cross bands,** crossing the whole thickness of the muscle fibre.

The relatively broad, dark bands are termed *A* **bands** or *A* **discs** (= anisotropic i.e., unequal refraction). The alternate light or less dense bands are designated as the *I* **bands** or *I* **discs** (= isotropic i. e., equal refraction).

In the centre of each *A* band is seen a slightly less refractile region named the *H* **band** (after Hensen who discovered it; some

authorities however believe that *H* is derived from the German word heller, for lighter.) Likewise in the centre of *I* band is formed a narrow line of highly refractile material which therefore looks dark and is called the *Z* line (from the German, Zwischenscheible = between-disc). The *Z* bands appear continuous with the sarcolemma. The substance included between two *Z* lines forms the functional unit of a muscle called the **sarcomere.**

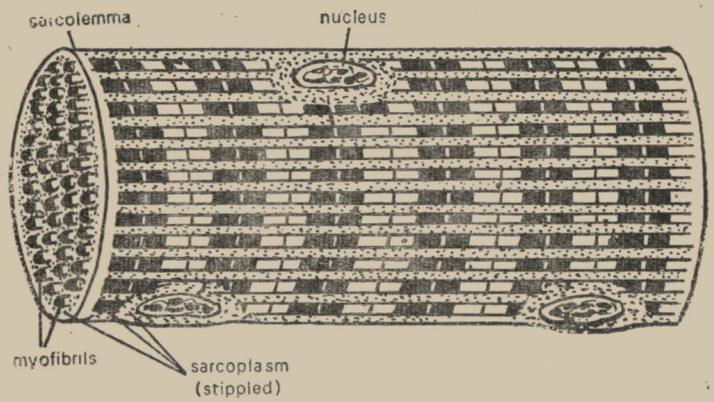


Fig. 4.30 The structure of a striped muscle fibre.

The muscles are composed of about 20% protein and 80% dilute solutions of salts. 65% of the protein of a muscle is fibrous in nature and the remainder is largely composed of enzymes. About half the weight of fibrous protein consists of **myosin** and the remaining is mainly another protein called the **actin.**

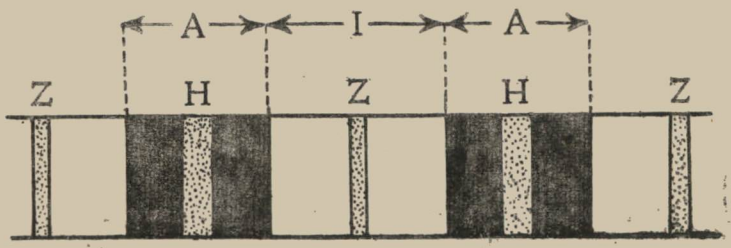


Fig. 4.31 Longitudinal section showing *A* and *I* bands and also *H* and *Z* lines.

The dense material of the *A* bands consists of **myosin** while the *I* bands are composed of the protein **actin.**

The electron microscopic studies have revealed more details which provide evidence for a working hypothesis for the mechanism of muscle contraction.

It is now known that each myofibril consists of two distinct kinds of filaments. The sections passing through the central part of each *A* disc i.e., the *H* zone show only the presence of hexagonal sets of **primary filaments** composed of myosin. The sections through the

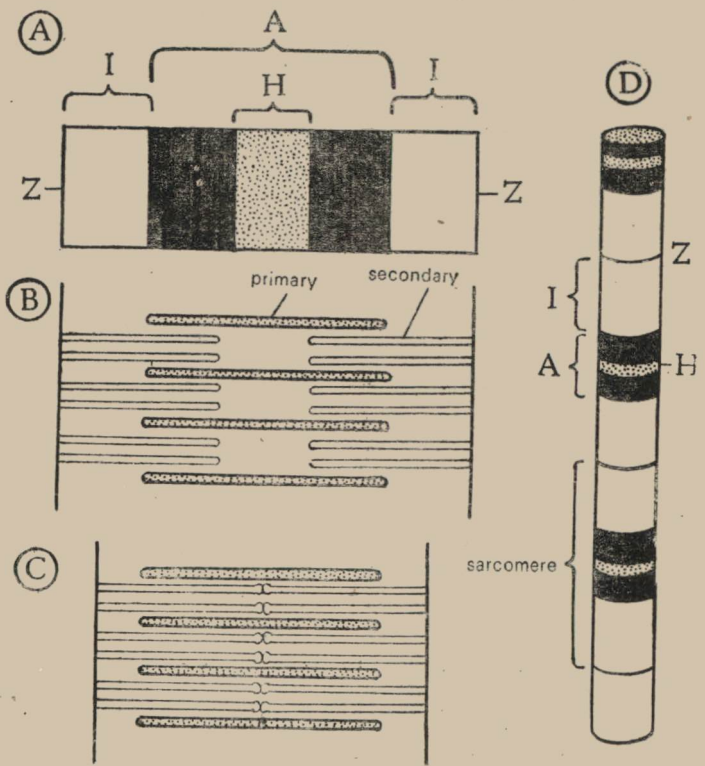


Fig. 4.32 The structure of stripped muscle. (A) Surface view of a single sarcomere. (B) Longitudinal section of a sarcomere to show position of filaments—relaxed state. (C) L. S. single sarcomere with filaments in a state of partial contraction. (D) Part of a myofibril.

I disc on the other hand show only the thinner secondary filaments composed of actin.

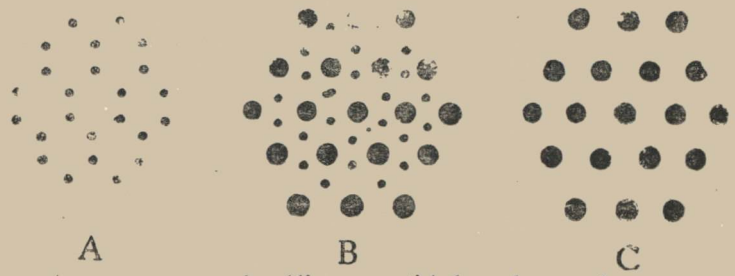


Fig. 4.33 Transverse section (diagrammatic) through part of a muscle fibre. (A) Through *I* band (secondary filaments only). (B) Overlapping region in *A* band with primary and secondary filaments. (C) In the *H* zone primary filaments only.

When the muscle fibre contracts, the distance between the successive *Z* lines becomes short but the length of each of the *A* bands remains the same. The *I* zones and the *H* zones also become short and finally disappear. The above facts can be explained if it is assumed that the two sets of filaments remain of constant length but that the secondary filaments slide inwards between the primary one [See Fig. 4.32 (B) and (C)].

The electron micrographs of the longitudinal sections of fibrils show that the primary or myosin filaments and the secondary (actin)

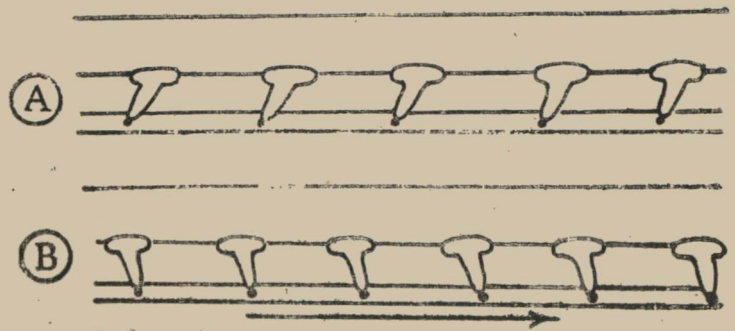


Fig. 4.34 The diagram showing the action of oblique bridges which pull secondary filaments inwards. (A) Relaxed state. (B) Contracted state.

filaments are linked by a complicated system of oblique cross bridges. It is presumed that these cross bridges pull the secondary filaments inwards, return to their original position and so on, many times a second. Their combined action is analogous to a sort of ratchet-like series of hook-ups energised by the break-down of *ATP* to *ADP*. When the *ATP* is no longer being broken down the bridges no longer combine and the muscle in this situation can relax and can also be elongated if stretched. The contraction of muscle fibres is thus brought about by a change in the arrangement of their protein molecules (i. e., myosin and actin filaments). The energy required is derived from the chemical energy of food.

Nerve Supply of Skeletal Muscles :

Skeletal muscles receive their nerve supply from the cerebrospinal nerves. This nerve supply places the skeletal muscle under **voluntary control.** As the motor nerve fibre reaches a muscle fibre

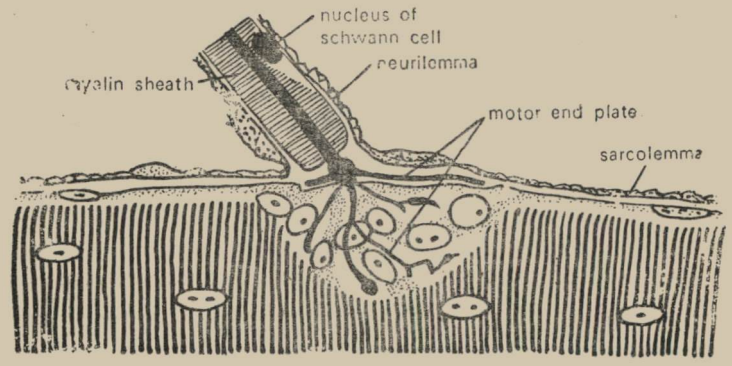


Fig. 4.35 Motor end plate in a striped muscle (diagrammatic representation).

the myelin sheath of the nerve fibre is lost. As a result of this, the nerve fibre may branch there to form fine terminal twigs or in the case of mammals these nerve fibres terminate in compact **motor end plates.**

The Cardiac Muscles :

Cardiac muscles as the name implies are found in the walls of the heart. The cardiac muscles although composed of separate cells, its fibres are however united by bridges to form contractile network. These interconnections or bridges distinguish the cardiac muscles

with the simple and striped muscles. The nuclei are situated at regular intervals of muscle fibres. The whole mass of muscle with the interconnections and nuclei thus forms a syncytium. The cardiac muscles are cross striped but are not surrounded by a definite sarcolemma. Where the muscle cells meet end to end they form **intercalated discs.** The cardiac muscles contract rhythmically. This is associated with the syncitial organisation of the cardiac muscle.

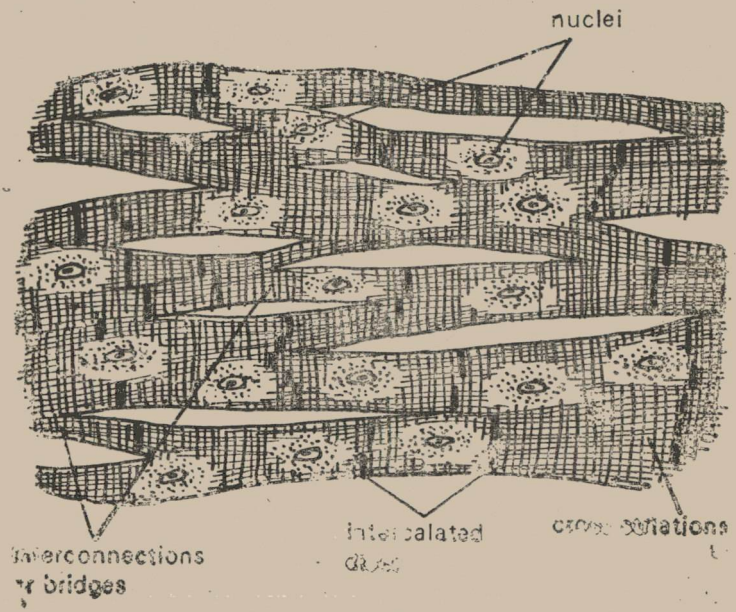


Fig. 4.36 Cardiac muscles.

It is also essential that a free circulation takes place regularly as any interference in the blood flow affects the normal rhythmical activity of the cardiac muscles. Cardiac muscle contractions are short in duration than the resting phase. Under normal conditions the cardiac muscle is immune to fatigue. Regeneration does not occur in cardiac muscle and enlargements of the heart in some adult animals is due to the increase in the size of the muscle fibres, not their number. The enlargement of the heart may also be on account of the increase in the connective tissue present in the cardiac muscles.

The cardiac muscle in mammals is supplied with blood through a rich capillary network carried between the fibres by the interpenetrating connective tissue.

The Myogenic Theory of Heart-beat :

The rhythmic contraction of the cardiac muscles are on their own accord. Only later in the adult animals the heart receives its nerve supply from the sympathetic and para-sympathetic nervous system. This nerve supply only modifies the strength and speed of contraction of heart. The heart-beat therefore is said to be **intrinsic** or **myogenic.**

The histology of the **nervous tissue** will be discussed under the nervous system of frog.

Revision questions

1. Define the terms tissue, organ and organ system.
2. What is an epithelial tissue ? Describe the functions and the kinds of epithelial tissues found in the vertebrates.
3. Give a detailed account of the structure, function and kinds of the stratified or compound epithelia met with in vertebrates.
4. What is a connective tissue ? Describe in brief the functions of the connective tissues.
5. Describe the structure, functions and kinds of cartilage.
6. Give an account of the structure and functions of a bone in mammals.
7. Describe the structure of the bone of a frog.
8. Describe the functions and kinds of muscular tissue.
9. Give an account of the microscopic structure, function and occurrence of the unstriped or smooth muscles.
10. Describe the microscopic structure and functions of the skeletal or striped muscles.
11. Give an account of the microscopic structure of the cardiac muscles. What is meant by the myogenic theory of heart-beat ?

CHAPTER V

THE DIGESTIVE SYSTEM OF FROG

The digestive system of frog consists of an alimentary canal which commences at the mouth and terminates at the cloacal aperture. The entire alimentary canal is suspended in the body cavity by a portion of the visceral layer of the peritoneum called the mesentery. The mouth leads into the buccal cavity—the detailed structure of which has already been described. (See pages 15-17 Chapter II.)

The buccal cavity as mentioned, narrows down at the back to form an indistinct **pharynx.**

The pharynx leads into the **oesophagus** or the **gullet.** The oesophagus is a short wide tube which remains attached to the dorsal wall of the body by a mesentery. The oesophagus passes on without a sharp line of demarcation into the **stomach.** The lining of the oesophagus is folded longitudinally to allow for expansion during the passage of food along it to the stomach.

The stomach is a thick walled slightly curved elongated sac lying to the left of the middle line. The end of the stomach where the oesophagus enters is called the **cardiac end** and the part of the stomach which is continuous with the small intestine is the **pyloric end** or **pylorus.** There is a slight constriction at the pyloric end known as the **pyloric constriction.** A band of circular muscles called the sphincter is found at the pyloric constriction. The sphincter as such is referred to as the **pyloric sphincter.** The inner walls of the stomach are well supplied with longitudinal folds of muscles. These help in the distension of the cavity of the stomach and further by means of these muscles a churning movement is maintained as long as the food remains in the stomach.

The pyloric end of the stomach is continuous with the small intestine. **The small intestine** is differentiated into two portions.

(a) The **duodenum** is that portion which follows the stomach. It runs forward and lies nearly parallel with the stomach. It is bound to the stomach by a fold of peritoneum or mesentery called

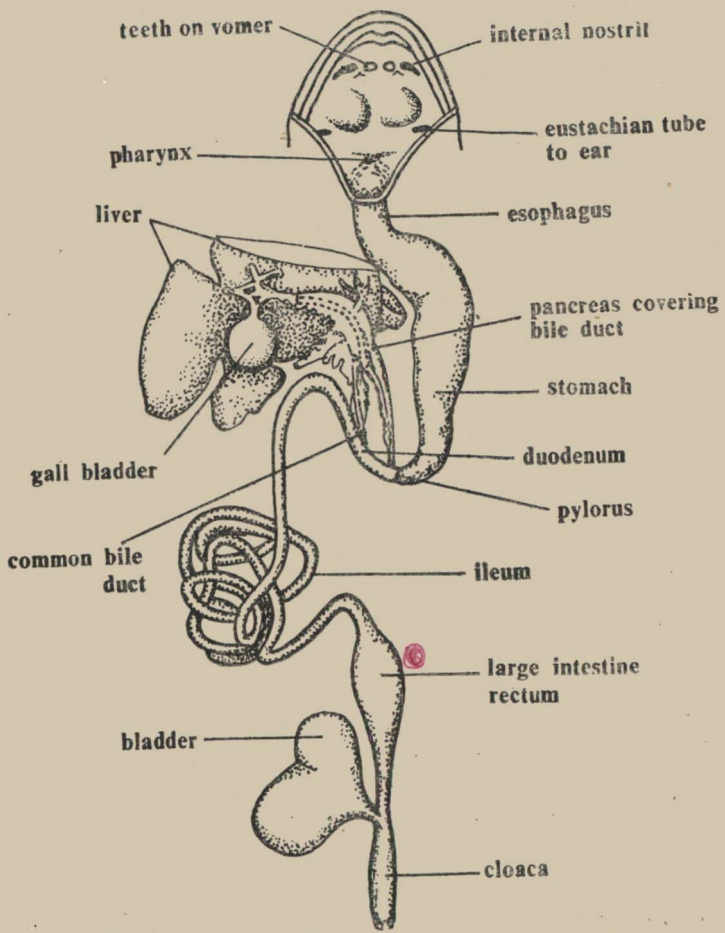


Fig. 5.1. The digestive system of frog seen from the ventral side. In order to expose the roof of the mouth cavity, the lower jaw has been cut away.

the **gastroduodenal omentum.** The distal end of the duodenum (i e., away from the stomach) is bound to the posterior end of the liver by the **duodeno-hepatic omentum.** The inner lining of the wall of the

duodenum is folded in the form of an irregular network appearing as transverse ridges. The duodenum at its distal end turns sharply backwards and is known as the **ileum**

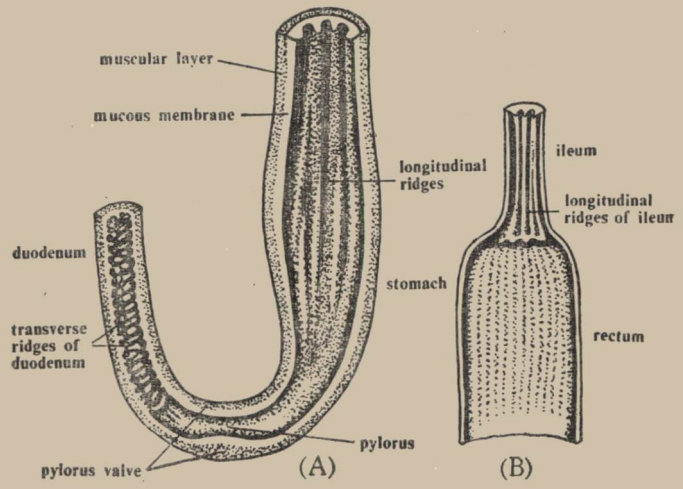


Fig. 5.2 Portions of the alimentary canal of frog in longitudinal section (A) Stomach and duodenum (B) Part of ileum and rectum.

(b) The **ileum** is a much coiled tube about four times the length of the duodenum. The coils of the ileum, of which there are at least three principal ones, are bound together by mesentery in which can be seen a fine network of blood vessels associated with this part of the gut. The inner wall of the ileum consists of longitudinal folds. True villi found in higher vertebrates are absent. The ileum with its coils pursues a complicated course and finally returns to the level of the hinder end of the stomach, where it leads abruptly into a swollen part of the alimentary canal called the **large intestine or rectum.** As the name indicates, it is straight compared with other parts of the gut. The rectum after running straight for just over an inch opens into the **cloaca.**

The **cloaca** is a chamber into which also open the **urinary bladder,** the ducts from the kidneys and in the female, the oviducts. The cloaca finally opens to the exterior through the cloacal aperture. A dark red spherical body called the **spleen** may be seen attached to the mesentery between the ileum and the rectum. It has however no physiological relation with the alimentary canal.

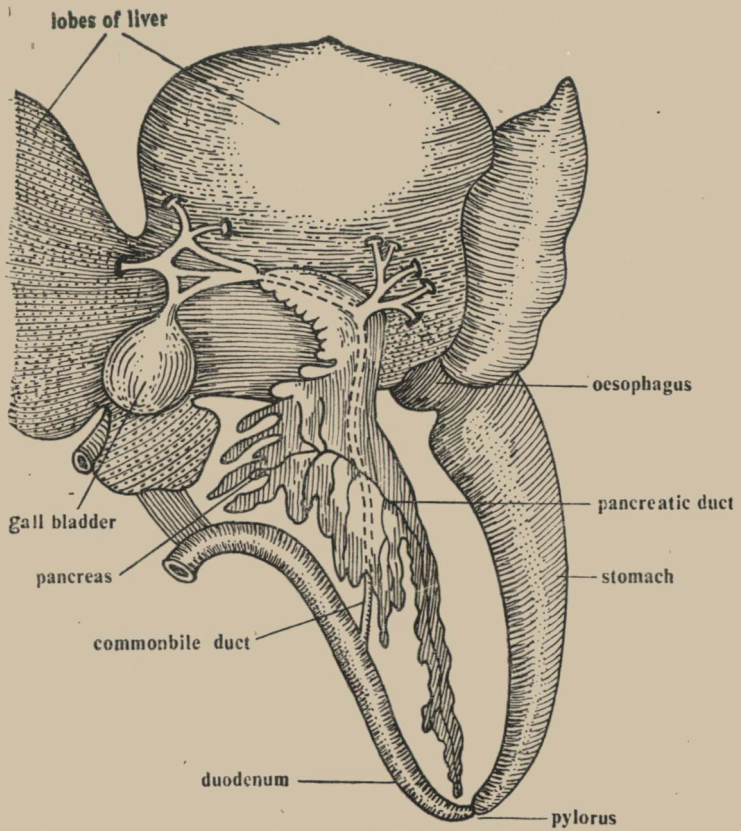


Fig. 5.3 Stomach, duodenum with liver and pancreas of frog.

Peristalsis : The squeezing movements of the wall of the alimentary canal causes the food to be moved along the various parts of the alimentary canal. These movements of the alimentary canal are called the **peristaltic movements** or **peristalsis**. In peristalsis, the muscular wall of the alimentary canal just in front of a mass of food or bolus contracts and pushes the food backwards into the next part. Later, the wall of this part also contracts and pushes the food still

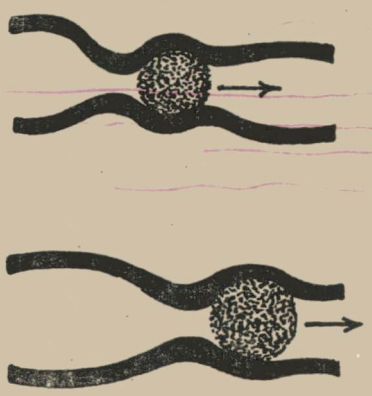


Fig. 5.4 A diagram showing the passage of food down the oesophagus due to peristaltic movements.

further. This process goes on in the form of regular waves of contractions in the wall of the alimentary canal, due to which the food is moved along the various parts of the alimentary canal. The series of peristaltic movements of alternate contraction and

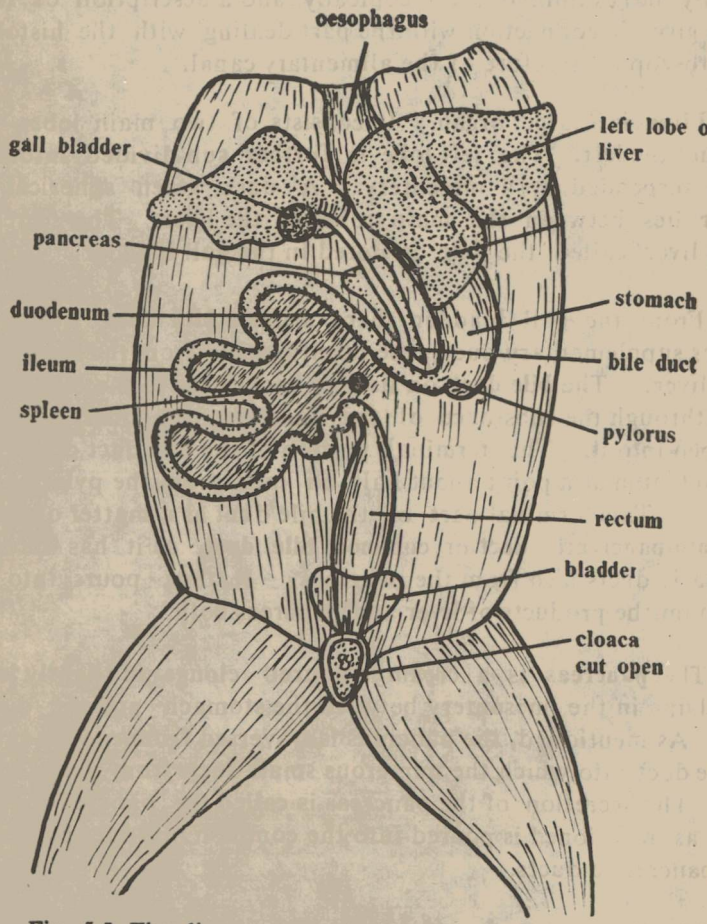


Fig. 5.5 The alimentary canal of frog showing the liver lobes and the position of the spleen.

relaxation of the wall of the alimentary canal are similar to those by which an earthworm makes its way over the ground. The peristaltic movements in the alimentary canal can very well be observed in a freshly chloroformed or pithed frog.

Glands of the Alimentary Canal :

The glands associated with the alimentary canal are the *liver*, *pancreas* and the *glands of the gut wall*. The glands of the gut wall can only be examined microscopically and a description of these will be given in connection with the part dealing with the histology or microscopic structure of the alimentary canal.

Liver is a large organ. It consists of two main lobes—the right and the left. The left lobe is further sub-divided into two, and is suspended by a mesentery. A dark green spherical **gall bladder** lies between the main robes of the liver. The secretion of the liver called the **bile** is stored in the gall bladder.

From the gall bladder there arises a **bile duct**, which also receives supplementary ducts, the hepatic ducts from the main lobes of the liver. The **bile duct**, on its way backwards to the duodenum passes through the substance of the pancreas, the ducts of which also open into it. The terminal portion of the bile duct opens into the duodenum at a point about half an inch from the pyloric constriction. This terminal part of the bile duct as a matter of fact is an **hepato-pancreatic duct** or **common bile duct**, as it has received pancreatic ducts also from the pancreas. It thus pours into the duodenum the products of liver and pancreas both.

The pancreas is a cream coloured elongated slightly lobed gland lying in the mesentery between the stomach and the duodenum. As mentioned, the pancreas is traversed from end to end by the bile duct into which the numerous small ducts from the pancreas open. The secretion of the pancreas is called the pancreatic juice which as mentioned is poured into the common bile duct by various small pancreatic ducts.

The liver and the pancreas are connected with the alimentary canal through the mesenteries.

The Food of the Amphibians :

Almost all adult Amphibia feed on invertebrates, mainly insects, partly also worms, slugs, snails, spiders and millipedes.

In the larval stages, usually the anurans and often the urodeles are herbivorous. The adult amphibians may be cannibalistic, feeding on the tadpoles of the same or other species.

The tongue of frog as described earlier is the characteristic organ for catching the food and is one of the special features required for terrestrial life. The teeth on the premaxillae, maxillae and vomers are used only to prevent the escape of the prey; a few amphibia bite.

Importance of Food :

Food, like air, is essential to maintain life. It is the **source of energy** which drives the chemical reactions of life processes. Food is also a source of chemicals essential for the **growth and repair** of the body. On the basis of their functional role the foods are classified as (i) **Energy yielding foods** (ii) **Body building foods** and (iii) **Protective foods** i. e., those which protect our body from infections by raising the power of resistence.

Nature of Food :

As a result of chemical examination it has been found that the various types of food the animals and man eat consist of **carbohydrates, fats, proteins, vitamins, mineral salts** and **water.** These classes of substances are sometimes referred to as **'food stuffs'** i. e., the stuffs of which food is composed.

We shall now discuss in general the nature of the above mentioned food stuffs and their importance to animals and man.

Carbohydrates : Carbohydrates are the cheapest and most abundant of food stuffs. In nature they are represented by cellulose; starches and sugars. Carbohydrates are only made up of three elements—carbon, hydrogen and oxygen. The simplest carbohydrates are the hexose sugars or monosaccharides or six carbon atom sugars e.g., glucose and fructose. Their empirical formula is $C_6H_{12}O_6$. Sucrose or cane sugar ($C_{12}H_{22}O_{11}$) is an example of a disaccharide. The polysaccharides are carbohydrates of high molecular weight

composed of a large number of monosaccharide units condensed together e.g., starches and cellulose. The empirical formula of a starch is $(C_6 H_{10} O_5)_n$. A good example of a polysaccharide in animals is, *glycogen.* It occurs mainly in liver and muscles.

The carbohydrates are the **rich sources of energy** to the **body.** They act as the **fuel substances** which on oxidation yield energy. Carbohydrate is a preferred fuel of the muscle and the only fuel of the brain. During digestion carbohydrate is converted into *glucose.*

Fats are composed of carbon, hydrogen and oxygen but unlike carbohydrates there is only a small amount of oxygen in the molecule. Meats, milk, seeds and nuts are all fairly good natural sources of fat. The common fats of vegetable and animal tissues are compounds of the higher fatty acids (i.e., palmitic, stearic and oleic acids) in combination with the glycerol. The resulting compound is called an *ester* or a *neutral fat* or *triglyceride.*

Fats serve several important functions in the body. The food **energy is stored in the form of fats** in the body. When the food is not available the fat of the body is utilized to obtain energy. In cases of starvation and undernutrition the fat stores of the body provide most of the calories required to keep the body alive. One gram of fat contains more than twice as much energy as a gram of either protein or carbohydrate. Fatty materials form a part of the structure of brain and nerve tissue. Fat is used in the formation of phospho-lipids of cell membranes. The health of the skin is maintained due to fat. Fat gives form and grace to the body. According to dietitians—the fats have a **satiety value.** It means that for equal bulk—the meal that contains the greater amount of fat will give the greater feeling of satisfaction. Fats during digestion are converted into fatty acids and glycerol.

Proteins : The term protein comes from Greek and means '*of primary importance.*' The proteins are needed in the formation and repair of all body tissues. The best source of proteins are meats of all kinds, milk, eggs, whole cereal grains, peas and beans.

Proteins contain nitrogen and often phosphorus and sulphur in addition to carbon, hydrogen and oxygen. About 16% of all

protein is nitrogen. In the gaseous state, nitrogen makes up about 79% of the air we breathe. The body however is incapable of using even a single atom of nitrogen in the air. The body should get this vital element from dietary proteins only.

All proteins consist of very large molecules which in turn are built up of smaller building blocks called amino acids. Some twenty-five amino acids have been discovered.

In main, there are about 10 amino acids which are to be taken in, with the diet, as these cannot be synthesised in the body. Such 10 amino acids are called the **essential amino acids** or **indispensible amino acids.**

Proteins form an essential part of the structure of every cell. They are the body building substances. A growing individual requires a large amount of protein. Pregnant women and people recovering from wasting diseases also require sufficient quantities of proteins. The proteins during digestion are converted into amino acids

Vitamins: It was known long back that animals which are fed on a diet containing purified proteins, fats, carbohydrates, water and minerals do not grow and develop normally. An English biochemist, **Sir Frederick Gowland Hopkins** (1861 — 1947) in 1906, emphasised the importance of a growth-promoting substance found in the milk, which was later identified as vitamin *D*. **Casimir Funk** a Swiss scientist also came to the same conclusion that besides proteins, carbohydrates, fats, minerals and water, other factors in the diet are necessary for normal health and growth. In 1912, Funk named these *accessory food factors* as **vitamins (vital amines).** The name was given on the assumption that these accessory food factors were chemically nitrogen containing substances called amines. After the discovery of many more accessory food substances it was known that all of them are not amines hence it was agreed to drop the final 'e' to form the modern term **vitamin.**

The deficiency symptoms of vitamins were known long before vitamins themselves were isolated and synthesised. **James Lind** (1753), a naval surgeon, emphasised the importance of '*lemons*' in

preventing *scurvy* and their use was also recommended by **Captain Cook** in 1772. Today we know that all citrus fruits contain vitamin *C* and the disease scurvy is caused by vitamin *C* deficiency.

According to their solubility in fats and water, vitamins are divided into two groups referred to as (i) **fat soluble vitamins** and (ii) **water soluble vitamins.** A brief information about some of the fat soluble and water soluble vitamins is given below:

Fat Soluble Vitamins:

Fat soluble vitamins are vitamins *A*, *D*, *E* and *K*.

Vitamin A is a complex unsaturated C_{20} alcohol. It is also called *retinol* as it is involved in vision. The deficiency of vitamin *A* leads to **night blindness** i.e., inability to see in dim-light. Vitamin *A* deficiency also leads to *dry eye* or *xerophthalmia*, a condition in which the lachrymal glands (tear glands) do not secrete tears; the conjunctiva becomes thick and the cornea is inflammed. Vitamin *A* is necessary to animals for growth, for good vision, healthy tissues and for reproduction. Recent investigations suggest that vitamin *A* intervenes in either or both, the *m*RNA and *t*RNA functions during protein synthesis.

Vitamin *A* is derived from certain members of the carotenoid family. The transport of vitamin *A* through the body depends on the presence of an adequate level of fat in the diet.

Vitamin D is a complex alcohol, unsaturated to some extent. The vitamin is involved in the mobilization from the intestinal tract of dietary calcium for bone building. There are two active forms known as D_3 and D_2.

The precursor of vitamin *D* is found in the skin. Sunlight acts on this precursor to induce photo-chemical rearrangement to form natural form of vitamin *D*. Vitamin *D* as such is also referred to as **sunshine vitamin**. Eskimos who are deprived of sunlight derive their supplies of vitamin *D* exclusively from fish liver oils. Fur bearing animals ingest the vitamin *D* synthesised in the skin when they lick their fur and birds when they preen their feathers. In human beings, it is presumed that some kind of internal transport is available to carry vitamin *D* to the intestines where it facilitates the

active transport of calcium ions across the gut wall. The severe deficiency of vitamin *D* and calcium causes **rickets**. The disease common in children is evidenced by abnormal tooth and bone development, irritability and malaise. The disease leads to **'bow-legs'** and **'pigeons' breast'** in growing children.

In adults, severe deficiency of vitamin *D* and calcium are manifested by **osteomalacia** – a disease predominating in women. Osteomalacia is a disease characterised by softening of bones with a liability to fracture.

Vitamin *D* plays an important part in calcium and phosphorus metabolism. It promotes their absorption from intestine and maintains their proper concentration in blood specially in bone forming regions. Vitamin *D* is also essential for normal eruption of teeth and in preventing dental caries.

Vitamin E is also a complex alcohol known chemically as tocopherol. It's role as an **antioxidant** is well proven. It is presumed to play an important part in maintaining the stability of biological cell membranes. Rats fed on diet deficient in vitamin *E* develop infertility. In man, vitamin *E* deficiency leads to **muscular dystrophy** or wasting. Vitamin *E* is also known to have a sparing effect on vitamin *A*. The major concentration of vitamin *E* is in seed and seed germ oils.

Vitamin K is a substituted naphthoquinone. It is required for the formation of prothrombin in the liver. This substance is necessary for normal clotting of blood. Absorption of vitamin *K* from the gut depends on the presence of bile salts. In human beings except in the newly born—the intestinal bacterial flora readily synthesize one form of vitamin *K* which is absorbed via the gut and passes to the liver.

Water Soluble Vitamins :

Few of the most important water soluble vitamins are described below :

Thiamine (vitamin B_1) is a complex substance, which can be identified as a substituted thiazole.

Vitamin B_1 plays an important part in carbohydrate metabolism. It forms a part of an enzyme system (acting as a coenzyme[1]) essential for the break-down of carbohydrates. It is necessary for the nutrition of nerve cells and its deficiency leads to the degeneration of the nerves. The severe deficiency of vitamin B_1 leads to a disease called **Beri-beri**. It is common among the people using white polished rice as during the process of milling, the husk containing vitamin B_1 is removed. The symptoms of the disease **Beri-beri** have been recognised in China as early as 2600 B C. The name of the disease is derived from a Singalese word meaning 'Cannot'. A patient suffering from Beri-beri becomes so weak that he 'cannot' do anything. The symptoms of Beri-beri are neuritis, paralysis, nerve leisons, digestive disorders, cardiac disturbances, oedema and neurasthenia (the fatigue syndrome). The symptoms of this disease may however disappear if vitamin B_1 is administered in time.

The deficiency of thiamine i.e., B_1 leads to the accummulation of pyruvic and lactic acids in blood and brain with marked impairment of nervous, circulatory, digestive and endocrine functions. Moderate deficiency results in irritability, loss of appetite, muscle tenderness and fatigue.

Vitamin B_1 is found in various animal and plant foods. Dry yeast and wheat germ are its richest natural sources. It occurs in the outer layers of seeds and in nuts, legumes, many vegetables, some meats (especially pork, liver and muscle).

Riboflavin (Vitamin B_2) is an orange yellow crystalline substance belonging to an important family of compounds known collectively as *flavins*.

Vitamin B_2 acts with thiamine and nicotinic acid in the process of oxidation of carbohydrates. It is also present in other enzyme systems, where it acts as a coenzyme.

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[1] Coenzyme is a thermostable and dialyzing organic compound in the presence of which certain enzymes can function normally. Many coenzymes are concerned with biological oxidations. They contain vitamins in their structure e. g., B_1, B_2, niacin etc. It is now generally believed that most vitamins have a coenzyme function in cells. Examples of some coenzymes are NAD. (Nictotine amide dinucleotide) and NADP (Nicotine amide dinucleotide phosphate.)

In combination with phosphoric acid, it is a component of coenzymes called flavoproteins which acting with nicotinamide containing enzymes, are essential in the oxidation reactions in normal metabolism of cell.

The deficiency symptoms of Riboflavin are inflammation of the tongue, lesions at muco-cutaneous junctions of the eyes and lips, congestion of conjunctival blood vessels and desquamation of the skin.

The natural sources of this vitamin are milk and milk products, leafy green vegetables, beef, fish and dry yeast.

Niacin (Nicotinic acid) (Pellagra-preventing factor) is a simpler derivative of pyridine. It is a constituent of coenzymes which act as carriers in essential oxidation processes. It's severe deficiency leads to a disease called '**Pellagra**' (in this disease the level of pantothenic acid is also found to be below normal). The disease is common among people eating corn. The disease is characterised by 3D's i.e., **dermatitis**[1], **diarrhoea**[2] and **dementia**[3]. The name pellagra is derived from the Italian word **Pelle agra**, which means rough skin. The disease in its severest form may be fatal. Nicotinic acid also plays an important part in the absorption and metabolism of carbohydrates.

The natural sources of this vitamin are the same foods that provide riboflavin. In addition to these, mushrooms, whole wheat products and poultry are the good sources of this vitamin.

Pyridoxine (Vitamin B_6) : The natural sources of vitamin B_6 are meat, eggs, nuts, whole grain, cereals and beans. Enough pyridoxine for the body needs of man can be synthesised in the intestine. It is therefore difficult to demonstrate its deficiency in man. A derivative of this vitamin pyridoxal phosphate is the coenzyme for a number of enzyme reactions in the metabolism of amino acids. The vitamin is also necessary for the formation of blood corpuscles. The animals fed on a diet deficient in pyridoxine fail to grow, become anaemic and lymph tissue, atrophies resulting in lack of white blood cells and antibodies with a consequent lowered resistence to infection.

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1. Inflammation of the skin (eczematous reaction.)
2. Loose and frequent evacuation of the bowels.
3. Irreversible organic deterioration of mental faculties.

Folic acid acts as an active coenzyme involved in the synthesis of amino acids and nucleic acids. Its role as an anti-anaemic factor is that of facilitating the nucleic acid synthesis involved in the production of red blood cells.

The natural sources of the vitamin are leafy dark green vegetables, liver, kidney and yeast. It can be synthesised by bacteria in the intestine. A synthetic form of this vitamin has been prepared.

The deficiency of folic acid leads to anaemia, leucopenia[1], hyperplasia[2], of the bone marrow. This vitamin has been proved effective against a disease **sprue**. It is a tropical disease characterised by glossitis, inflammation of the digestive tract, loss of appetite, emaciation and pronounced macrocytic anaemia. When used in combination with B_{12} it has a marked haemopoietic effect. That is why it is used in the treatment of pernicious anaemia.

Cyanocobalamin (Vitamin B_{12}) consists of a large complex molecule centered round the cobalt atom. It is the only vitamin containing a metal. It consists of deep red, needle-like crystals soluble in water and alcohol. It is found in high concentration in the liver. Like folic acid it is essential for the formation of red blood cells. In man, pernicious anaemia and other macrocytic anaemias are thought to be due to deficiency in both folic acid and B_{12}. Vitamin B_{12} is also thought to be involved in synthesis of nucleoproteins and in transformation of carbohydrates to fats.

The natural sources of vitamin B_{12} are the animal tissues particularly liver, kidney, muscle, milk and milk products. It can be synthesised by certain micro-organisms (e. g., *streptomyces griseus*.) It's daily requirements in man are not definitely established. Two micrograms daily is recommended as maintenance allowance.

Pantothenic acid : The role of panthothenic acid, is not definitely known. This vitamin has been referred to as *anti-grey hair factor*, but there appears to be little evidence to support this theory. The vitamin probably plays a role in the detoxication of certain drugs and is needed for the formation of acetylecholine which passes on nerve impulse from one nerve fibre to the next. The vitamin forms part of a 'Coenzyme *A*' which is important in a number of steps in the metabolism of carbohydrates, fats and proteins and in the transfer

1. Decreased number of leucocytes in blood.
2. Excessive formation of cells.

of energy. During the war some prisoners in Japanese prison camps, who suffered from a disorder called the **burning foot syndrome** responded well to treatment with pantothenic acid.

The rich sources of this vitamin are eggs, meat, sweet potatoes and pea nuts.

Biotin: This was first discovered as a factor. Its presence in extremely small amounts are shown to be necessary in the diet of mammals. Like pyridoxine it is produced in the intestine. In experimental animals, the deficiency of this has resulted in loss of hair, loss of weight, abnormal gait and posture. Experimentally induced deficiency in man has resulted in dermatitis, pallor, lassitude, insomnia, anorexia and coronary insufficiency. Biotin is probably involved in protein metabolism.

The rich sources of biotin are, molasses, egg yolk and liver. The white of an egg contains a protein called **avidin**, which combines with biotin in the intestine and prevents absorption. However, avidin is destroyed by heat, so that the cooked egg white does not interfere with the absorption of biotin. A case of biotin deficiency was reported in a man who lived almost entirely on raw eggs and wine. He suffered an inflammation of the skin. It cleared up when biotin was administered.

Ascorbic acid (Vitamin *C*), (anti-scorbutic vitamin) is a water soluble vitamin. It is a white crystalline compound ($C_6H_8O_6$). Its most important function in the body is to control the formation of dentine, cartilage and the matrix of bone. It also plays an important part in the formation of red blood corpuscles as the deficiency of this vitamin gives rise to anaemia. The healing of wounds and the joining of broken bones is delayed in the absence of vitamin *C*. It plays an important part in the metabolism of certain amino acids. It is necessary for the formation of collagen, a protein substance forming an essential part of the white fibres of connective tissue. This vitamin maintains integrity of intercellular cement, in many tissues especially capillary walls. The level of storage of vitamin *C*, drops, in conditions of stress such as those which follows severe burns and injuries. Due to this reason vitamin *C* is thought to play an important role in stress reactions although the exact nature of its function is not known.

The pronounced deficiency of vitamin *C* results in a disease called **scurvy**[1]. Some of the symptoms of this disease are redness, swelling and bleeding of gums, as a result of which the teeth are lost. The increased fragility of the capillaries leads to sub-cutaneous haemorrhages. The healing of soft tissues and injured bones is delayed. Oedema occurs. Secondary anaemia is developed. There is pain and tenderness in the extremities.

There is also a belief by some scientists that there exists a sort of relationship between vitamin *C* and infection and immunity. The level of vitamin *C* in the blood is found to be lowered during infections.

The natural sources of vitamin *C* are fresh citrus fruits such as lemons, oranges, tomatoes, etc., and vegetables (especially cabbage and peppers). Although potatoes contain small amounts of vitamin *C*, this source is of considerable importance because of the large quantities of potatoes consumed by people in many countries. Human milk contains some vitamin *C*, as such the breast fed babies get sufficient supplies of vitamin *C*.

Mineral salts : The principal minerals in the body are found in the form of salts and have many important roles to perform. These minerals may either be used as ions, as in the case with sodium and potassium, or they may be built up into complex organic substances as with iodine and cobalt.

The importance of certain important minerals to the body is mentioned below.

Calcium is essential for the development of bone and teeth, clotting of blood, normal heart action and normal muscle irritability.

Milk and cheese are the best sources of calcium in the diet. Smaller amounts are found in eggs, nuts, oranges and vegetables.

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1. Scurvy was prevalent on long sea voyages of past centuries; the British sea captains who later carried limes for food to prevent scurvy were known as **'Lime juicers'**

The calcium deficiency in the body results due to the lack of its absorption in the gut and is closely related to the action of vitamin *D*.

Phosphorus mainly functions with calcium as calcium phosphate. It is essential for the development of bone and teeth. Phosphorus is extremely important in carbohydrate and protein metabolism. It plays as such an important role in liberation of energy for muscle contraction and in other bodily processes which involve energy transfer. Milk is the natural source of phosphorus.

Potassium is an essential constituent of all cells. It is important in maintaining normal osmotic pressure and acid base balance of the body fluids. It is also essential for normal nerve conduction and muscle contractility.

Sodium and Chlorine : Blood and other body fluids are about 0·9 per cent salt and most of this is **sodium chloride**, the **common table salt.** Sodium and chlorine are important in maintaining osmotic balance in the body. They are of primary importance in the maintenance of proper acid base balance in the body and in the distribution of extra cellular fluids. The deficiency of sodium chloride hardly occurs as the diet normally contains relatively large amounts of sodium chloride usually far in excess of the body's needs.

In certain conditions like severe heat, or excessive muscular exercise, there is to be seen an increased loss of salt through sweating. The excessive decrease in salt level under these conditions results in exhaustion and **muscular cramps.** In such a case, when excessive loss of salt takes place in perspiration it is beneficial to give dilute sodium chloride solution to such persons.

Iron is required by the body for the production of haemoglobin, an iron-protein complex—which is produced in the bone marrow and is responsible for the carriage of oxygen in the blood. Lack of iron leads to *iron deficiency anaemia* which is more common in the lower income groups, where the diet high in carbohydrates, is low in iron content. Meat, egg yolks, liver, kidney, cabbage and peas are the best sources of iron.

Sulphur is an important constituent of all proteins and specially abundant in protein of hair and nails.

Magnesium is an essential component of a number of enzyme systems.

Iodine is an essential constituent of the hormone thyroxine secreted by the thyroid gland. Minute amounts of iodine are as such needed for the normal functioning of the thyroid gland. Its deficiency leads to a disorder called **simple goitre**. In this disease the thyroid gland enlarges and the enlarged gland can be detected by touching the neck. This enlargement of the gland may be in the form of a small swelling or in the form of a large disfiguring mass.



Fig. 5.6 Victims of simple goitre (enlarged thyroid) from an area where there was iodine deficiency in water and vegetable produce.

Iodine is found in sea water, vegetables and fish. In the regions where the diet is found to be deficient in iodine content; it has now become a common practice to add small amounts of potassium iodide to the common table salt to counteract the iodine deficiency.

Fluorine : Recently the importance of fluorine in the diet has focussed the attention of all. It is thought to play a role in the prevention of tooth decay. It is essential for normal bone and tooth

structure. It increases resistance of dentine to caries. It is now a common practice to add flouride salt to the drinking water. This has resulted in a striking decrease in the incidence of dental caries.

In addition to the above mentioned minerals there are some that are needed in traces only and which are described below.

Copper in traces is known to be necessary for the absorption of iron.

Manganese is an essential part of certain enzyme systems.

Cobalt as mentioned is a principal component of vitamin B_{12}.

Zinc is an important component in certain enzyme systems, especially the carbonic anhydrase system.

Selenium is an important trace element which acts with vitamin *E*, synergistically to help regulate oxidation-reduction processes in membranes.

Water : Water is the principal chemical constituent of the living substance. Some 70—80% of the living substance consists of water. Nearly three quarters of the body weight is water. It is needed as the main component of blood and to remove waste products from the body. 1½ pints of water are required per day by an adult. Much of this will be water from food.

Water is the universal solvent. Substances in solution are free to move about within the cell or from one cell to another. Most chemical reactions of living organisms take place only in solutions, and enzymes act only in a fluid medium. In water, substances like acids, bases and salts readily ionise.

Water plays an important part in the regulation of body temperature. Water serves as a reacting agent and is essential in all hydrolytic reactions.

Digestion :

Most of the solid food eaten by the vertebrates (with the exception of the mineral salts and some of the sugars) is insoluble or

even if it mixes with water, forms a **colloidal solution.** Such type of food is incapable of passing through the lining membrane of the alimentary canal. In order to make the food available to the needs of the body of an animal, the insoluble food has to be converted first into a soluble state or diffusible form. In this state only it can be absorbed through the lining membrane of the alimentary canal and is eventually taken into the blood or lymph from where it can be supplied to the various cells of the body.

The process by which the food is rendered soluble and diffusible is called **digestion**. The digestion is a process during which the breaking up of large molecules of food into smaller ones takes place. This action involves a chemical reaction of **biological hydrolysis,** (Gk. *Hydro*: water; *Lysis* : lossening) whereby water is inserted across the junctions of the initial larger molecules of food, breaking this as such into many smaller units. The food by this process of splitting achieved by hydrolysis is transformed into a true soluble state. The example of this reaction is given below whereby the hydrolysis of cane sugar yields glucose.

$$\underset{\text{(Sucrose)}}{C_{12}H_{22}O_{11}} + \underset{\text{(Water)}}{H{\cdot}OH} \xrightarrow{\text{Enzyme}} \underset{\text{(Glucose)}}{C_6H_{12}O_6} + \underset{\text{(Fructose)}}{C_6H_{12}O_6}$$

The above reactions of digestions can only take place in the presence of certain substances called the **enzymes.** (Gk. *Zyme* : yeast). Enzymes are complex protein substances produced by the living cells. The enzymes induce with ease and rapidity, chemical reactions. Each particular enzyme acts only upon a particular substance or a group of substances called the **substrate**—and, at the end of the reaction, the enzyme itself remains unaltered. The enzymes are as such the **organic catalysts.** Enzymes act best at a particular temperature — called the *optimum temperature.* The enzymes can produce its effect only within a limited pH range i. e., the medium in which they work shall have a certain alkalinity or acidity (pH value).

Enzymes are classified in accordance with the type of substance upon which they act. Taking into consideration the three principal

food stuffs i. e., carbohydrates, fats and proteins, three distinct types of digestive enzymes are recognised.

The enzymes that can digest carbohydrates only are called the *diastatic* or *amylolytic* enzymes (*carbohydrases*). The enzymes digesting the fats are known as *lipolytic enzymes* or *Lipases*. Likewise, the enzymes digesting proteins are referred to as *proteolytic enzymes* or *proteases*. In each group, there are numerous enzymes which are named according to their source and the particular substance upon which they act.

The Process of Digestion in Frog:

Digestion in frog follows on the whole, the typical vertebrate pattern.

Ingestion: The process and method of capturing the food has already been given on pages 13, 14. The insect seized by a frog is quickly swallowed. The teeth as described earlier only help in disallowing the prey from being escaped. No process of digestion takes place in the mouth cavity of frog. Frog is devoid of salivary glands. The secretions of the mouth however, serve merely as a lubricant.

The process of digestion starts when the food reaches the stomach.

Digestion in the Stomach:

The gastric glands of the stomach secrete the **gastric juice.** The gastric juice contains **hydrochloric acid** and also an enzyme called **pepsin.** It is a proteolytic enzyme which acts exclusively on proteins and converts them into substances of small molecular weight. **Kingsbury** (1894), has also reported the presence of a second enzyme **rennin** in the gastric juice of *Necturus*. Since no amphibian normally drinks milk, its function in amphibia is obscure.

Once the food is within the stomach, it is at first alkaline in nature. The hydrochloric acid destroys the alkalinity of the food and renders it acidic. The acidic also kills the majority of the bacteria taken in with the food. It also makes some insoluble salts soluble.

The hydrochloric acid macerates and breaks-down the food molecules. Tough fibrous material in plant and animal food is loosened; the cement between the cells is eroded and as such the acid causes the food mass to fall apart.

The food once rendered acidic, the proteolytic enzyme pepsin of the gastric juice now acts upon the proteins of the food, reducing them to proteoses and peptones by attacking the protein chains in the middle parts.

$$\text{Proteins} + H_2O \xrightarrow[\text{acid medium}]{\text{Pepsin}} \text{Proteoses or Peptones}$$

The food is retained in the stomach for sometime. The retention of food is facilitated by the presence of pyloric sphincter. During the retention of the food in the stomach, the rhythmical contractions and relaxations of the stomach muscles churn the food thoroughly. On account of this churning action, the gastric juice can mix up with the food thoroughly. As a result of this action the food eventually takes the form of a thick, creamy, acid fluid called **chyme**.

When the food is completely reduced to the condition of a chyme, the pyloric sphincter relaxes and the chyme spurts in small jets into the duodenum by the contraction of the stomach.

Digestion in the Small Intestines (Duodenum + ileum):

From the point of view of digestion the duodenum is the most important part of the alimentary canal. The secretions of the *pancreas* and the *liver* are poured into the duodenum.

The partly digested food entering the duodenum as described is acidic. The acidic food activates first the intestinal glands to produce a hormone called **secretin** which is soon released into the blood. On reaching the pancreas, secretin induces the pancreas to pour forth its highly alkaline pancreatic juice into the duodenum. The alkaline nature of the pancreatic juice first stops the action of pepsin and initiates the second series of digestive processes in

which the enzymes of the **pancreatic juice**, **bile** from the liver and the enzymes of the **succus entericus** secreted by the intestinal glands are involved. The details of the contents and mode of action of bile, pancreatic juice and succus entericus are given below.

The **bile** as described earlier is the secretion of the liver. It is stored up in the gall bladder. The bile is poured into the duodenum through a common *hepato-pancreatic duct* or *common bile duct*. The bile is a greenish alkaline watery fluid which however contains no digestive enzymes. The functions of the bile in the process of digestion are however as follows :

(1) The bile provides alkaline medium to the food. (2) It adds water to the food. (3) The salts present in the bile are essential to complete the digestive process in the intestine. (4) The bile is further stated to prevent putrefaction. (5) Bile also stimulates the peristaltic movement of the gut.

The bile salts are sodium bicarbonate, sodium glycocholate and sodium tauroglycocholate. The sodium bicarbonate reduces the acidity of the intestinal contents of the food. The two other salts lower the surface tension of the fats due to which the **emulsification** of fats takes place. The emulsification of fats is a process in which emulsion or suspension of fat droplets is obtained within the chyme. As the fat is broken into small droplets, a greater surface area is created due to which the lipolytic enzymes can act efficiently and this consequently results in the increase in the speed of digestion of fats.

When bile salts are absent from the intestine, e.g., when the bile duct is obstructed (e. g., in obstructive jaundice in man), the absorption as well as the digestion of fats is impaired and much of the fat eaten is lost in the faeces.

The bile also contains the pigments bilirubin (red in colour) and biliverdin (green in colour) which colour the faeces. These pigments are in a measure excretory products, as they are produced from the break-down of haemoglobin of red blood corpuscles.

In certain cases in man when the bile duct is obstructed, the bile pigments are not present in the faeces. This faeces becomes whitish or clay coloured. In such a condition and in certain impairments of the functioning of the liver, the bile pigments accumulate in the blood and tissues, giving a yellowish tinge to the skin, a condition known as **jaundice**.

The **pancreatic juice** is a watery alkaline fluid, rich in enzymes. It contains **trypsin** a proteolytic enzyme, **amylase** a diastatic enzyme and **lipase** the **lipolytic** enzyme.

The trypsin is secreted in an inactive form, **trypsinogen** which becomes active trypsin after being mixed up with succus entericus which contains an activator called *enterokinase*.

The **succus entericus** is the digestive juice secreted by the glands of the duodenum and the ileum. It is an alkaline watery fluid, which contains besides the enzymes enough quantity of mucus. The enzymes of the succus entericus are **amino-peptidases** and **dipeptidases**, as parts of a mixture once called **erepsin.** They are proteolytic enzymes. In addition to these, the other enzymes of the succus entericus are **enterokinase** (an activator), **lipase** (lipolytic enzyme), **invertase**, **maltase** and **lactase** (the diastatic enzymes).

The food during its passage through the duodenum and the ileum receives in addition to enzymes, still more water from various secretions and is turned in the form of a fluid emulsion called **chyle.** The chyle by peristalsis is slowly forced through the duodenum and the ileum. The enzymatic action continues the whole time during the movement of the food from the duodenum to the ileum.

The details of the process of digestion in the region of the small intestine are summarised below.

The addition of the pancreatic juice and the sodium bicarbonate of bile renders the food alkaline after which the enzymes of the pancreatic juice and that of succus entericus act efficiently.

As regards the pancreatic enzymes, trypsin is the most important with reference to the carnivorous diet of the amphibians. Trypsin as mentioned is secreted in an inactive state called trypsinogen. It is activated by the enterokinase of the succus entericus and is converted into active form of trypsin. Trypsin continues the protein digestion begun in the stomach and converts the partly digested proteins (proteoses) chiefly to the peptone stage.

$$\text{Proteoses} \xrightarrow{\text{Trypsin}} \text{Peptones}$$
$$+$$
$$H_2O$$

The amylase of the pancreatic juice converts starches (also glycogen) i. e., polysaccharide into maltose.

$$\text{Polysaccharide (starches)} + H_2O \xrightarrow{\text{Amylase}} \text{Maltose}$$

The lipase splits certain fats into fatty acids and glycerol.

$$\text{Fats (emulsified)} + H_2O \xrightarrow{\text{Lipase}} \text{Fatty acids} + \text{Glycerol.}$$

The enzymes of the succus entericus complete the process of digestion. The enterokinase as mentioned, activates the pancreatic enzyme trypsinogen and converts it into trypsin.

$$\text{Tripsinogen} \xrightarrow{+\text{Enterokinase}} \text{Trypsin}$$

The succus entericus as mentioned also contains a proteolytic enzyme earlier called **erepsin.** The erepsin in fact is a mixture of proteolytic enzymes **aminopeptidases** and **dipeptidases.** These enzymes complete the digestion of proteins. They convert the peptones into amino acids.

$$\text{Peptones} + H_2O \xrightarrow[\text{(Erepsin)}]{\text{Aminopeptidases and dipeptidases}} \text{Amino acid}$$

Thus, aminopeptidases and dipeptidases complete the work begun by pepsin and trypsin of converting finally the proteins into amino acids.

The **lipase** of the succus entericus as before, hydrolyses fats into fatty acids and glycerol.

The other enzymes of succus entericus are diastatic. Of these the **invertase** turns sucrose (cane sugar) into glucose and fructose, the **maltase** turns maltose into glucose, and the **lactase** turns lactose into glucose.

$$\text{Sucrose (cane sugars)} + H_2O \xrightarrow{\text{Invertase}} \text{Glucose} + \text{Fructose}$$

$$\text{Maltose} + H_2O \xrightarrow{\text{Maltase}} \text{Glucose}$$

$$\text{Lactose} \xrightarrow{\text{Lactase}} \text{Glucose} + \text{Galactose}$$
$$+$$
$$H_2O$$

The digestion as studied is thus a process of hydrolysis which results by the action of enzymes on the substrates. As a result of the enzymatic action we can now conclude that all the proteins of food are hydrolysed to amino acids, the carbohydrates to glucose or similar monosaccharide sugars (simple sugars) and the fats to fatty acids and glycerol.

Absorption and Assimilation :

The products of digestion are absorbed mainly by the walls of the small intestine. Very little absorption of digested food takes place either in the buccal cavity or the stomach.

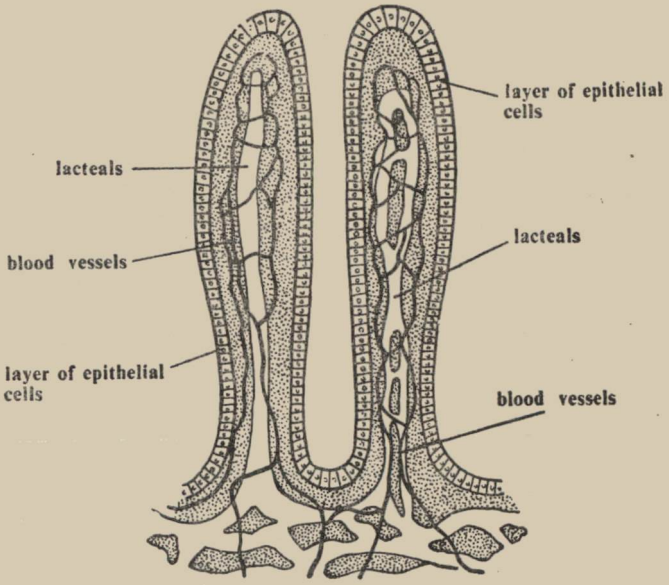


Fig. 5.7 Two villi from the intestine of a mammal as seen under high magnification.

The absorptive area of the small intestine (ileum) is greatly increased by the presence of **intestinal villi** or the **longitudinal ridges.** Each villus is well supplied with capillary blood vessels. In the centre of each villus is a lymphatic vessel called the **lacteal** which is a part of an extensive lymphatic system (to be described later).

The digested carbohydrates in the form of monosaccharide sugars chiefly glucose and proteins as amino acids are absorbed by the blood capillaries of the intestinal villi. These capillaries in turn lead to the factors of the hepatic portal vein. The hepatic portal vein enters the liver where it breaks up into capillaries in the substances of the liver. All the digested carbohydrates and proteins are thus first conveyed to the liver through the portal vein, before they enter the general circulation.

The **liver** acts as a regulating centre for the redistribution of the digested food. A required amount of sugar is allowed to enter the blood through the hepatic vein into the general circulation. Any excess of glucose is turned into **glycogen** or **animal starch** and is stored in the liver. Various tissues especially the muscles store glycogen, but the liver serves as the general depot. If the sugar level in the systemic circulation falls, then the glycogen stored in the liver is turned once again into glucose and released in the blood.

The amino acid brought to the liver are released in suitable quantities into the blood stream and these are later elaborated into body proteins by complex mechanisms.

The complex mechanism in the elaboration or synthesis of body proteins from amino acids involves the nucleic acid like DNA[1], RNA[2], cell organelles like ribosomes, certain synthesising enzymes and above all chemical energy in the form of ATP.

The amino acids in excess of the required needs of the body, however undergo a process of **deamination** in the liver. As a result of deamination, part of the amino acids are converted into a relatively harmless nitrogenous substance called **urea** $CO(NH_2)_2$. The urea thus manufactured in the liver is ultimately eliminated by the kidneys to the outside of the body.

The digested fat as fatty acids and glycerol is reformed into fats in the intestinal cells and passes directly into the lacteals. Within the lacteals the fat is transformed atonce into minute globules of fat so that the lymphatic vessel contains a whitish fat emulsion from the milky appearance of which it gets its name **lacteal.** The lymphatic vessels join the systemic circulation by way of thoracic

1. (DNA) Deoxyribonucleic acid.
2. (RNA) Ribonucleic acid.

duct and the right lymphatic ducts. The fat from the lymphatic vessel as such enters the blood stream by the above mentioned route.

The fats not used atonce by the tissues are stored chiefly in the **liver** and the **adipose body**. The importance of liver as a place of fat storage is particularly to be noted in hibernation and in the early spring mating season, since fat can be most rapidly mobilised from the liver.

The **adipose bodies** are found just anterior to the gonads. Some frogs have a prominent fat body just anterior to the calvicles and various narrow mouthed toads have small fat bodies beneath the skin. In salamanders, large accumulations of fats are usually found in the tail. In the case of proteus, the fatty tissue forms a thin sheet under the skin.

The products of digestion after being conveyed to the tissues in the manner already mentioned, eventually undergo a process of assimilation. Assimilation is a process during which the digested products either build up new protoplasm or they are utilised to provide a source of energy for the vital activities of the body.

Egestion : After the absorption of digested food products, the remaining fluid mixture contains indigestible portions of the food materials consisting of the remains of various secretions and organic detritus. These indigestible parts are passed on from the ileum to the rectum or the large intestine. Here the indigestible portions are retained for sometime. During this retention, enough water from the indigestible contents is reabsorbed by the lining of the rectum. This conservation of water by a process of reabsorption is most essential for terrestrial animals and is also necessary for those like frog spending its life partly on land and partly in water. Excessive loss of water from the body leads to serious consequences as the tissues that become depleted of their water content cannot function. The animal due to excessive loss of water may suffer from dehydration which may result in its death.

After the reabsorption of water the remaining indigestible portions of the food in a semi-solid form called the faeces is stored in the rectum for sometime. Later at intervals the excreta or faeces pass out through the cloacal aperture to the exterior. This process of elimination of faeces to the exterior is referred to as **egestion.**

Revision questions

1. Draw a labelled diagram of the alimentary canal of frog and describe the various parts of it in detail.

2. Describe in brief the food of amphibians with a mentioning about the importance of food to living organisms.

3. What are food stuffs? Describe in detail the chemical structure and the role of carbohydrates, proteins, fats, mineral salts and water with a special reference to the importance of these substances to the living body.

4. Write what do you know about vitamins? How are they classified? Mention in brief the importance of various vitamins to the body with a reference to the various disorders caused due to their deficiency.

5. Explain the terms ingestion, digestion and egestion. Describe in detail the process of digestion in frog.

6. Write a note on enzymes with a particular reference to their important characters, specificity, classification and mode of action.

7. Give a detailed account of how the digested food is absorbed and assimilated in frog.

8. Write notes on the following :
   (a) The role of bile in the process of digestion.
   (b) Emulsification.
   (c) Peristalsis.
   (d) Pyloric sphincter.
   (e) Essential amino acids.
   (f) Rickets.
   (g) Pellagra.
   (h) Beri-beri.
   (i) Biotin.
   (j) Scurvy.

CHAPTER VI

THE MICROSCOPIC STRUCTURE OF THE SKIN OF FROG

and

The Histology of the Alimentary Canal and Associated Digestive Glands of Frog

The Skin of Frog:

The skin of frog besides acting as a **protective outer covering**, also serves as a **respiratory surface**. In order to perform the **skin respiration** or **cutaneous respiration**, the surface of the skin has to be kept moist, even when the animal is out of water. To keep the skin moist, there are to be found numerous mucous secreting glands in it.

The structure of the skin can well be followed if we observe the vertical section of the skin i. e., the section taken at right angles to its surface.

The skin as revealed by its vertical section can be seen to be distinguished into two distinct cellular layers — the outer layer, the **epidermis** and the inner layer, the **dermis**. It is a good example of startified or compound epithelium.

The **epidermis** is composed of several layers of epithelial cells. These cells differ greatly in form according to their position. The cells of the inner or deeper layer are columnar in shape, and form the **germinative layer** or the **malpighian layer**. The cells in this layer divide actively and as they move upward they become squamous or scaly in shape and much of their living substance turns into a horny substance. These cells as such form a comparatively hard and insensitive superficial covering to the body. The most superficial horny layer of cells is cast off or sloughed off from time to time as shreds.

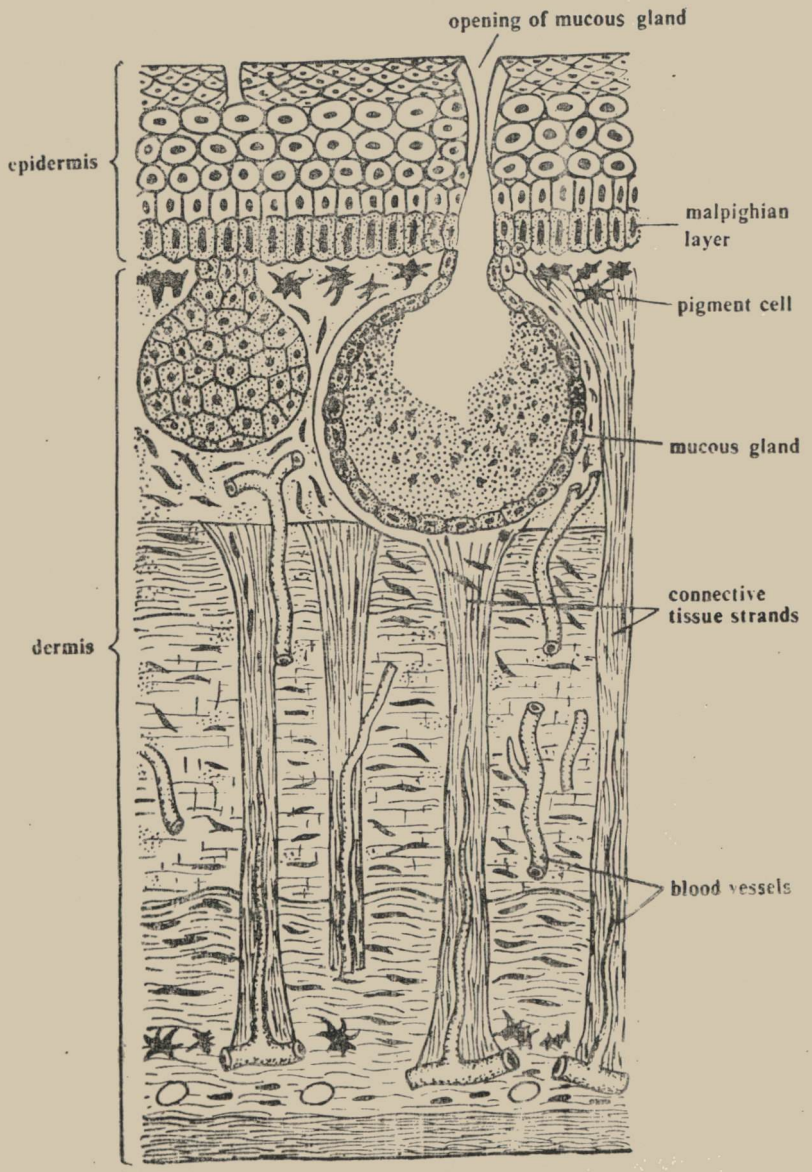


Fig. 6.1 Structure of the skin of frog as seen in vertical section.

As the superficial cells are sloughed off, the cells from the inner layers, by their multiplication increase in number, and move upwards. There is thus a regular and continuous movement of cells from inner to the outer surface of the epidermis. As the cells pass towards the outer surface they become more and more flattened and at last squamous and horny. The whole process goes on in such a way that the multiplication of the columnar cells of the germinative or Malpighian layer is just sufficient to make good the loss of the squamous cells in the superficial layer.

Below the epidermis lies the **dermis** which is formed of connective tissue, the fibres of which are mostly horizontal, or parallel to the surface of the skin. There are also found at intervals bands of vertical fibres. The dermis gets abundant blood supply. The blood capillaries pass through the substance of the dermis in all directions. Nourishment is supplied to the skin through these capillaries and further this capillary net-work also makes the skin an efficient respiratory surface. The dermis is also well supplied with nerves, the fibres of which innervate the deeper layer of the epidermis. In the superficial region of the dermis are also found irregularly shaped **pigment cells**. The cytoplasm of these cells contains pigment, often appearing intensely black. The contractions and expansions in the pigment cells are responsible for the appearance of coloured patches in the skin of amphibians and consequently frequent changes in the colour of the skin of frogs and toads are noted.

In the superficial part of the dermis are also found flask shaped, **cutaneous glands** or the **mucous glands**. These glands secrete a transparent substance which serves as a lubricant and also keeps the skin moist on land.

In section, the flask-shaped mucous gland is seen to consist of a nearly globular cavity from which a narrow duct, like the neck of a flask passes through the epidermis to open on the external surface. The body and neck of the gland are lined by epithelial cells. The cells lining the body are nearly cubical or columnar and are continuous with the malpighian layer. The cells which line the neck are squamous in shape. The epithelial cells of the body of the

gland form minute droplets of the fluid, out of the materials supplied to them by the blood. The droplets so formed accumulate in the interior of the gland from where this fluid in the form of a slimy sticky secretion called the *mucous*, is discharged to the surface of the skin by the duct of the gland. Each mucous-secreting cutaneous gland is formed as an inpushing of the epidermis deeply into the dermis, the narrow neck of the gland opening on the surface. Besides keeping the skin moist, the additional advantage of the secretion of mucous by these glands is that the skin becomes slippery and makes the animal difficult to hold. Some of the cutaneous glands in amphibians produce a distasteful and possibly poisonous substance which serves as a further protection against capture by enemies. Many toads possess such type of poison glands.

As mentioned earlier, the skin of frog is attached to the underlying muscles only at intervals so that it is extremely loose. The spaces below the skin are filled in with the lymph, hence called the lymph spaces.

Further, as mentioned earlier, the male frogs in the breeding season develop a deeply pigmented cutaneous thickening on each thumb forming what are referred to as *copulation* or *nuptial pads*. These as described are used for holding the female firmly during the deposition of eggs and their fertilisation. The skin also becomes thickened over the tips of the digits to form a sort of claw.

The General Histological Structure of the Alimentary Canal:

The cavity or lumen of the alimentary canal is lined by a mucous membrane composed of columnar epithelial cells. In the different parts of the alimentary canal e. g., stomach and intestine four distinct regions of the cellular layers can be recognised. These cellular layers from the lumen of the alimentary canal to the outer side are as follows :

(1) **The Mucosa**, lining the cavity or lumen of the alimentary canal consists of columnar epithelium. Just below the mucosa

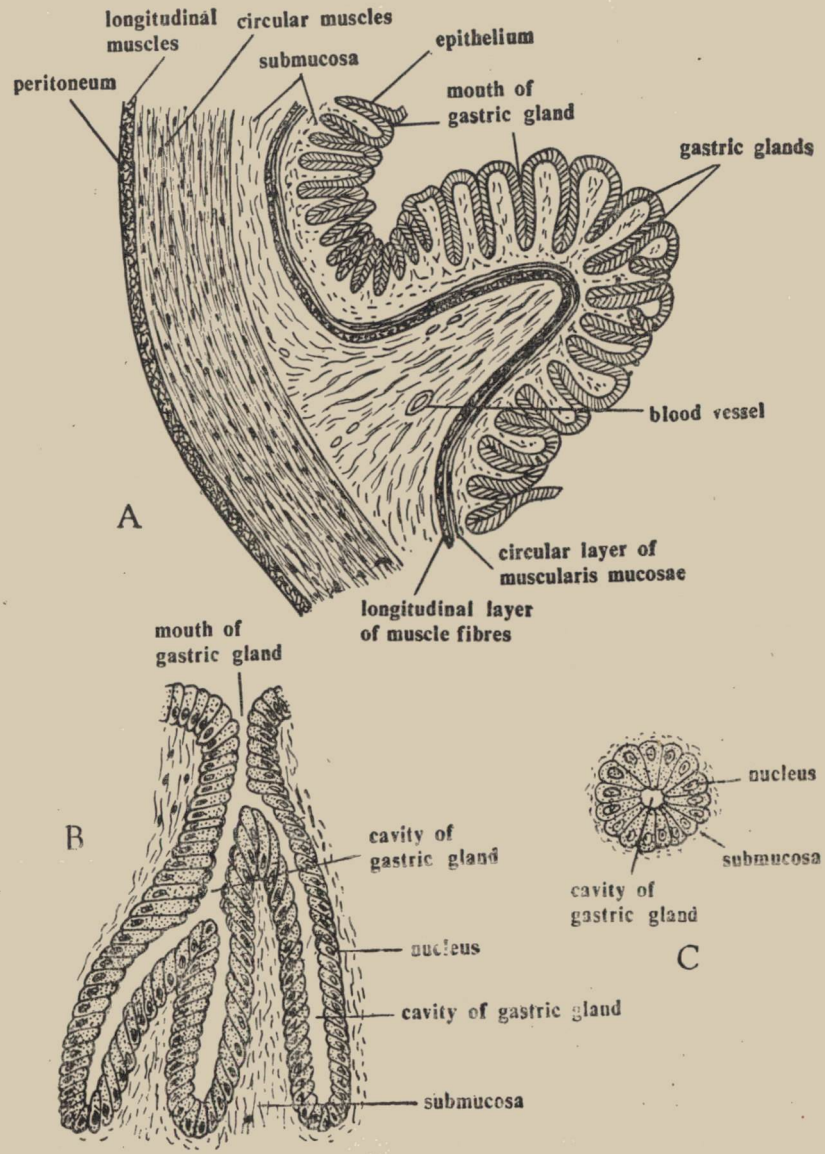


Fig. 6.2 (A) Part of a transverse section of the frog's stomach. (B) Gastric glands in longitudinal section. (C) Transverse section of a gastric gland.

is found the **muscularis mucosae**. (2) The **sub-mucosa** lies next to the mucosa. It is composed of areolar connective tissue, blood and lymph vessels. (3) **muscular coat** is composed of the circular and longitudinal muscle fibres. (4) The **serous membrane** or **serosa** is continuous with the peritoneal sheath. It forms the outer-most covering of the alimentary canal.

The Histology of the Stomach of Frog:

The lumen of the stomach is lined by the **mucous membrane** or **mucosa.** It can be seen as a very soft, thick and smooth layer when the stomach is in a distended condition i. e., when it is full of food. In an empty stomach this mucous membrane is seen to consist of longitudinal folds. These longitudinal folds are formed by the sinking of the mucous membrane into the underlying connective tissues. The longitudinal folds are the simple or branched tubular glands called **the gastric glands.** The gastric glands are to be regarded as devices for increasing the surface area of the glandular epithelium and to produce the gastric juice. The gastric glands are simple or slightly branched tubular glands. They are deep, but very narrow and are in the form of cylindrical pits. These cylindrical pits or the gastric pits are embedded vertically in the wall of the stomach. The cylindrically secretory parts of the gastric glands, through their minute ducts open on the surface of the mucous membrane through minute holes called the mouths of the gastric glands. The gastric glands are lined by epithelial cells. There are three distinct types of epithelial cells in the different parts of the gastric gland.

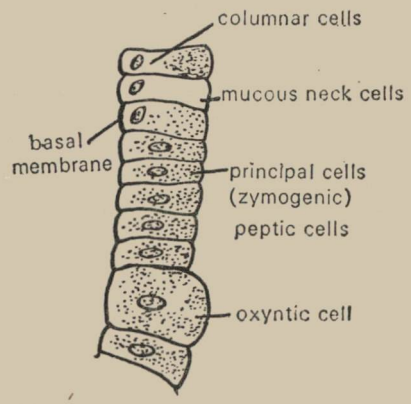


Fig. 6.3 Transverse section of the epithelium of gastric gland to show three distinct types of gastric cells.

(1) The cells round the mouth of the glands and extending a short way down the tubes (at the neck) are simple columnar cells arranged in somewhat radiate manner. They secrete mucus and are called **mucous cells.**

(2) The **principal cells** or **peptic cells** or **'Zymogen cells'** line the deeper secretory parts of the glands and extend the greater part of their length. These cells are cuboidal and granular. Their nuclei are placed centrally. They secrete **pepsin.**

(3) There are also large cells ovoid in shape with prominent nuclei called the **oxyntic cells.** They are less numerous than the above two. They occur most abundantly a short way below the mouths of the glands and secrete hydrochloric acid.

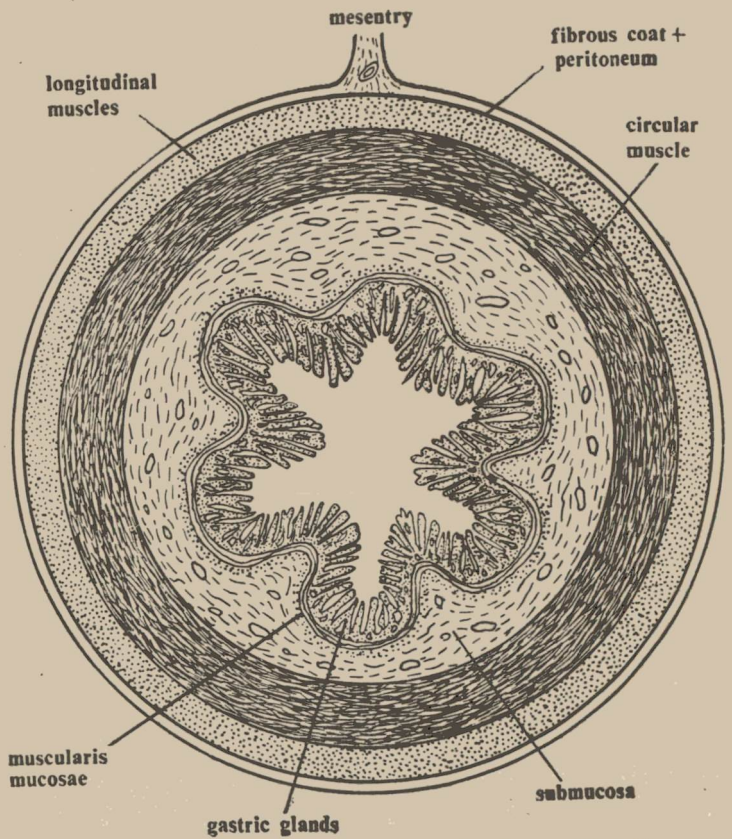


Fig. 6.4 Transverse section passing through a frog's stomach (diagrammatic).

Below the mucosa lies the **sub mucosa** composed of connective tissue, blood vessels, lymphatics and nerves.

The sub-mucosa of the stomach is traversed by a narrow band of unstriped muscles called the **muscularis mucosae**. It is composed of an outer thin layer of longitudinal muscle fibres and an inner thin layer of circular muscle fibres facing towards the gastric mucosa.

The sub-mucosa in the stomach is covered by a very thick coat of **muscular layer.** It is divisible into two parts—An outer layer of *longitudinal muscle fibres* which run parallel with the long axis of the cavity of the stomach and an inner much thicker layer of *circular muscle fibres*. The circular muscle fibres lie at right angles to the longitudinal fibres.

The most superficial layer forming an outer covering to the stomach is called the **serous coat** or the **serosa.** It is formed of a thin layer of loose fibro-elastic connective tissue with an outer covering composed of squamous epithelium.

Histology of the Intestine of Frog :

A transverse section passing through the ileum reveals the structure of the intestine. As observed in the case of stomach, the wall of the ileum also consists of the usual four coats.

1. The inner lining of the intestine called the **mucosa** or mucosa coat is thick, highly vascular and is thrown into a large number of folds. These folds in the duodenum are found in the form of a network. True villi are absent in the case of frog's intestine. However the mucosa is found in the form of a network of ridges, 'villi' which considerably increase the absorptive surface of the intestine.

The mucosal epithelium consists of a single layer of columnar cells with their long axes at right angles to the elevations into which the mucosa membrane is thrown. Within this columnar epithelium may be recognised two types of cells — (i) ordinary absorptive **columnar cells** and amongst ordinary cells are found

(ii) numerous mucus secreting **goblet cells.** This mucosa is devoid of simple tubular or branched glands as were seen in the stomach.

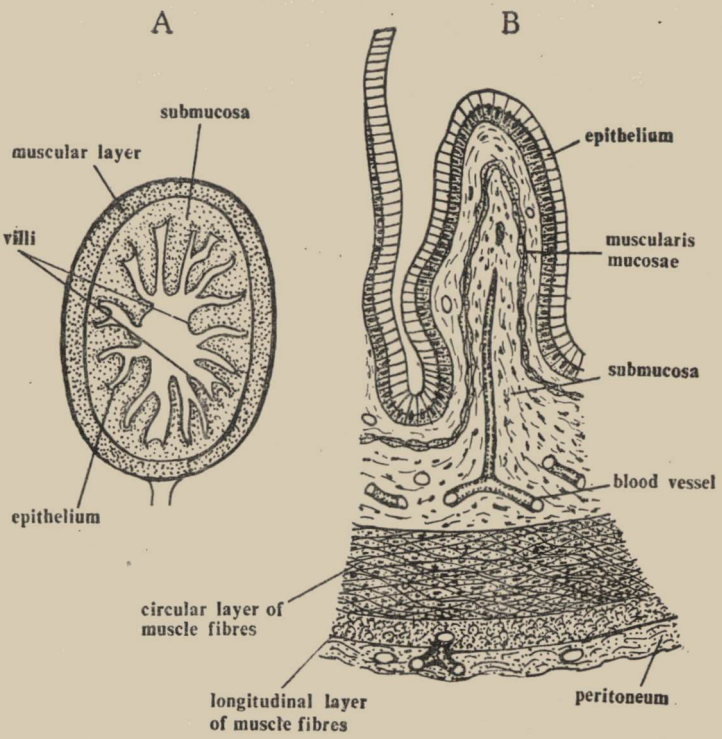


Fig. 6.5 (A) Transverse section passing through the ileum of frog.
(B) Small portion of the same under high magnification.

2. The mucosa is followed by the **sub-mucosa** consisting of a connective tissue in which are to be seen blood vessels, lymphatics and nerves. The sub mucosa is traversed by a very thin layer of **muscularis mucosae.**

The sub-mucosa is covered at its outer side by a muscular coat in which two types of **muscular layers** like stomach are recognised; an outer layer of *longitudinal muscle fibres* and an inner thick layer of *circular muscle fibres.* In intestine, the muscular coats are not so well developed as in the stomach.

3. The muscular layer is covered towards its outer surface by **serosa** or serous coat formed of a thin inner layer of connective tissue and an outer layer of squamous epithelium.

The Histology of the Liver of Frog :

The liver of frog is made up of innumerable large, polyhedral cells. These polyhedral cells, called the **hepatic cells** or **liver cells** are arranged in columns and are surrounded by extremely fine channels or **bile passages.** The bile passages are found to open into one another and finally lead to definite tubes called the **smallest bile ducts.** These, in turn, unite into longer and larger tubes which join to form the **hepatic ducts.** The hepatic ducts ultimately open into the **common bile duct.**

The hepatic or liver cells are glandular and secrete the bile. The bile as it is formed goes into the bile passages from where it passes into the hepatic ducts. The hepatic ducts either communicate directly with the common bile duct or with the ducts which ultimately open into the **gall bladder.** The gall bladder as mentioned earlier thus stores the bile in it. The bile from the gall bladder as and when needed is passed into the *common bile duct* or the *hepato-pancreatic duct* which ultimately pours the bile into the duodenum. The entire substance of the liver is traversed by a complex network of capillaries, formed partially from the hepatic artery and partly from the hepatic portal vein. The blood thus supplied to the liver brings with it, the digested carbohydrates and proteins.

Functions of the Liver :

1. The secretion of the liver called the bile contains no digestive enzymes. The importance of bile however in the process of digestion has already been discussed in detail under the physiology of digestion (See pages 112 and 113).

2. The liver is not primarily an organ of digestion. It's main role is the reception and storage of food substances assimilated in the intestine.

The liver allows some quantity of glucose to pass in the blood. The excess of carbohydrates are stored in the liver as **glycogen** or **animal starch.** Liver is also chiefly concerned in the further elaboration of fatty substances and the storage of fat. In the cold blooded animals like frog more fat is stored in the liver during hibernation and in the early spring mating season. Dolk and Postma (1972), have demonstrated that the frogs during hibernation use their stores of fat in the liver and not their glycogen reserves.

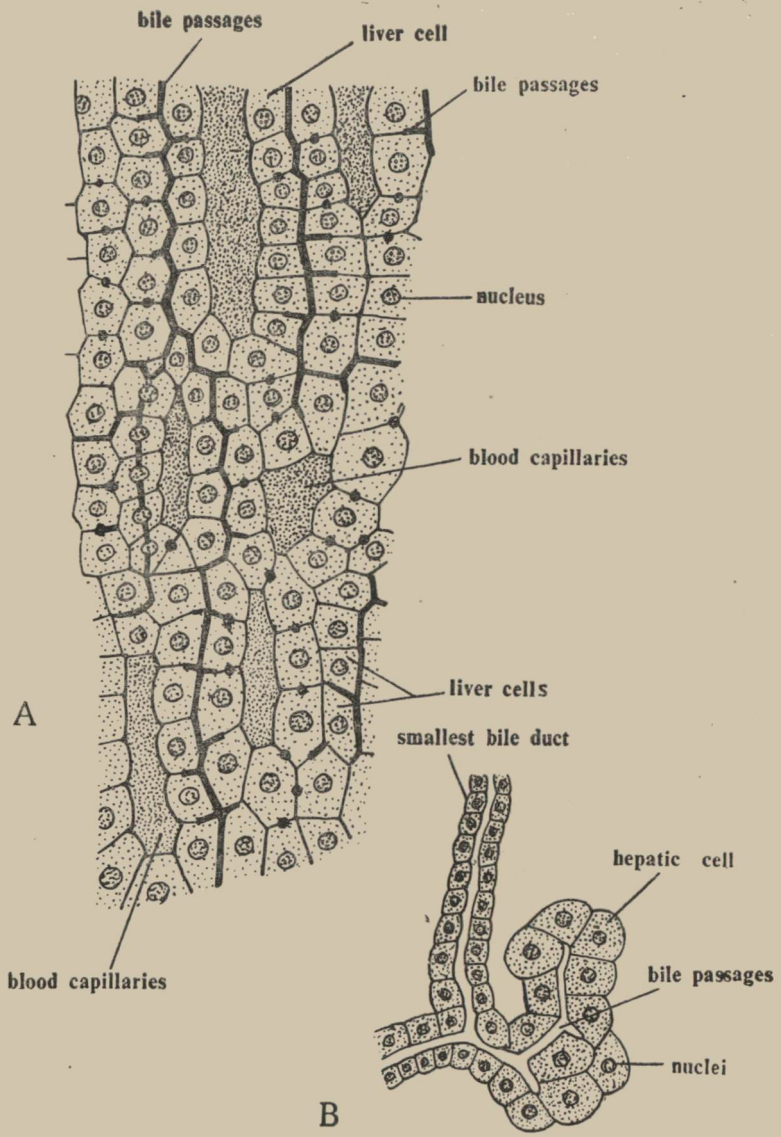


Fig. 6.6 (A) Part of a section passing through the liver of frog.
(B) Small portion of the same under high magnification.

3. During the break-down of the haemoglobin of the red blood corpuscles in the liver, the bile pigments are produced. The iron from the haemoglobin is retained in the body and used for the formation of more blood pigment.

4. The liver also converts excess of proteins by a process of deamination into urea $CO(NH_2)_2$ which is eventually eliminated from the kidneys.

5. The liver also plays an important part in the removal of waste products and foreign matters and general detoxication of the blood.

Histology of the Pancreas of Frog :

The section passing through the pancreas shows that it is made up of microscopic masses or **lobules.** Each pancreatic lobule

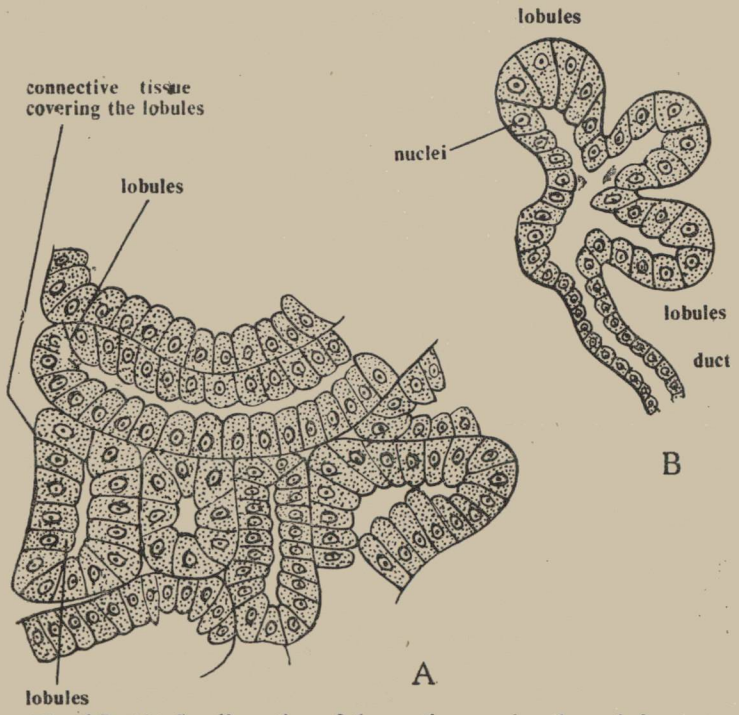


Fig. 6.7 (A) Small portion of the section passing through frog's pancreas. (B) Part of the same under high magnification showing the connection between the lobules and the ducts.

in turn is formed by a bunch of gland cells enclosing a very narrow central space. Central spaces of the adjacent lobules communicate with one another and open into tubes or ducts lined with epithelium. These ducts join with one another and finally open into the bile duct as it traverses the substance of the pancreas. The pancreas according to its structure is also similar to the bunches of grapes and is referred to as a racemose or grape bunched gland. The duct can be compared to the branched stalk and the lobules to the grapes. The gland cells of the pancreas secrete the pancreatic enzymes already mentioned.

The sections of the human pancreas and of other animals like the rabbit, dog, etc., show that among the clusters of gland cells, there are found rounded masses of cells. These rounded masses of cells are quite different in structure from the gland cells forming the pancreatic lobules. These masses of cells are called the **'Islets of Langerhans.'**

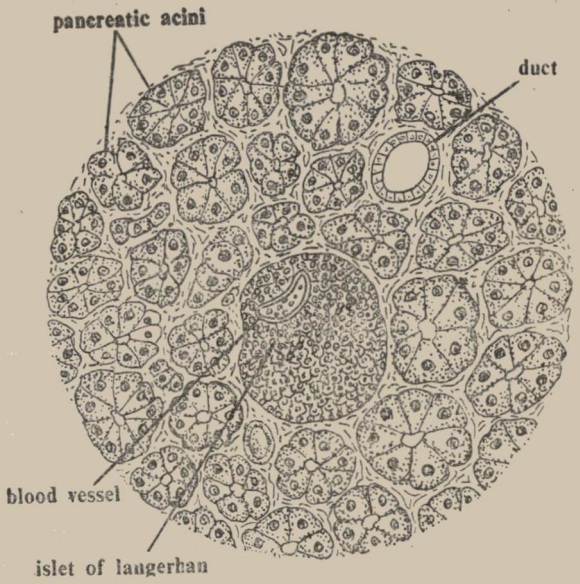


Fig. 6.8 T. S. Passing through a mammalian pancreas.

In amphibia, the islets of Langerhans occur as cords of cells associated with the small pancreatic ducts but have no lumen,

The cytoplasm of the cells is clear and contains granules. By special techniques it is revealed that islets of Langerhans are composed of several cell types.

The islets of Langerhans are endocrine glands which secrete a hormone called **insulin** directly in the blood. The insuline regulates the amount of sugar in the blood by facilitating the assimilation of sugar by the tissues. If insulin is not present in the blood, glucose is neither oxidised nor converted into glycogen but accumulates in the blood and is excreted in the urine. Impairment in the normal functioning of the islets of Langerhans leads to *diabetes mellitus*, a disease characterised by excess of sugar in the blood and also its presence in urine.

The pancreas as such is an organ having two functions. The gland cells of the pancreas form the *exocrine part* which secrete the pancreatic juice, digestive in function. The islets of Langerhans secreting insulin are the *endocrine part* of the pancreas. Pancreas as such is both an exocrine and an endocrine gland.

Revision questions

1. Describe in detail the microscopic structure and functions of the skin of frog.
2. Give an account of the histological structure of the stomach of frog.
3. Mention in detail the microscopic structure of the intestine of frog.
4. Describe the histology of the liver of frog and mention in brief the functions of the liver.
5. Describe the structure of the pancreas of frog mentioning its functions. What is the function of the islets of Langerhans?

CHAPTER VII

THE FROG - VASCULAR SYSTEM

The vascular system of vertebrates consists of a system of **vessels** or tubes in which the fluid **blood** or **lymph** circulates. It is therefore referred to as the **circulatory system.** The system of vessels through which the blood circulates is called the **blood vascular system** and the system of vessels through which the lymph flows is known as the **lymph vascular system**. In vertebrates, the two vascular systems are very closely interconnected.

The main function of the vascular system is to carry the digested food from the alimentary canal to all parts of the body. The oxygen is also conveyed to various parts of the body through the vascular system. Like-wise the waste products from the tissues of the body e. g., CO_2 and nitrogenous wastes are collected by the vascular system and are then taken to the organs concerned for elimination.

The main parts of the blood vascular system of frog will now be described.

The Heart :

The heart of frog is somewhat conical in shape with its apex directed backwards. It lies in the anterior part of the body cavity on the ventral side. It is encircled by the pectoral girdle and is situated just above the sternum.

The heart is enclosed in a double walled sac, the **pericardium**. The inner wall of the pericardium closely invests the heart. It is called the **visceral layer of pericardium.** The outer wall of the pericardium is called the **parietal layer of pericardium.** Between the two layers of the pericardium lies the **pericardial cavity**, filled with **pericardial fluid** The pericardium with its pericardial fluid protects

the heart from any friction or mechanical shocks. The pericardial cavity of frog, in fact is a modification of the body cavity.

After the removal of the pericardium, the various parts of the heart are well exposed.

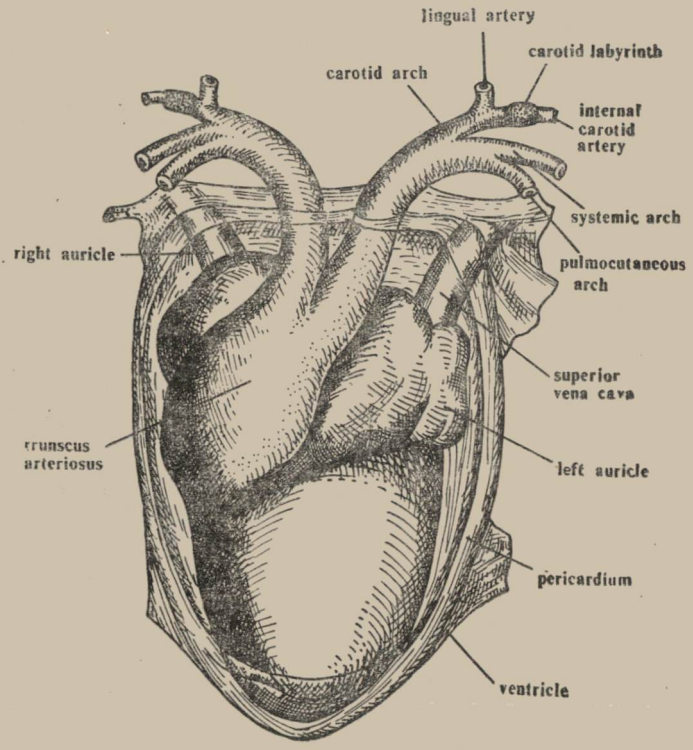


Fig. 7.1 The heart of frog with it's pericardium as seen from the ventral side.

The heart of frog consists of **three chambers**. The upper two chambers situated at the base of the heart are called the **auricles** or **atria** (singular : atrium). A single chamber situated at the lower side or apex of the heart is called the **ventricle**.

The **ventricle** is roughly conical in shape, the apex of which is directed posteriorly. It is usually somewhat paler than the rest of the heart. This is on account of its thick and less transparent wall.

The **two auricles**—right and left, occupy the anterior part of the heart. The walls of the auricles are comparatively thin. The relation of the main blood vessels to the heart is as follows:

The **truncus arteriosus** arises from the right side (your left) of the ventricle, immediately below the right auricle. It inclines to the left (your right) and lies on the ventral surface of the heart between the two auricles. At about the anterior border of the auricles, or even a little before, the truncus anteriosus divides into two main arterial trunks called the **right and left aortic arches.** Each aortic arch divides almost immediately into three main arterial arches. The upper, i.e., the foremost is called the **carotid arch**, the middle, the **systemic arch** and the lowermost, the **pulmocutaneous arch.**

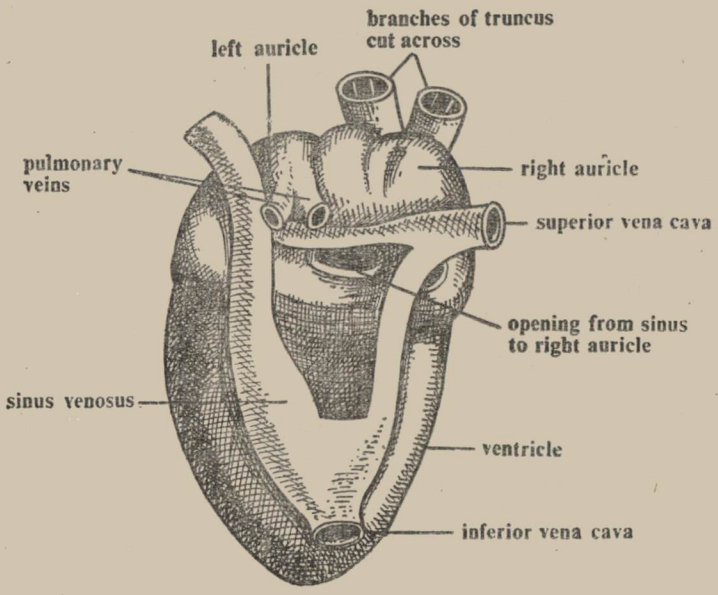


Fig. 7.2 The heart of frog seen from the dorsal side. The pericardium is removed.

If the heart is turned upwards, and is deflected towards the head, one can notice a ▽-shaped **sinus venosus.** It is a thin walled triangular chamber occupying the greater part of the dorsal surface of the heart. The **sinus venosus** opens into the right auricle. The

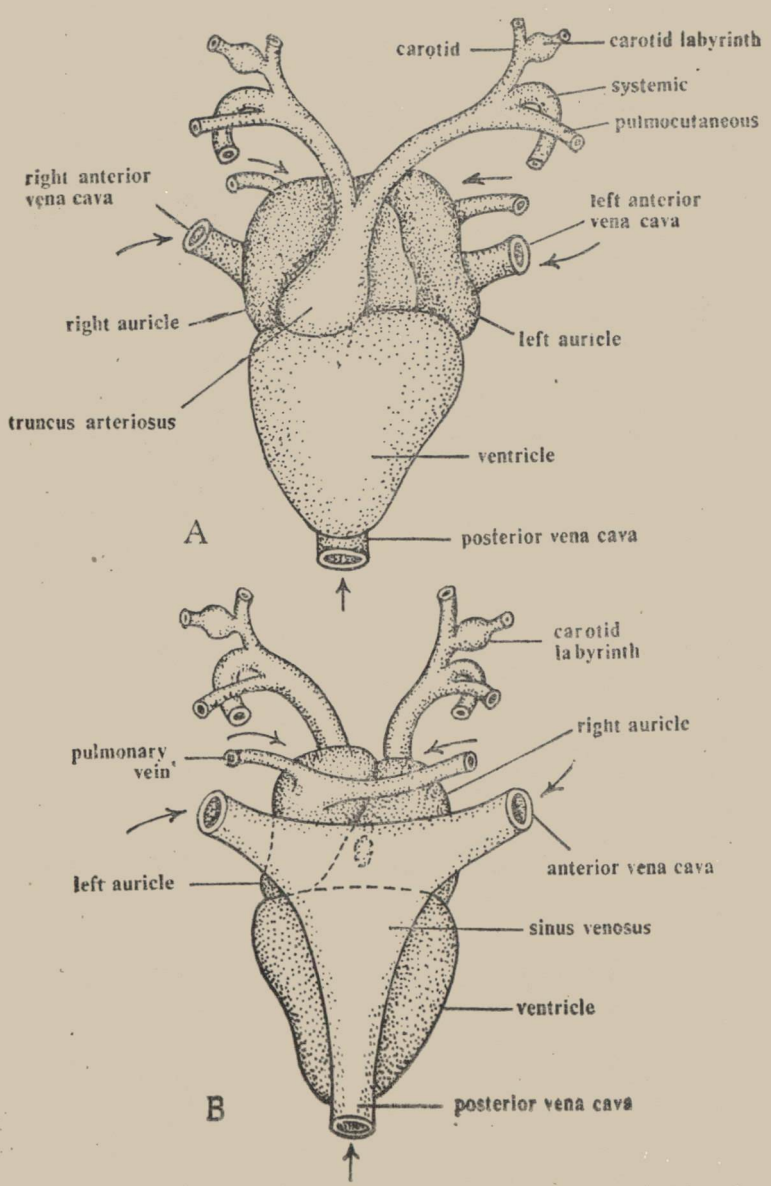


Fig. 7.3 The heart of frog (A) Ventral and (B) Dorsal views.

sinus venosus further receives at it's each angle, three **vena cavae** i e., **two anterior** (or **superior**) **vena cavae** and one **posterior** (or **inferior**) **vena cava.**

The **pulmonary vein** formed by the union of the right and left pulmonaries from the lungs, opens into the left auricle.

The blood vascular system of frog can be studied thus under the following headings.

1. *The arterial system*—i.e., the principal arteries arising from the heart and supplying blood to various parts of the body.
2. *The venous system*—i. e., the principal veins which collect blood from different parts of the body and ultimately bring it back to the heart.
3. *The internal structure of heart* and its mode of action.
4. *The blood*—its structure and functions.

The Arterial System

It has already been mentioned that the main arterial trunk, the *truncus arteriosus* divides into two aortic branches and each in turn, on each side gives rise to the *carotid arch*; the *systematic arch* and the *pulmo-cutaneous arch.*

I. **The carotid arch** is the most anterior of the three arches. It curves outward and forward and gives off on each side the **lingual artery.** It runs under the hypoglossal nerve and supplies blood to the muscles of the tongue. From the origin of the lingual artery the carotid arch is continued as the carotid artery. The beginning of the carotid artery is marked by a swelling on the vessel known as the **carotid gland** or the **carotid labyrinth.** The carotid labyrinth consists of minute vessels formed by the breaking up of the carotid artery. The friction of the blood against the large surface provided by the breaking up of carotid artery in the labyrinth, is responsible for the high pressure in the carotid arch. The small vessels of the carotid labyrinth reunite to form the carotid artery again. The carotid artery beyond the labyrinth ultimately enters the orbit. At the point where the carotid artery enters the orbit, it gives off the **palatine**

artery which supplies blood to the roof of the buccal cavity. The carotid artery after entering the orbit divides into the external and internal carotids supplying blood to the brain.

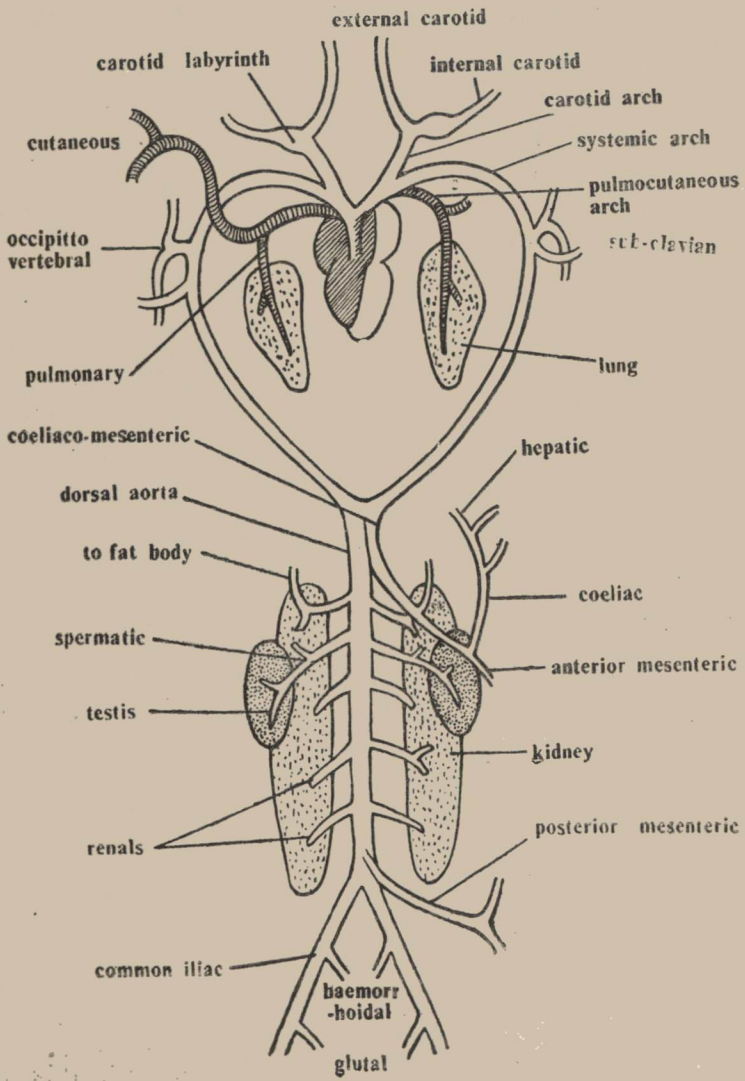


Fig. 7.4 The arterial system of frog showing the principal arteries.

11. The systemic arch of each side curves upwards, backwards and inwards round the oesophagus and then finally joins with its fellow of the opposite side to form a single median vessel, the **dorsal aorta.** The dorsal aorta passes backwards just beneath the vertebral column and between the kidneys.

As it sweeps round the gullet, the systemic arch of each side gives off an **occipito-vertebral artery** to the vertebral column and part of the head. It also gives off a short **oesophageal artery** to the oesophagus. There also arises from the systemic arch of each side a **sub clavian artery** which passes into the fore-limb of its own side as **brachial artery** and supplies blood to the fore-limb.

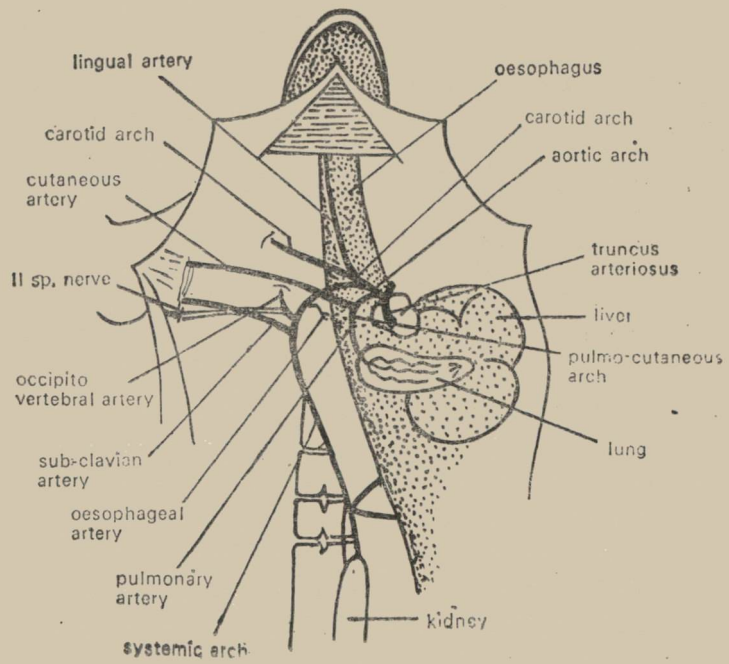


Fig. 7.5 The anterior arteries of frog.

At the junction of the systemic arches in the middle line, there arises a single large **coeliaco-mesenteric artery.** The coeliaco-mesenteric artery soon divides into the following arteries.

(a) **The coeliac artery** which sub-divides into –

(i) the **hepatic artery** to the liver

(ii) the **gastric artery** to the stomach ;

(b) **the mesenteric artery** which divides into –

(i) the **anterior mesenteric** or **intestinal artery** to the first part of the intestine.

(ii) **the posterior mesenteric artery** to the posterior portion of the intestine, including the rectum, and

(iii) the **splenic artery** to the spleen.

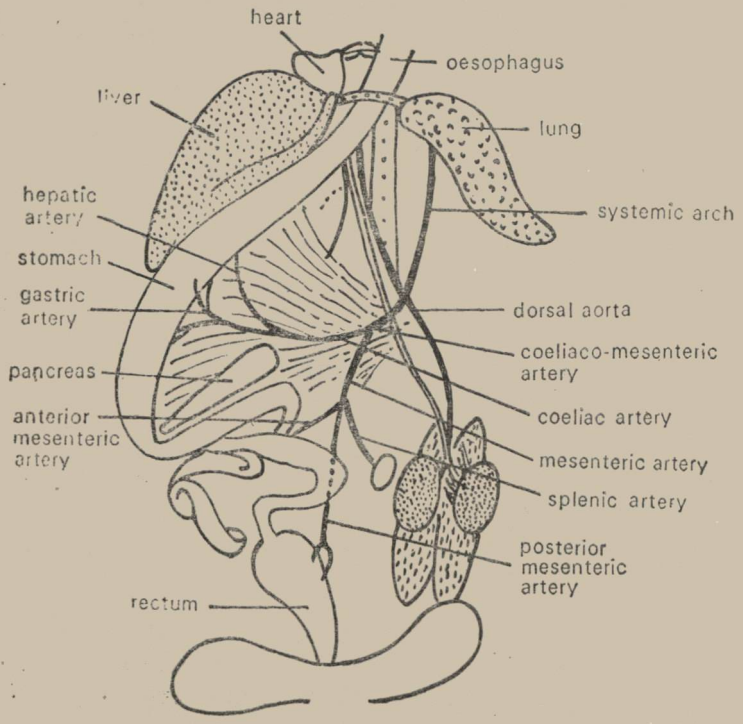


Fig. 7.6 The coeliaco-mesenteric artery and its branches.

The dorsal aorta as mentioned is formed by the union of the systemic arches of the right and left sides. This union takes place close against the back-bone, just in front of the kidneys. The dorsal

aorta passes beneath the kidneys (i. e , dorsal to them) and between them in the mid-dorsal line. The dorsal aorta gives off the following arteries.

1. **Four renal arteries** on each side arise from the dorsal aorta and immediately enter the kidney of their own side.

2. The **gonadial arteries** appear to originate either directly from the dorsal aorta or as a branch from the renal artery on each side. The arteries to the ovaries are called the **ovarian arteries** and to the testes are referred to as the **spermatic arteries.**

As the dorsal aorta emerges from beneath the kidneys, it divides into right and left **iliac arteries.** Each iliac, after giving off a small **hypogastric artery** to the urinary bladder, passes into the leg as a **sciatic artery.** The sciatic artery runs in the leg along side the sciatic nerve and vein.

Just before the point of bifurcation of the dorsal aorta, a small **posterior mesenteric artery** is given off to the rectum.

III. The pulmo-cutaneous arch is the most posterior of the three arches. Soon after leaving the main aortic arch, the pulmo-cutaneous trunk divides into two main branches—(a) The **cutaneous** and (b) the **pulmonary.**

(a) **The cutaneous artery** is a slender artery which runs diagonally forwards and outwards to the dorsal side of the body in the region of the shoulder. The cutaneous artery eventually forms an extensive system of branches over the skin.

(b) **The pulmonary artery** of each side curves round towards the dorsal surface and atonce enters the lung of its own side where it can be seen to branch out into a number of sinuous arteries.

The Venous System

The blood from all parts of the body returns to the heart through a system of veins forming the **venous system of frog.**

The blood from the anterior parts of the body returns to the heart by the two (i. e., right and left) **anterior vena cavae** or **superior vena cavae** or **pre-cavals.** They open into the **sinus venosus** i. e., each vein opens at each anterior angle of sinus venosus. The blood from the posterior parts of the body returns to the heart via **posterior**

vena cava or **inferior vena cava** or **post caval vein** which joins the sinus venosus at its posterior angle. The blood from sinus venosus ultimately enters the right auricle of the heart.

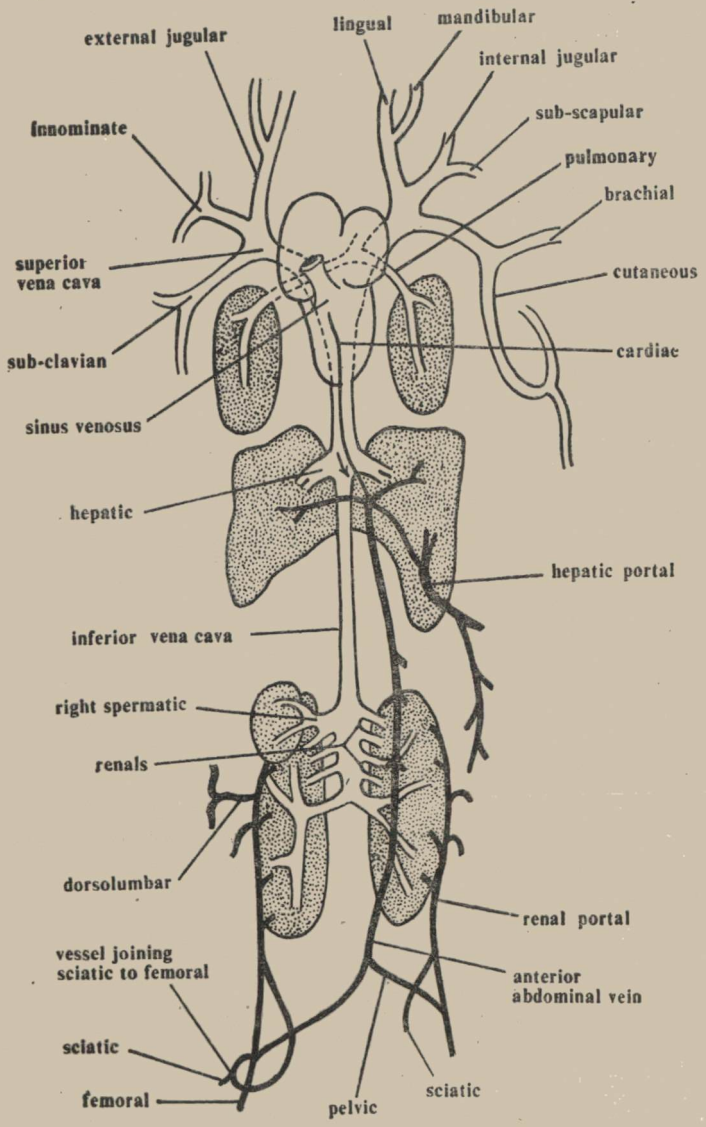


Fig. 7.7 A diagram showing the principal veins of frog.

Each **anterior vena cava** is formed by the confluence of three veins—(i) the **external jugular**, (ii) the **innominate** and (ii) the **sub-clavian.**

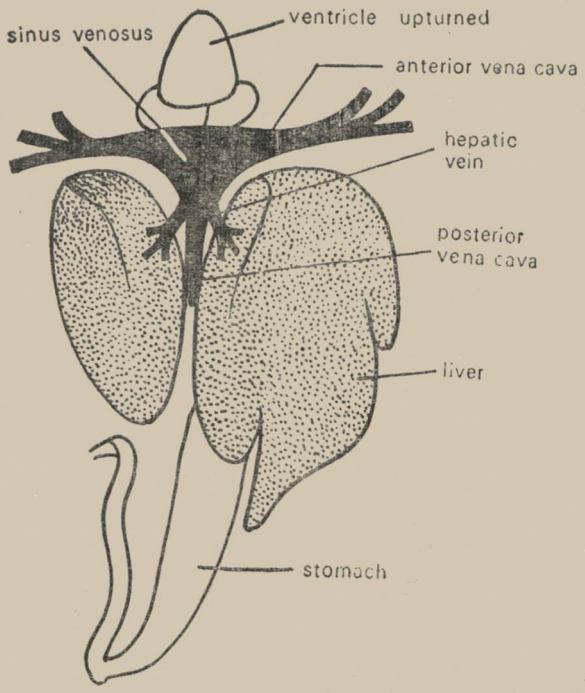


Fig. 7.8 The sinus venosus and vena cavae.

1. **The external jugular vein** returns blood from the head. It is formed by the slender and sinuous **lingual vein,** getting blood from throat and tongue and the **mandibular vein** bringing back blood from the outer margin of the lower jaw.

2. **The innominate vein** comes from the dorsal regions of the body and is formed by the confluence of the **internal jugular** and the **sub-scapular veins.** The internal jugular vein returns blood from the cranial cavity and orbit. The **sub-scapular vein** brings back blood from the dorso-lateral pectoral region i.e., from the shoulder and the back of the arm.

3. **The sub-clavian vein** is formed by the **brachial** from the upper arm and **musculo-cutaneous vein** from the skin of the side and

back. Much of the blood in the musculo-cutaneous vein gets oxygenated in the skin.

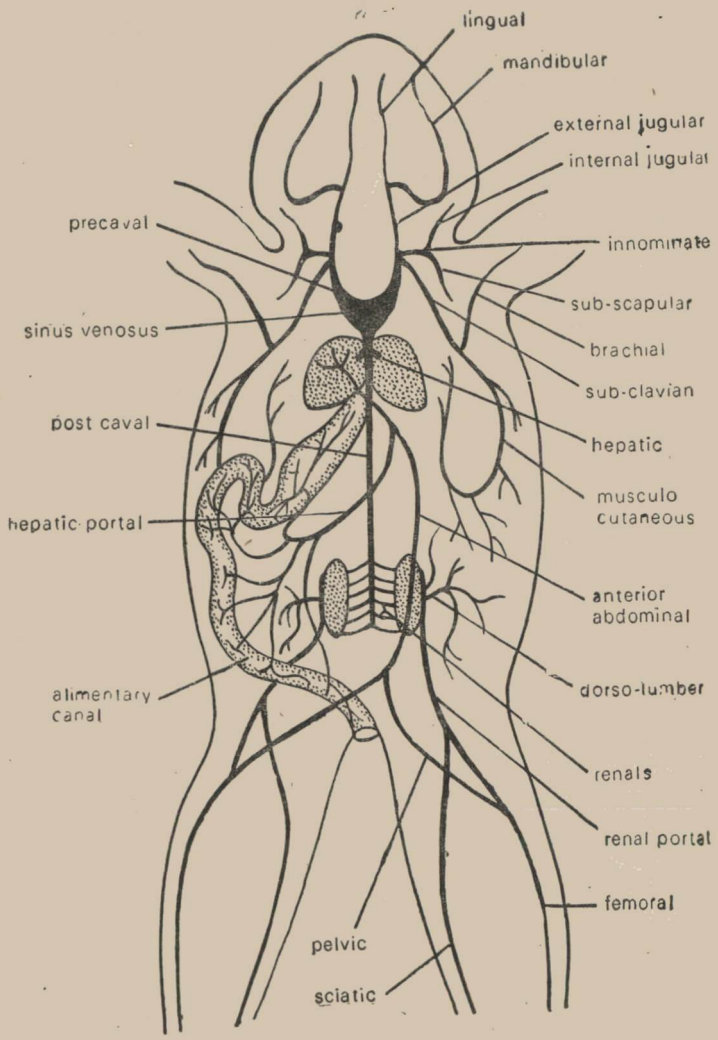


Fig. 7.9 The chief veins of frog. Pulmonary veins are not shown.

The **posterior vena cava** or the inferior vena cava or post caval vein is a large vein lying in the middle of the trunk beneath the dorsal aorta. It is formed between the kidneys by the union of

four or five **renal veins** from the kidneys on each side. In the male frog, the posterior vena cava receives the **spermatic veins** from the testes and in the female the **ovarian veins** from the ovaries. The posterior vena cava runs forwards dorsally to the liver, from which it receives a pair of **hepatic veins** just before it enters the sinus venosus.

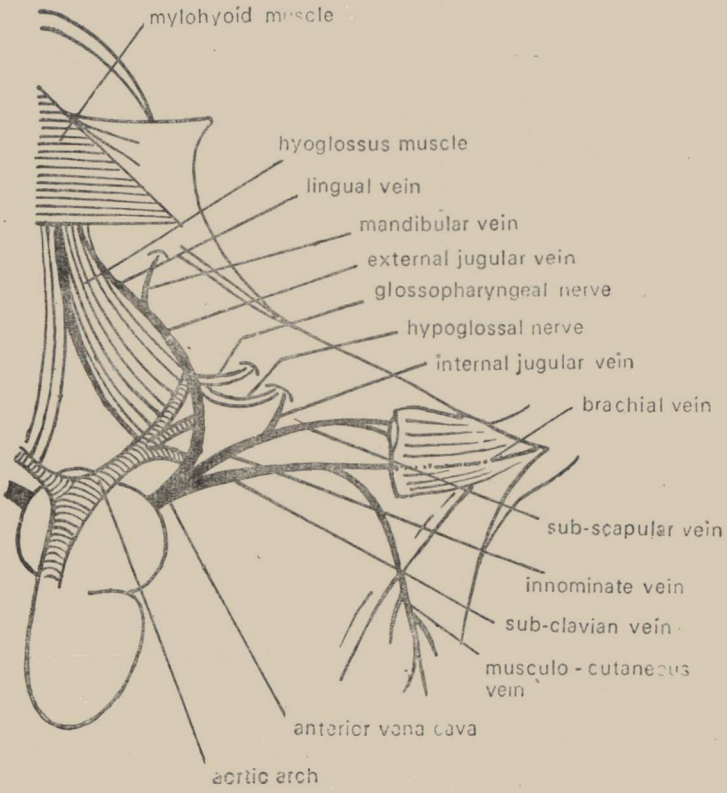


Fig. 7.10 The anterior veins of frog.

The oxygenated blood from the lungs is poured into the **right and left pulmonary veins** which unite to form a **common pulmonary vein** opening into the left auricle.

The portal systems: *A portal vein is one, which breaks up, on its way to the heart, into a set of capillaries in some intermediate organ,*

like the kidney or the liver. Thus, a group of veins which break up on their way to the heart into the kidneys form the **renal portal system** and those which break up into the liver on their way to the

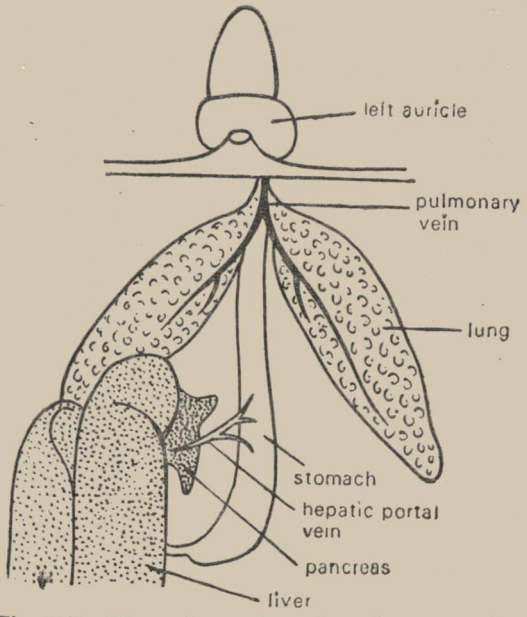


Fig. 7.11 Dissection to show the pulmonary veins.

heart constitute the **hepatic portal system.** In frog, both the renal and the hepatic portal systems are present. They are described below.

The Renal Portal System :

The renal portal system is formed by the following veins. On each side of the body the blood is brought from outer aspect of the hind leg into the trunk by a **femoral vein** and from its inner aspect by a **sciatic vein** The femoral and sciatic veins of each side, in the posterior part of the abdomen, unite to form the **renal portal vein.** The renal portal vein so formed on each side, runs forwards along the outer edge of each kidney and sends its branches into it. These branches of the renal portal vein in the kidneys, break up into capillaries. Blood from the lumbar region of the body wall (muscles of the back) is discharged into the renal portal vein on each side by

one or several **dorso-lumbar veins**. Thus, all the blood in the kidneys, whether carried to them through the renal artery or through the renal portal vein, is removed from them by the renal veins. These renal veins as described, eventually empty their blood into the posterior vena cava.

The Hepatic Portal System :

As the femoral veins enter the abdominal cavity, each gives off a branch called the **pelvic vein.** The two pelvic veins unite in the mid-line and form the **anterior abdominal vein.** The anterior

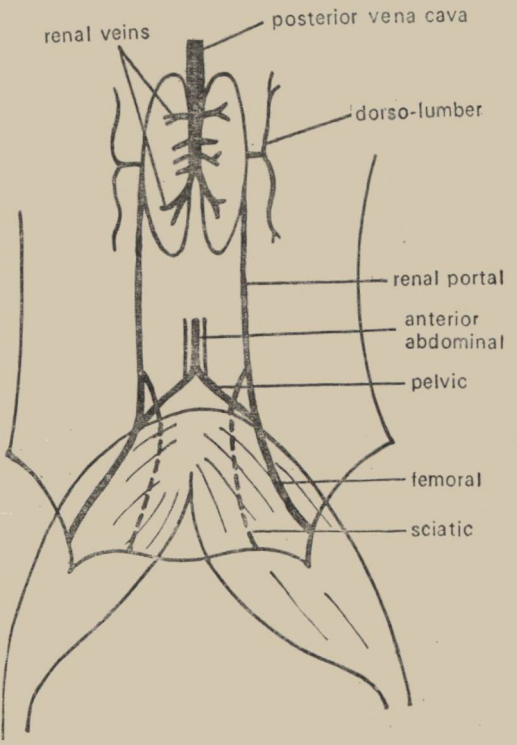


Fig. 7.12 The posterior veins along with the renal portal system.

abdominal vein lies superficially in the mid-ventral line just below the skin. It runs forward mid-ventrally and at the level of the liver after receiving a small vessel, the **cardiac vein**, joins the hepatic portal vein.

The hepatic portal system of frog is constituted by the **anterior abdominal vein** as described and the **hepatic portal vein**. The **hepatic portal vein** is formed by the confluence of the veins from the stomach, intestine, pancreas and spleen. The veins are referred to respectively as, the **gastric, intestinal, pancreatic** and the **splenic veins.**

The conjoined anterior abdominal and hepatic portal vein, divide into three branches, each of which enters one of the lobes of the liver and branch into capillaries. The liver thus receives

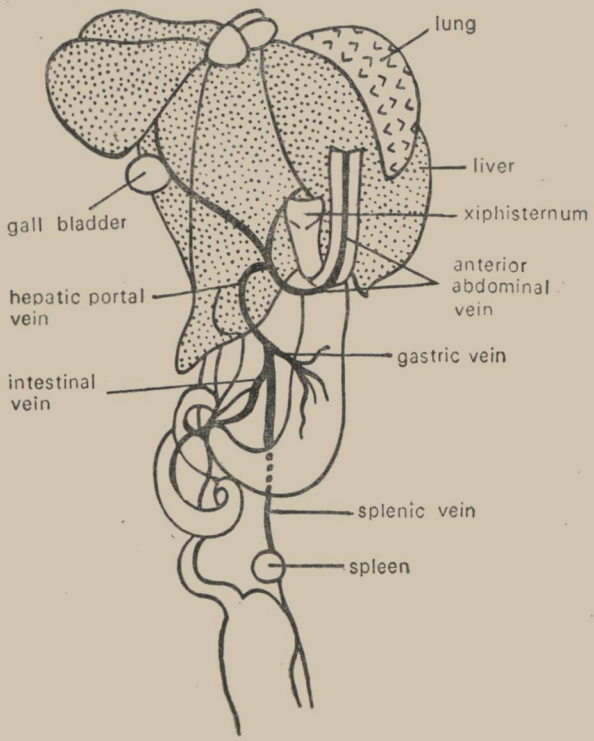


Fig 7.13 The anterior end of the anterior abdominal vein. The hepatic portal vein with its factors is also shown.

deoxygenated blood from the hind-limbs and gut, but also oxygenated blood through the hepatic artery, a branch of the coeliaco-mesenteric. All the blood in the liver leaves it, through the hepatic veins which join the posterior vena cava as already described.

Significance of Portal Systems :

The portal systems act as short circuits through which the products in the blood reach particular organs directly, instead of first going to the heart and the lungs.

The waste products from the posterior parts of the body through the renal portal system go directly to the kidneys where they are immediately removed.

The digested food from the stomach and intestine goes to the liver through the hepatic portal vein. In the liver, the excess of carbohydrates are removed from the blood and are converted into glycogen. The liver, as mentioned, also removes immediately the harmful ammonia salts produced during protein digestion. These, as mentioned, are converted into urea which is finally eliminated by the kidneys.

The Internal Structure of Frog's Heart :

The roughly pear-shaped or conical heart as mentioned consists of **three chambers**, the anterior two auricles and the posteriorly directed, conical single ventricle.

The auricles: The right and left auricles or atria are relatively thin walled chambers. The right auricle is larger and the left auricle is smaller in size. The right and left auricles are both completely separated from one another by the **inter-auricular septum.** Situated in the dorsal wall of the right auricle; close to the inter-auricular septum, is a large transverse, more or less oval opening called the **sinu-auricular aperture.** Through this aperture the blood from the sinus venosus enters the right auricle. The sinu-auricular aperture is guarded by two lip-like flaps or valves referred to as **sinu-auricular valves.** These valves allow the blood to pass freely from the sinus venosus into the right auricle and prevent it's flow in the opposite direction. The pressure of blood in the right auricle causes the free edges of the sinu-auricular valves to meet and close the sinu-auricular aperture as such. The blood due to this, cannot flow back into the sinus venosus. The pulmonary veins from the lungs open into the left auricle by a **common small opening** in the dorsal wall of the left auricle towards the anterior end. The blood from

the pulmonary veins through this aperture enters the left auricle. This opening is not guarded by any valve but as the opening is obl que, it is automatically closed by the contraction of the auricle and the blood is thus prevented from flowing back from the left

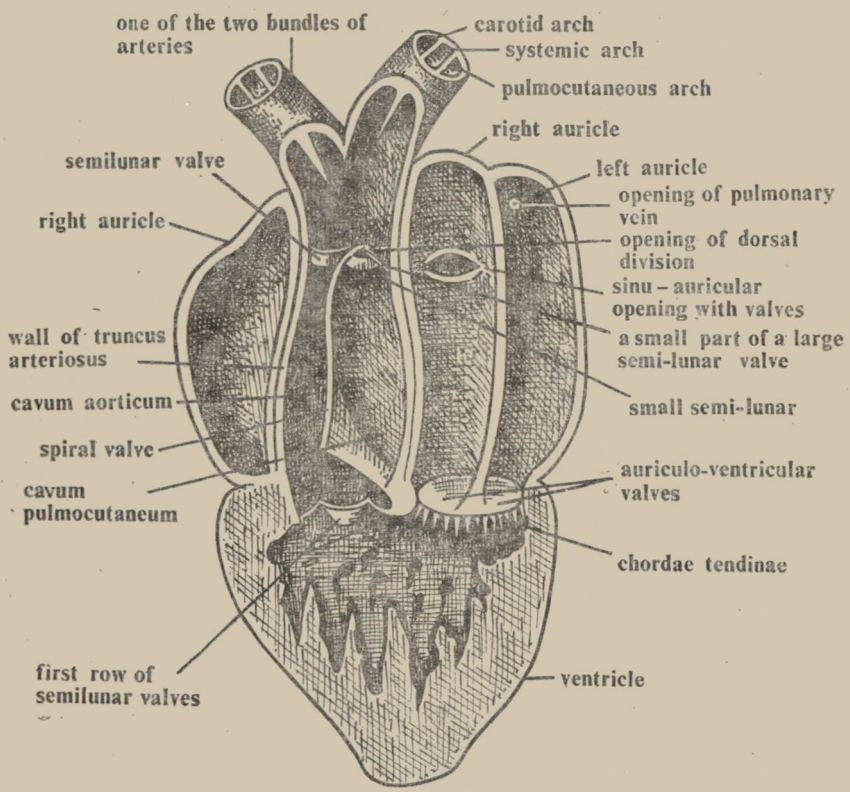


Fig 7.14. A ventral view of the heart of a frog, opened to show its internal structure. The ventral wall of the truncus arteriosus, ventricles and auricles has been removed to show their internal structure.

auricle into the pulmonary veins. The right and left auricles together communicate with the ventricle by a common **auriculo-ventricular aperture.** The auriculo-ventricular aperture is partly divided by the free lower edge of the inter-auricular septum into right and left divisions admitting blood to enter from right and left auricles into the ventricle. The auriculo-ventricular aperture is guarded by two flap-like valves called the **auriculo-ventricular valves**. Out of these

two valves, one arises from the dorsal and the other from the ventral edge of the auriculo-ventricular aperture. The free edges of the valves are connected to the muscular walls of the ventricle by fine threads called **chordae tendineae**, or tendinous chords. The valves can open in the direction of the ventricle. As the auricles contract the pressure of the blood forces the two valves apart and allows the blood to flow from the auricles into the ventricle. If, however, the blood tends to flow back from the ventricle into the auricles the auriculo-ventricular valves are brought together by the pressure of the blood from behind and the aperture as such is closed. The function of the chordae tendineae is to prevent the auriculo-ventricular valves from being pushed into the auricles by too much pressure.

The ventricle: The ventricle which is conical in shape, has thick muscular walls. The inner surface of the ventricular wall is raised into longitudinal ridges which are separated by deep fissures. The function of these ventricular ridges is perhaps to prevent to a large extent, the mixing of oxygenated and deoxygenated blood entering the ventricle from the left and right auricles respectively.

The truncus arteriosus: As mentioned, the truncus arteriosus arises from the right side of the base of the ventricle. The ventricle leads into the truncus arteriosus. The opening of the ventricle into the truncus arteriosus is guarded by three **semi-lunar valves** or **watch-pocket shaped valves** which are attached to the walls of the truncus by fibrous cords. The closed ends or convex surfaces of the semi-lunar valves are turned towards the ventricle and their open ends i.e., the concave surfaces are directed away from it. Because of this arrangement, the blood from the ventricle flows into the truncus arteriosus pushing through between the valves. It, however, cannot flow back into the ventricle as pressure in that direction leads to the semi-lunar pockets being filled up with blood as a result of which the edges of the valves are brought together so as to come in contact with each other and block the passage as such.

The cavity of the truncus arteriosus is divided internally into two unequal parts by a second row of semi-lunar valves. The long proximal part lying next to the ventricle is called the **pylangium** or

conus arteriosus. The short distal part is called the **synangium** or **bulbus arteriosus** (**ventral aorta**) or **bulbus aorta**.

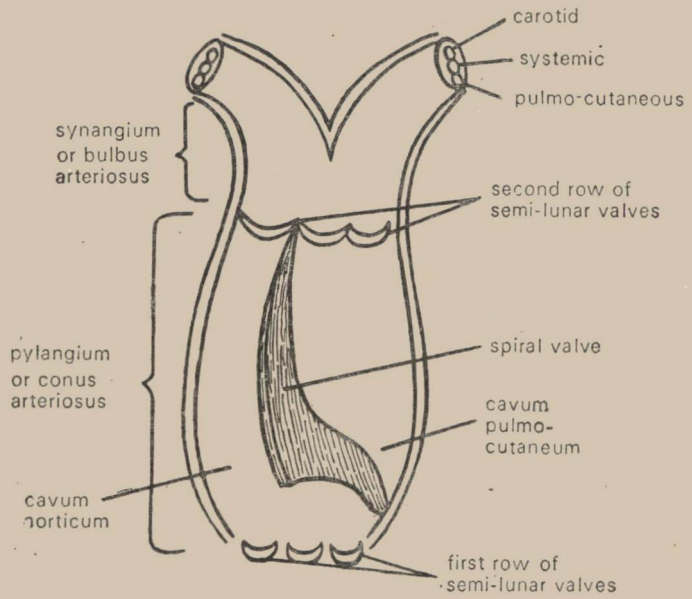


Fig. 7.15. The internal structure of Truncus arteriosus (Diagrammatic).

The pylangium contains a **spiral valve** in the form of a spirally twisted longitudinal fold. The spiral valve runs obliquely and is attached to the wall of the pylangium by its dorsal edge while its ventral edge is free. The spiral valve further is also attached anteriorly to one of the semi-lunar valves of the second row. On account of the presence of the spiral valve, the pylangium is incompletely divided into a **cavum aorticum** and **cavum pulmocutaneum**. The cavum aorticum begins on the right side of the pylangium and then curves round to the left to become ventral. The cavum pulmocutaneum begins on the left side of the pylangium and later curves round to the right to become dorsal.

The **synangium** or the **bulbus aorta** is completely divided into dorsal and ventral chambers by a horizontal partition. The dorsal chamber communicates behind with the cavum pulmo-cutaneum through an aperture guarded by a separate valve of its own.

Anteriorly this dorsal chamber communicates with the pulmocutaneous trunks distributing blood to the lungs and the skin. The ventral chamber of the synangium communicates behind with the cavum aorticum and in front with the systemic and carotid trunks distributing blood to the trunk and the head respectively.

Mode of action of the heart: It has already been mentioned that heart is a muscular pump. The contraction of the muscular wall of the heart is called **systole** due to which the blood squeezes out of the heart chambers. The systole of the heart is soon followed by relaxation or expansion of the walls of the heart referred to as the **diastole**. During diastole, the heart regains its original size and the blood flows into its chambers through the veins. The systole and diastole occur in regular rhythmic sequence. This regular systole and diastole in the heart is referred to as **heart beat**. As mentioned the rhythmic heart beats are myogenic in origin.

In the lower vertebrates (including frog), the contraction of the heart starts in the sinus venosus. There occurs a special type of tissue in the sinus venosus which initiates the contraction of the heart. This special zone of sinus venosus is called the **sinu-atrial** or **auricular node**. The sinu-atrial node is referred to as the **'Pace maker'** as it initiates the contractions of the heart.

As regards the working of the heart in frog the sinus venosus first contracts. The blood received in it through two anterior vena cavae and the posterior vena cava, is forced into the right auricle through the sinu-auricular aperture. Its backward flow however is prevented by the sinu-auricular valves. At the same time the left auricle is also filled up with blood received from the common pulmonary vein through its opening in the left auricle.

Once both the auricles are filled up with blood completely, they now contract simultaneously. This results in the entry of blood into the ventricle through the auriculo-ventricular aperture. The right side of the ventricle receives the 'deoxygenated' blood from the right auricle and the left side of the ventricle receives the oxygenated blood from the left auricle. The mixing of the two types of blood

is prevented to a great extent by the deep fissures in the wall of the ventricle. Some blood however may get mixed up in the mid region of the ventricle. Soon after the contraction of the auricles the ventricle contracts due to which the blood is forced into the truncus arteriosus. The auriculo-ventricular valves stop the re-entry of blood into auricles during the ventricular contraction.

As the opening of the truncus arteriosus is situated on the right side of the ventricle the deoxygenated blood found in the right side of it, on the contraction of the ventricle, first forces its way in the truncus by pushing aside the semi-lunar valves. After this, there will then follow a certain amount of mixed blood; and finally as the ventricle reaches the limit of its contraction, the oxygenated blood from the left side of the ventricle will be forced into the truncus arteriosus. Thus, the contraction of the ventricle results in the flow of blood from it into the truncus arteriosus, in the following order. First, the deoxygenated blood from the right side of the ventricle, next the mixed blood from the mid-region of the ventricle and finally at the peak of ventricular contraction, the oxygenated blood from the left side of the ventricle.

The deoxygenated blood entering first into the truncus, first goes into the cavum pulmocutaneum and through the dorsal chamber of the synangium into the pulmocutaneous trunks. It takes this course because of the least resistance seen in the pulmocutaneous trunk on account of the shortness of the route. The deoxygenated blood as such received in the truncus from the ventricle goes to the lungs and skin for oxygenation.

When the pulmocutaneous trunks become filled up with blood, the resistance in this circuit increases. As a result of this, the remaining blood entering the truncus from the ventricle consisting of mixed and oxygenated types passes through the cavum aorticum into the ventral chamber of the synangium. By this time the conus arteriosus also starts contracting due to which the free ventral edge of the spiral valve comes in contact with the wall of the pylangium. As a result of this, the cavum pulmocutaneum is completely cut off from the cavum aorticum as well as from the ventricle. Now from the ventral chamber of the synangium the blood again takes the course offering least resistance. Since the carotid labyrinth offers high

resistance in the carotid trunks, the mixed blood from the conus first goes into the systemic trunks and thence to the viscera and the limbs. Finally as the pressure in the systemic arches increases, the remaining oxygenated blood goes to the carotid trunks and is distributed from there to the head region. According to this interpretation about the working of heart, the 'deoxygenated' blood enters first the pulmocutaneous trunk, then the mixed blood goes to the systemic trunks and finally the oxygenated blood enters the carotid trunk.

The mode of action of the heart described above has however been disputed and contradicted to a great extent, on the basis of experimental data available, regarding the working of the frog's heart. Thus, the new concept about the working of frog's heart is discussed in detail, below.

The New Concept about the Mode of Action of Frog's Heart:

The mode of action of frog's heart described above is based on the hypothesis first put forward by **Brucke** and **Sabatier.** Since then several workers have doubted various aspects of this classical hypothesis.

In the light of recent experimental work carried out by **Vandervael and Foxon,** it has been revealed that the deoxygenated blood from the right auricle and the oxygenated blood from the left auricle become mixed up to a great extent in the ventricle.

Further by injecting X-ray opaque substance into the pulmonary veins or sinus venosus, the course of the circulation of blood in the chambers of heart and blood vessels was observed. It was seen that the X-ray opaque substance was distributed equally and almost simultaneously along all the three arterial arches leaving the heart. The blood in the three arches of the frog's heart more or less showed uniform composition. In the frog, it will be noted that along with lung respiration, cutaneous and buccal respirations also take place most efficiently From this we can conclude that the blood entering the sinus venosus from the buccal cavity and skin will not be completely deoxygenated. A mixture of this blood i.e., from sinus venosus, and the oxygenated blood from the lungs would

probably be good enough for an animal like frog with comparatively low metabolic activity.

On the basis of experimental findings, the general consensus of opinion seems to be that there is

(a) *very little difference of actual pressure in the three main arterial vessels and further*

(b) *no difference of time of movement of the blood in the three main arterial vessels is to be seen.*

Certain experiments were performed on the basis of which it was proved beyond doubt, that certain conclusions drawn, regarding the working of heart according to old hypothesis, were erroneous.

Few such experiments done, on the working of the heart are as follows :

For example, injection of dyes into the venous blood returning to the heart gave evidence for a random distribution of the left and right auricular blood into the three arches.

Vandervael injected Indian-ink particles in suitable dilutions, into the left pulmonary vein. He found, that the ink particles after passing through the heart chambers, were distributed to all the three arterial vessels—the carotid, systemic and pulmo-cutaneous trunks simultaneously. These injected particles can very well be seen in a heart illuminated from below.

Another worker **Savolin** injected particles of various kinds, including starch grains into a large vein (the posterior vena cava) of the toad *Bufo bufo*. After one or two beats, the heart has been stopped and the grains were recovered from the arterial vessels. A statistical count was made on the basis of which it was concluded that there is a very considerable mixing of blood from the two sides of the auricles in the heart.

A more accurate experiment was later performed during which a substance opaque to X-rays, was injected and the courses of this radio opaque medium through heart and vessels were followed. **Foxon** and **Walls**, first of all injected the X-ray opaque medium

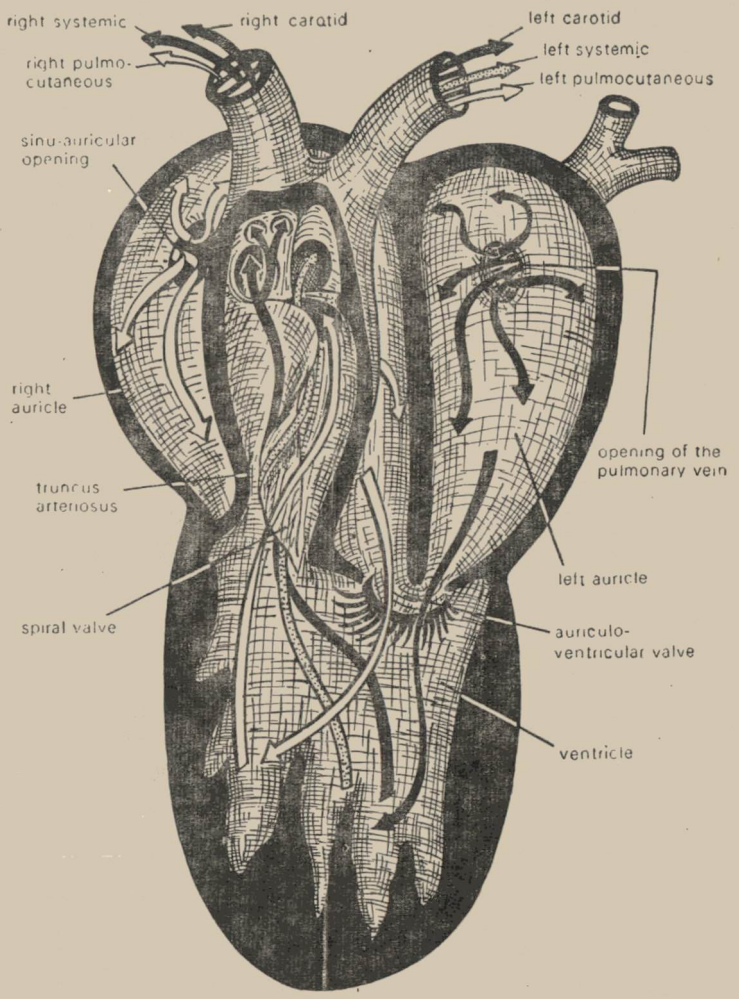


Fig. 7.16 The heart of frog. Path of the blood indicated by injection experiments. Blood from the pulmonary vein (black arrow) i.e., from left auricle passes to the carotids and mainly to the right systemic. The blood from vena cava (white arrow) i.e., from right auricle mainly enters the pulmocutaneous arches (white arrow) and to left systemic (stippled arrow).

Thorotrast (a colloidal suspension of thorium dioxide) into the pulmonary veins of frogs and toads with the help of micrometer injection apparatus. The radiographs were later made at intervals of a few seconds for about fifteen seconds to half a minute, according to the rate of heart beat. The radiographs did not reveal any build up of the thorotrast in the head region such as would be required by the old hypothesis. As a matter of fact, the thorotrast was usually first conspicuous by its shadow in the systemic arch, undoubtedly because this vessel is larger than the others. Then by the time the thorotrast was plainly discernible in the head region, it was also visible in the pulmocutaneous trunk and the lungs. This experiment with the distribution of an X-ray opaque substance however showed once again that there was no selection of blood for the head. This experiment proved that the distribution of blood in the aortic arches was random and gave strong support to the new concept of **mixing hypothesis**.

Blood vessels :

It has already been mentioned in connection with the study of blood vascular system, that blood vessels are of three major types—the **arteries**, the **veins** and the **capillaries**.

The capillaries : The **capillaries** form a vast network in the fibro-elastic connective tissue throughout the body. They are narrow and delicate thin walled tubes. The diameter of a capillary varies from a minimum of slightly more than the diameter of an erythrocyte to a diameter several times more than that. The capillary is lined with **endothelium**. The endothelium is composed of endothelial cells which are derived from the mesenchyme.

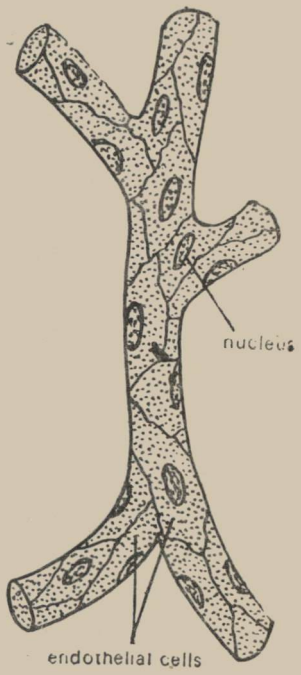


Fig 7.17 A part of capillary net-work showing the endothelial cells.

The Arteries : A transverse section passing through an artery reveals that it consists of usually three coats – (i) an inner, **tunica**

intima, (ii) a middle, **tunica media**; and (iii) an external, **tunica externa** or **adventitia**.

The **intima** is composed of the endothelial lining (surrounding the lumen) with a slight amount of reticular and fibro-elastic connective tissue. It is separated from media by an **internal elastic lamina** or **membrane**.

The **tunica media** is composed of smooth muscles associated with varying amounts of fibro-elastic connective tissue In larger vessels the elastic-fibre appears more prominently in the media and an **external elastic membrane** adjoins the adventitia.

The **tunica externa** or **adventitia** is chiefly a fibro-elastic connective tissue. It is usually not as thick as the media but much thicker than the intima.

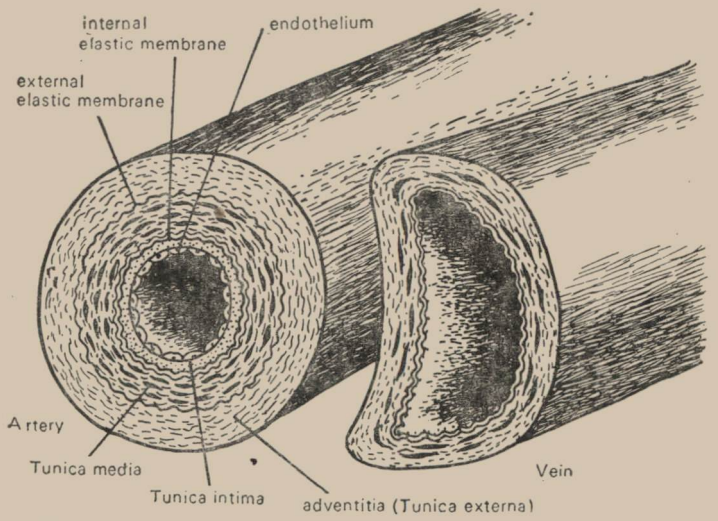


Fig 7.18 Diagrammatic cross section passing through a typical artery and vein from a vertebrate animal.

The veins: The veins are comparatively thin walled vessels. A vein is also composed of the same three coats i. e., **intima**, **media** and **adventitia**, but the elastic tissue is less developed and the muscular layer is much thinner. The three coats in a vein are very

often difficult to be distinguished. A vein thus has a **thinner wall but a wider lumen** It is less elastic as compared to an artery of the same thickness. Because of thin walls, the veins often appear collapsed in microscopic preparations. The elastic laminae or membranes are also not usually present.

The veins also differ from arteries in that they possess valves which are pocket-like extensions of the endothelium with a thin core of intimal connective tissue. Such valves open towards the heart so that a backward flow of blood is prevented. In the connective tissue that supports an artery there is usually a companion vein which has a greater volume i.e., wide lumen and usually appears collapsed in microscopic preparations.

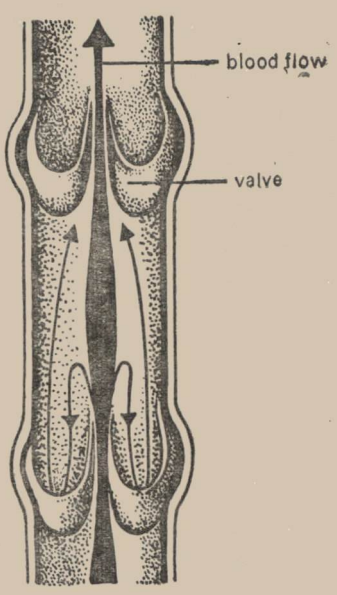


Fig. 7.19 The valves within a vein. These valves regulate the flow of blood in veins. When the blood flows to the heart, the valves allow it to pass. However, if the blood tends to flow in opposite direction (small arrows) the valves fill up and stop back flow.

The Blood of Amphibia :

The blood of amphibia like other vertebrates is composed of a liquid part called the **plasma**, in which **corpuscles** float. The corpuscles are of three types — (i) **erythrocytes or red blood cells**, (ii) the **leucocytes or white blood cells** and (iii) the **thrombocytes or spindle cells.**

Plasma :

The plasma contains a high percentage of water, various proteins, salts, sugars and fats, as well as oxygen and the products of metabolism. Waste products like urea ; vitamins, hormones and protective substances like anti-toxins are also found in the plasma.

The plasma also contains a substance called **fibrinogen** which is responsible for the clotting of blood.

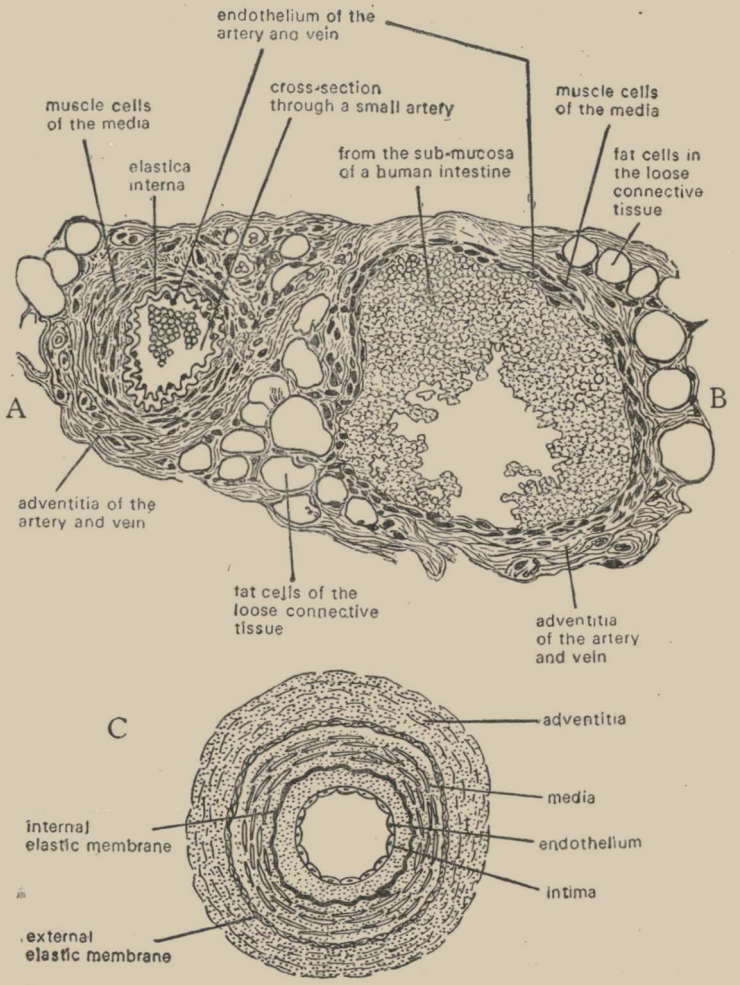


Fig. 7.20 (A) Cross-section through a small artery and (B) its accompanying vein (C) Diagram of a muscular artery (cross-section).

The Red Blood Corpuscles :

The red blood corpuscles (RBC's) or erythrocytes of amphibia are much larger than those of mammals. In the Urodele

Amphiuma the red blood corpuscles reach the immense size of 70 μ. The size of the erythrocytes in amphibia normally exceeds 20 μ.

The red blood cells of amphibia are in the form of elliptical discs; sometimes bulging in the centre where a distinct oval nucleus occurs. The red cells contain an iron-protein compound called the **haemoglobin.** The number of erythrocytes varies from nearly 700,000 per cubic millimetre in *Hyla arborea* to 56,633 in Necturus and 36,000 in *Proteus*. In one cubic millimetre of the blood of frog, there are more than half a million of the red blood corpuscles. There is also to be seen a pronounced sexual difference in the number of red blood cells in some species, at least, the male having the greater number of erythrocytes.

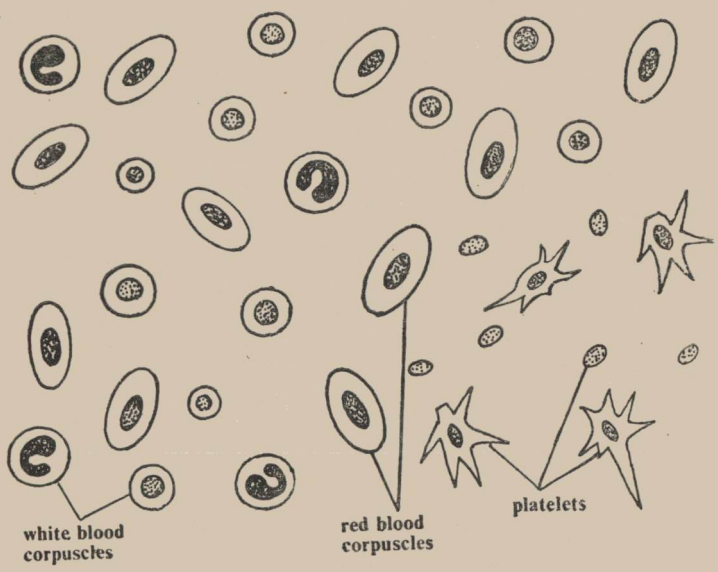


Fig. 7.21 Three types of corpuscles in the blood of frog.

In the case of frog, the life of any one erythrocyte is probably not over 100 days. The red blood cells are removed from the blood stream by the liver and the spleen.

One interesting feature to be seen in amphibia is the presence of **plasmocytes** which are obatined from the fragmentation of the red

blood cells. The fragmentation or breaking up of the red blood cells takes place after they have entered the blood stream, giving as such a number of **enucleated fragments**. In the case of *Rana*, only small portions of the cytoplasm are broken off.

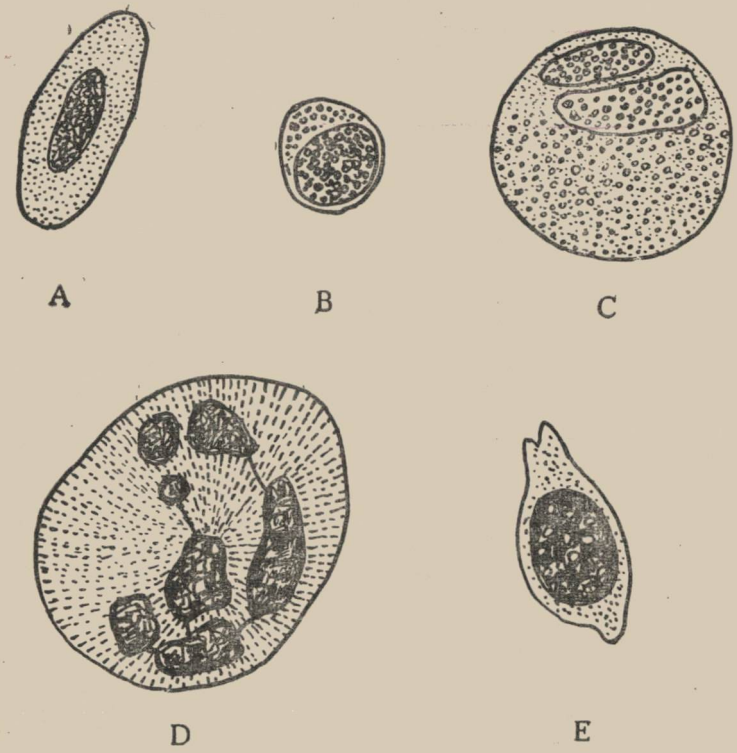


Fig. 7.22 The blood cells in the frog *Rana pipiens*.
(A) Normal erythrocyte. (B) Small lymphocyte. (C) Eosinophil.
(D) Polymorpho nuclear leucocyte. (E) Thrombocyte (spindle cell).

The White Blood Corpuscles :

The white blood corpuscles or leucocytes include the lymphocytes, monocytes and three kinds of granulocytes i.e., **neutrophils**, **eosinophils** (acidophils) and **basophils**.

The white blood cells vary much more in size and form. They are further less abundant in blood than the erythrocytes and the thrombocytes.

The **lymphocytes** are nucleated blood cells with a large nucleus and comparatively a small amount of non-granular cytoplasm. The small lymphocytes are often found associated with rapidly growing tissues and it has been suggested that they may have growth stimulating properties.

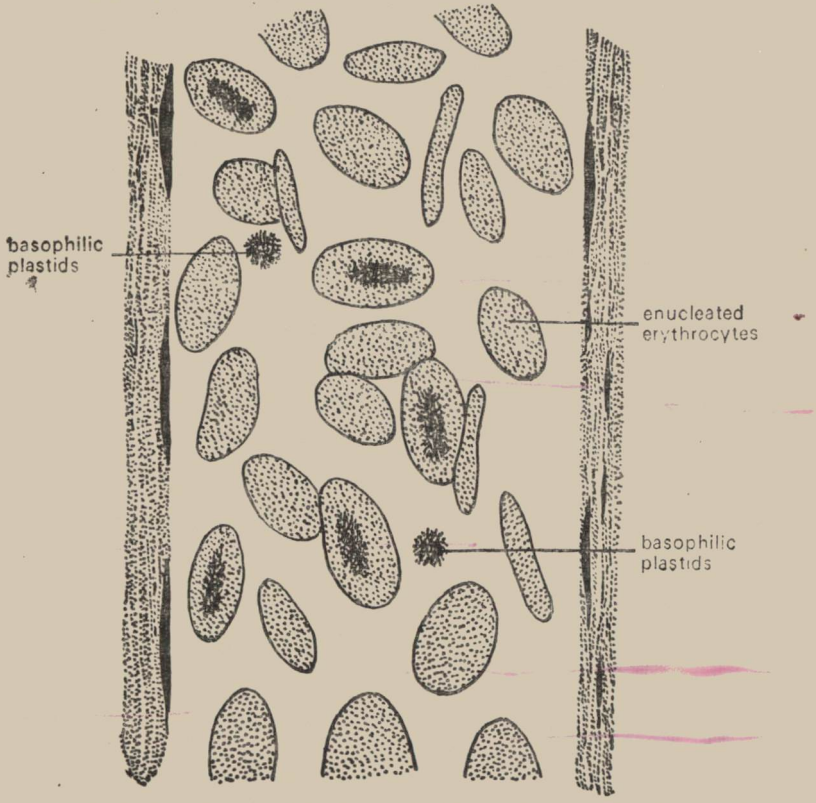


Fig. 7.23 Optical section of a blood vessel of Batrachoseps showing enucleated erythrocytes (plasmocytes) and basophilic plastids.

The large lymphocytes specialised for phagocytosis are called **monocytes**. They wander by amoeboid movements through the tissues. They engulf the bacteria, cell debris, or other injurious

material. They may be found outside the blood stream and because of their phagocytic activity mentioned above are often referred to as **'Macrophages'**. They usually get out of the capillaries by squeezing their way between the epithelial cells of the capillary wall. In case of infection, the number of monocytes also increases to fight the infection.

The granulocytes are characterised by the presence of fine granules in their cytoplasm. Further the nucleus of granulocytes on their maturation assumes very irregular forms (i.e., lobed) or may even divide into several parts. Thus, the granulocytes are polymorphonuclear cells.

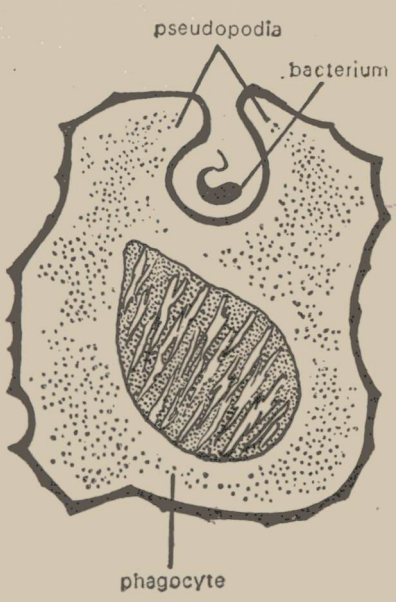


Fig. 7.24 A phagocyte sends out pseudopodia to engulf an invading bacterium.

Some of the granulocytes have phagocytic functions. For example, the neutrophils, which have a finely granular cytoplasm, unlike the other leucocytes, induce the break-down of worn tissue, while the macrophages (monocytes) carry away the debris. The **eosinophils** can be identified by their large eosin staining granules. They are found commonly along the digestive tract and may have phagocytic function similar to neutrophils. Granulocytes, like monocytes, are not confined to the blood vessels but may migrate into any of the tissues of the body or may even make their way carrying their phagocytosed substances to the outside of the body by wandering out on mucous and epidermal surfaces. According to **Jordan and Speidel**, the eosinphils which pass through the intestinal epithelium and disintegrate among the faecal contents of the tract may have an immunizing function against the intestinal bacteria. Most of the leucocytes which escape from the blood vessels are returned to them again by way of lymphatic vessels.

The *thrombocytes* or spindle cells resemble the erythrocytes but they are relatively smaller and have pointed ends. They have a granular endoplasm and a clear cytoplasm. They are quite unstable. They break-down, when they are brought in contact with foreign substances and release a substance which acts on fibrinogen in the presence of blood calcium to form an insoluble clot. In this process, the insoluble fibrin is formed from fibrinogen and blood corpuscles become entangled in the resulting gel, to form the clot.

Origin of Blood Corpuscles: Blood corpuscles in amphibia originate from a single type of cell indistinguishable from the lymphocyte of the circulating blood. These types of cells are located for the most part in the kidney of the tadpoles and in the spleen of adult frogs such an *Rana pipiens*. The bone marrow as in the case of mammals, also however, becomes the locus for blood histogenesis only for a short period in the spring when the metabolic rate is high. In *Rana temporaria*, with its higher metabolism, the bone marrow is the source of red cell formation as it occurs in mammals. It has been suggested that the shift of the primary centre of blood cell formation from the kidney in fish to the bone marrow in mammals is correlated with an increase in the metabolic rate during phylogeny. The amphibia as such are of great interest in showing, during their ontogeny the whole range of possible loci of blood formation.

In some species, red blood cells and the granulocytes are formed at different loci. Thus, **Jordan** and **Speidel** reported that in the *newt* the spleen was the sole organ concerned with the formation of erythrocytes and thrombocytes while the granulocytes were formed in the outer portions of the liver.

As regards lymphocytes, there are to be seen various masses of lymphoidal tissues in the bodies of amphibia. The more conspicuous are found anterior to the clavicles of frog or between skin and muscle near the girdles of burrowing species. These tissues during spring produce both lymphocytes and leucocytes but appear to store fat at other seasons. Accumulation of lymphocytes in the connective tissue and overlying epithelium of the lingual region occurs in both frogs and urodeles.

Clotting of blood : The best known property of blood is its ability to clot or coagulate, when it escapes from a blood vessel as a result of injury.

The mechanism of clotting of blood however is extremely complex and many substances, called clotting factors are necessary for it to take place.

In the process of clotting, basically the soluble fibrinogen in the blood plasma is converted into the insoluble fibrin crystals. These are needle shaped and stick together to form a mesh work. This mesh work gradually shrinks and in this mesh corpuscles are entangled resulting in the formation of a clot. During the process of shrinkage of the fibrin crystals, the fluid components of the plasma are expelled. This fluid part of the plasma without the corpuscles is called the **serum**. Serum as such is the fluid part of the plasma from which fibrinogen has been removed and it also lacks blood corpuscles as they are entangled in the insoluble fibrin of the clot.

The clotting is also a function of the plasma and takes place even when the corpuscles have been removed e. g., by centrifuging. A clot formed from whole blood is stiff because corpuscles become entangled in the shrinking fibrin network, but a clot formed from pure plasma is soft and spongy.

The clotting normally occurs only when the blood is shed. The stimulus which initiates the clotting process is a *roughened surface* e. g., injured or damaged tissue, or *wettable surface* e. g., glass. The details of clotting are summarised below :

1. The substance which initiates blood clotting is called **Thromboplastin** or *factor III* (or Thrombokinase). This is released by the disintegrating blood platelets and from the walls of the vessels.

2. Thromboplastin combines with calcium (Ca^{++} ions *factor IV*) and inactive **prothrombin** (*factor II*) in the blood and this produces a substance called **Thrombin**. Prothrombin needs a supply of vitamin *K* in the diet for its formation.

3. The **thrombin** and the **fibrinogen** (*factor I*) react together to precipitate a protein called **fibrin.** The protein forms a dense weave of threads across the wound and in these platelets, red cells and white cells become entangled and a clot so formed plugs up the wound. The clot gradually shrinks, expelling the **serum.**

The clotting process in its simplest form may be expressed thus :

Preparatory reaction

1. **Prothrombinogen** a precursor of prothrombin stimulated by roughened or wettable surface ⟶ **prothrombin** (*factor II*).
   This needs vitamin *K* also for its formation.
2. Damaged tissue or disintegrating products of blood platelets ⟶ **Thromboplastin** (*Thrombokinase factor III*)

Key reaction

Prothrombin (*factor II*) + **Thromboplastin** (*factor III*). + Ca^{++} ions (*factor IV*) ⟶ **Thomrbin**

Effective reaction

Thrombin + **fibrinogen** (*factor I*) ⟶ **Fibrin** ⟶ Clot.

The time taken for rat's blood to clot is 2½ minutes, while for human blood it is about 7 minutes. This difference is due to the greater concentration of fibrinogen in rat than in human blood.

The clotting thus depends on the presence of platelets, prothrombin, thrombokinase together with calcium ions.

The clotting does not normally take place while blood is in circulation in the body. It is due to the fact that **heparin** formed by the liver and other tissues, including the walls of the blood vessels, prevents the platelets from sticking to the walls and acts as an anti-prothrombin and an anti-thrombin, inhibiting the production of thrombin from prothrombin and the effect of any thrombin present on fibrinogen.

Functions of the Blood :

After studying the structure of the blood, its functions can now be summarised.

The functions of blood can be discussed under two headings—(1) Blood as a transport medium and (2) the role of blood in the protection of the body against disease.

1. Transport:

(1) The blood conveys food materials from the alimentary canal to the tissues where they are utilised or stored.

(2) The blood carries oxygen from the lungs or any other respiratory surface to other parts of the body.

Though some oxygen in solution is present in the plasma, the greater part of oxygen carried, combines with the haemoglobin in red corpuscles to form *oxy-haemoglobin.*

(3) The blood carries waste materials from the tissues to the places where they are excreted. It carries urea to the kidneys and CO_2 to the lungs. The CO_2 as stated is carried chiefly as *carbamino-haemoglobin* in the red corpuscles.

(4) The blood plays an important part in the transportation of hormones from the endocrine organs to the tissues which are effected by these chemical messengers.

(5) The blood *transmits heat* from the more active organs to the less active ones and thus helps to maintain an even body temperature in different parts.

2. Protection:

(1) The blood is helpful in the maintenance of tissues in a healthy condition as it supplies them with their material needs and with the conditions best suited to their life. In this regard, the constancy of the osmotic pressure and the pH of the blood are very important.

(2) The white corpuscles contact with the invading organisms. The lymphocytes produce antibodies and antitoxins while the phagocytes actively engulf them and eventually destroy them.

(3) The clotting of blood closes the wounds and thus arrests haemorrhage, the cut is also sealed which checks the entry of germs.

The Lymphatic System :

It has been mentioned that a part of the blood plasma containing digested food and oxygen exudes through the blood capillaries and delivers these substances to the tissue cells and takes up waste products from them. This watery fluid which oozes out of

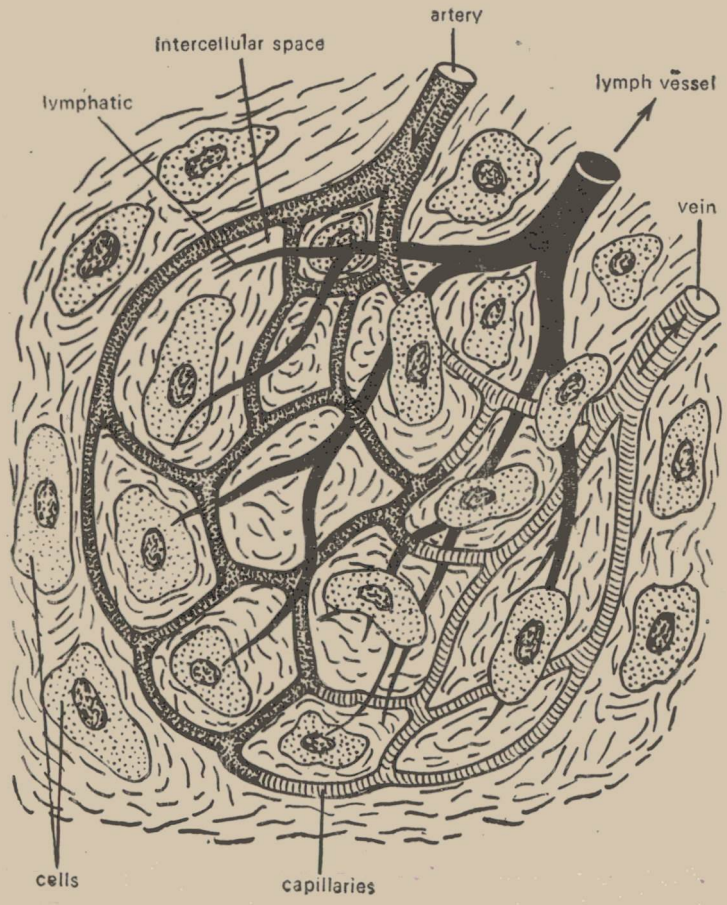


Fig. 7.25 The lymph capillaries and lymph vessels along with the blood capillaries.

the thin capillary walls is called the lymph. Lymph has much the same composition as the blood plasma but lacks red corpuscles and has various other minor differences.

The lymph has more lymphocytes, which originate in the lymphatic system but less of other type of white corpuscles. The lymph always bathes the tissues surrounding the minute capillaries. It usually consists of lymph capillaries, open lymph spaces, lymph vessels and lymph nodes as well as lymph hearts (pulsating vessels).

The Lymph Vascular System of Frog :

The lymphatic system in frog is very extensive. The lymph which exudes from the blood capillaries is collected by the lymph capillaries which communicate with the lymphatic vessels. The lymphatic vessels open into the lymph spaces or sinuses e. g., the **sub-cutaneous lymph spaces** beneath the skin and **sub-vertebral lymph sinus** below the vertebral column (See Fig. 2-7). Just behind the transverse process of the third vertebra are found anterior lymph hearts (pulsating tubes) one on each side of the vertebral column.

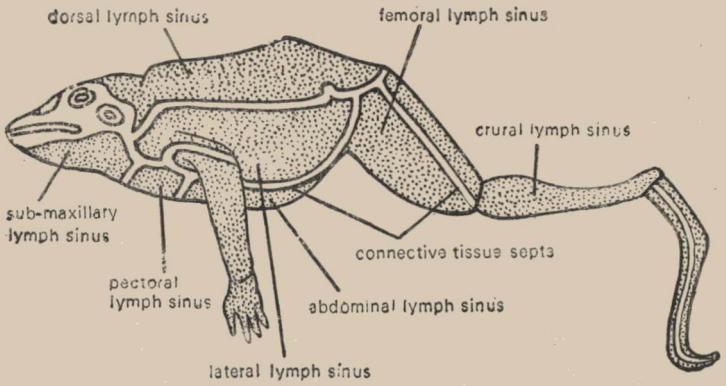


Fig. 7.26 Lymph spaces or sinuses in frog (Diagrammatic)

Posterior lymph hearts lie one on either side of the tip of the urostyle. The anterior lymph hearts drain the lymph into the sub-scapular veins and the posterior hearts into the femoral veins. The opening of the lymph hearts into the veins are guarded by semi-lunar valves

which prevent the lymph from flowing back into the hearts. No valves are however found at the opening through which lymph enters the hearts from the lymph sinuses. The coelom or abdominal cavity is also a large lymph sinus which communicates with the renal veins through minute apertures in the wall of the kidney called **nephrostomes.** Lymphatic vessels present in the villi of the intestine which absorb digested fats are called *lacteals* (See Fig. 5·7).

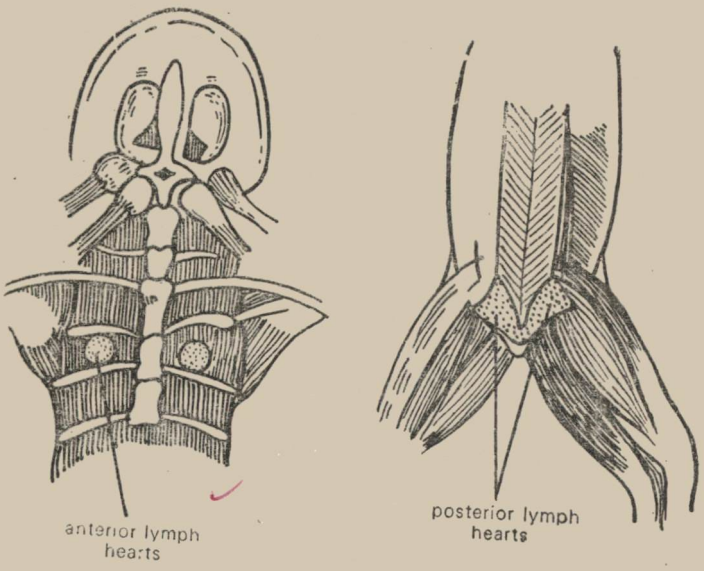


Fig. 7.27 Anterior and posterior lymph hearts of frog.

The lymph which escapes through the walls of the blood capillaries is finally returned to it through various veins. The lymphatic and blood vascular systems are therefore closely interconnected.

The functions of the lymph are summarised below :

(1) Production of lymphocytes in lymph glands.

(2) Fatty acids and glycerine diffuse into the lacteals and may pass into the blood stream with lymph, near the heart.

(3) As lymphocytes fight harmful organisms, the lymph circulation as such helps to prevent harmful organisms from invading the blood.

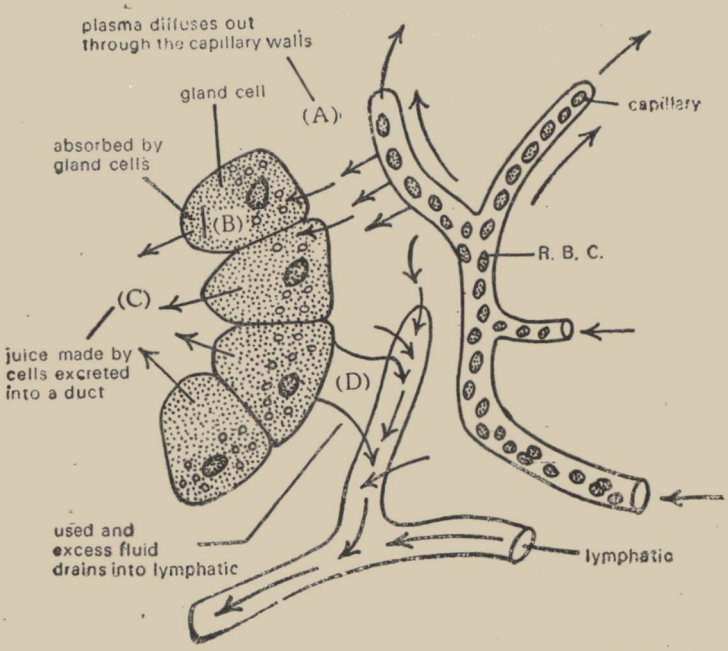


Fig. 7.28 Tissue cells, blood capillaries and lymph vessels showing inter-relations.

The Spleen :

The spleen is the largest simple lymph gland in all forms, but contains no lymph sinuses. It is similar to hemolymph nodes as it is being associated with the blood vascular system instead of lymphatics. In fishes, the spleen is in the form of an irregular mass closely associated with the stomach and intestinal walls. In frog, it occurs as a spherical mass in the mesentery supporting the intestine (See Fig. 5·5). The cells of the spleen destroy effete red corpuscles and certain minute parasites. Among the mammals it is in the form of a flattened structure near the stomach.

The spleen is surrounded with a capsule of fibro-elastic connective tissue and smooth muscles. A number of *trabeculae*

consisting of connective tissue and smooth muscles extend from the capsule and divide the spleen into *lobules*. The larger arteries and veins supplying the spleen are carried by the trabeculae. The lobules of the spleen contain splemic cells of all sizes. These cells may be pigmented. Within the lobules are found small whitish masses, the

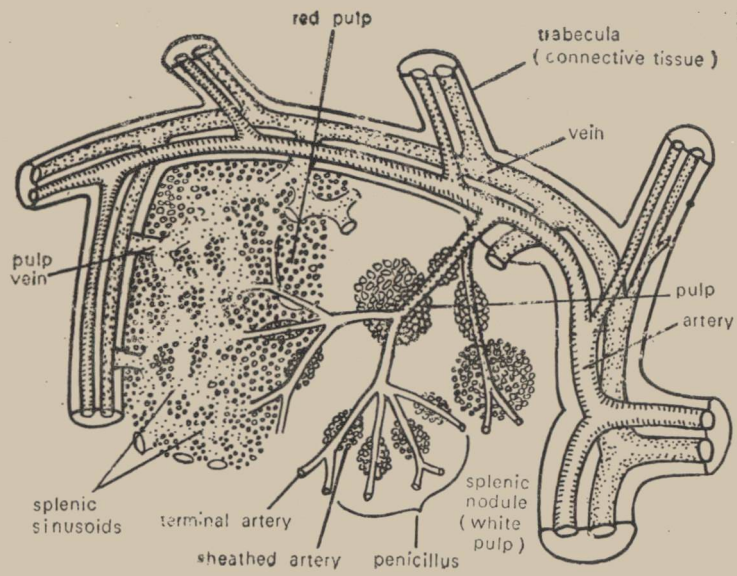


Fig. 7.29 Diagram showing the general structure of spleen.

white pulps, distributed throughout a red tissue. The white pulp is composed of lymph nodules which form a sheath around the arteries. The red tissue or **red pulp**, is composed of a reticular net-work, diffuse lymphoid tissue, and sinusoids filled with blood.

Revision questions

1. Describe the external features of frog's heart as revealed by its ventral and dorsal views.

2. Give an account of the arterial system of frog mentioning in detail the principal arteries which supply blood to different parts of the body.

3. Describe the venous system of frog with a particular reference to the principal veins which bring back blood from different parts of the body to the heart.

4. What is a portal vessel? Describe in detail the hepatic and renal portal systems of frog. How are they linked up with one another in frog? Mention the importance of portal systems.

5. Describe the internal structure of frog's heart and the flow of blood in heart chambers according to the old concept.

6. Give a detailed account of the mode of action of frog's heart in the light of recent investigations. Compare and contrast the views held about the working of heart according to the classical hypothesis and the new concept of mixing hypothesis.

7. Describe in detail the histological structure of a capillary, artery and a vein and mention in brief the main differences between an *artery* and a *vein*.

8. Describe the structure of the amphibian blood and origin of blood corpuscles in amphibia.

9. Describe the mechanism of the clotting of blood and its advantages to the animal.

10. Describe the structure of lymph and its functions.

11. Mention in brief the lymphatic system of frog.

12. Describe in detail the structure and functions of the spleen.

13. Write notes on the following:
    (a) Closed vascular system (b) Carotid labyrinth
    (c) Sinu-auricular and atrio-ventricular nodes
    (d) Plasmocytes.

CHAPTER VIII

THE FROG – RESPIRATORY SYSTEM

Respiration is a process which is concerned with the exchange of *oxygen* (air) and *carbondioxide* between active body cells and the out side environment. This process is also called **respiratory gas exchange**, since both oxygen and carbondioxide are gases at ordinary temperatures. The organs through which exchange of gases with the environment takes place are called the **respiratory organs** which form the **respiratory system.**

External respiration is the means by which oxygen is obtained and carbondioxide is removed. This exchange of gases takes place at the respiratory surfaces like *lungs* usually in the vertebrates and through *gills* commonly in aquatic forms like fishes.

The act of taking in oxygen by the respiratory surface like lungs is called **inspiration** and the act of giving out carbondioxide is called **expiration.** Inspiration or breathing in oxygen followed by the expiration or beathing out of carbondioxide is also referred to as the process of **breathing.**

The exchange of respiratory gases i.e., taking in of oxygen and giving out of carbondioxide at the level of cells or tissues, is referred to as **cellular respiration**, **tissue respiration** or **internal respiration.**

Internal or tissue respiration involves the oxidation of a variety of food substances. Due to this, the step-wise degradation of food molecules takes place, the **energy** is released, and carbondioxide and water are produced. The energy released is synthesised in the form of a compound called **adenosine triphosphate or A.T.P.** A.T.P. contains energy rich bonds and is the current energy currency of the living body. The A.T.P. so formed provides a source of energy for the performance of various activities by the animals. When A.T.P. is used, it breaks down to form adenosine diphosphate and free phosphate, both of which are then available for resynthesising into A.T.P.

$$\text{A T.P.} \rightleftharpoons \text{A.D.P.} + \text{P}$$

Respiration as such is the most vital process, as it provides the energy required by the animals to maintain their structure and also to carry out their varied activities. An organism can live for sometime without food but no organism can survive without respiration.

Respiratory System of Frog :

The respiratory exchange of gases in frog takes place by the **lungs**, the **mucous membrane** of the **buccal cavity** and **the skin.** These processes are referred to as **pulmonary respiration** (lung respiration), **buccal respiration** and the **cutaneous** or **skin respiration** respectively.

Frog being an amphibious animal, the pulmonary respiration is supplementary. The cutaneous and buccal respirations however take place mainly.

The three types of respiration in frog along with the associated respiratory organs will now be discussed in detail.

Pulmonary Respiration :

Pulmonary respiration is performed by the **lungs.** The lungs in frog are paired. They are in the form of highly vascular sacs

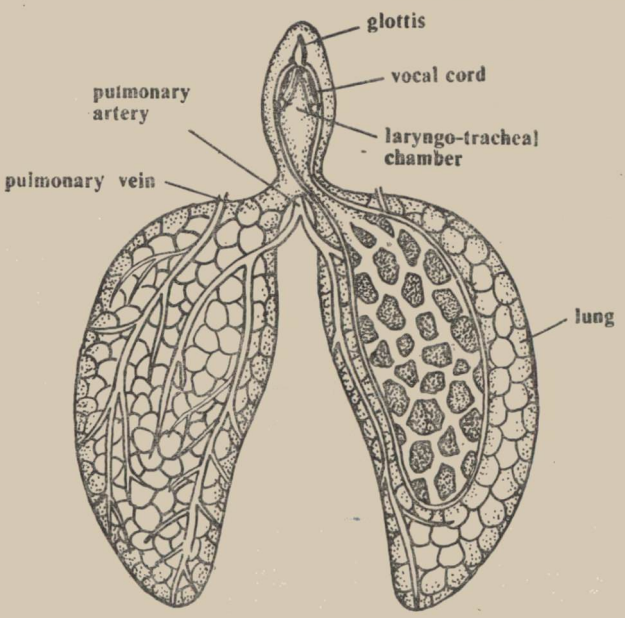


Fig. 8.1 Frog-Lungs ; laryngo-tracheal chamber and glottis,

which lie freely in the anterior part of the body cavity. Both the lungs arise directly from the **larynx.** In the absence of a neck in frog there is no trachea or wind pipe. The larynx of frog therefore represents in fact the **laryngo-tracheal chamber.**

The larynx opens into the buccal cavity through the **glottis.** The glottis, as is already mentioned, lies behind the tongue in the form of a median longitudinal slit in the pharyngeal region. (See also Fig. 2·5)

The **laryngo-tracheal chamber** opens behind into the lungs by a pair of apertures. Anteriorly, the larynx communicates with the pharynx through the glottis. The larynx is supported by cartilages. The cartilages which surround the larynx are the following.

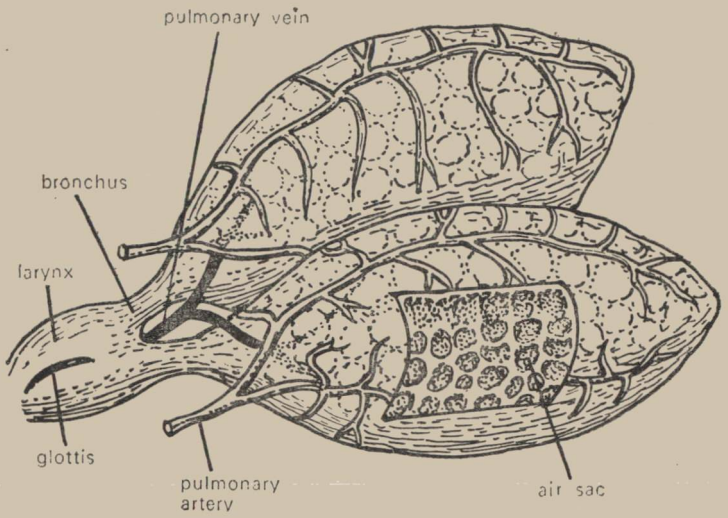


Fig 8.2 Frog—Lungs and glottis.

The **cricoid cartilage** is in the form of a ring produced backwards into a spine. From either side of this ring arises a process which is bent backwards to form a loop. The two processes are further united with a transverse extension of the cricoid lying on the ventral side of the larynx.

The paired **arytenoid cartilages** are in the form of semi-lunar valve-like structures encircled by the cricoid ring and supported from below by the transverse expansion of the cricoid.

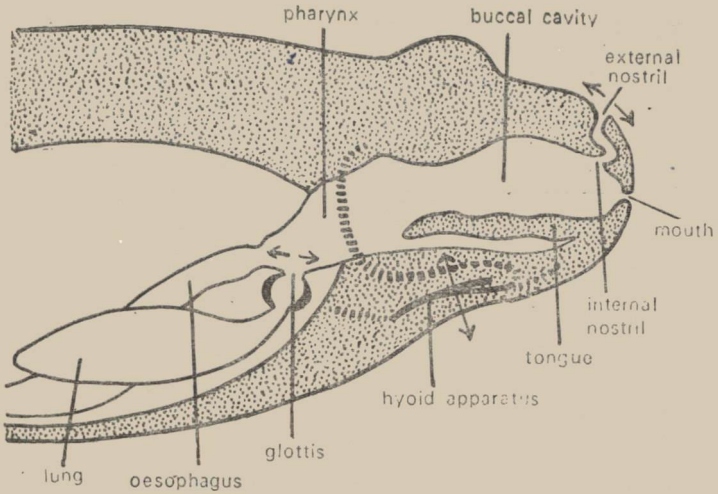


Fig. 8.3 Frog—Diagram showing the position of nostrils, buccal cavity and lungs,

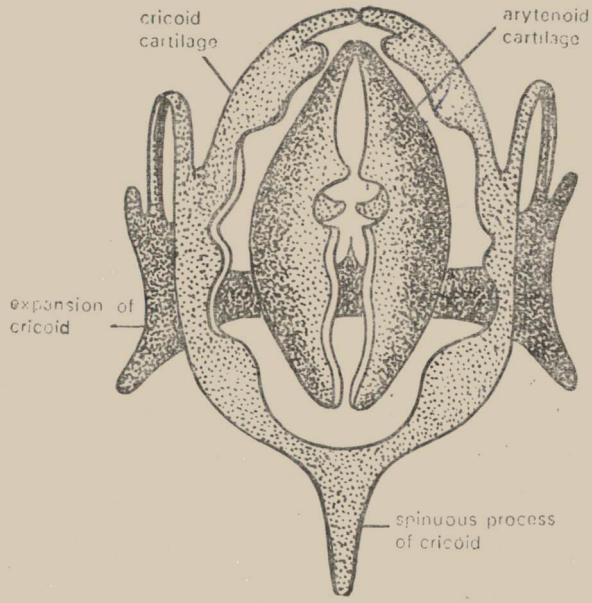


Fig. 8.4 Cartilages of the larynx of a frog as seen from the dorsal side.



The movements of air to and from the lungs cause **two flaps of epithelium** the **'so called vocal cords'** in the laryngeal chamber, to vibrate, due to which the characteristic sound of the frog called the **croak** is produced. A reference has already been made to the presence of the **vocal sacs** in male frogs (Fig.2·3) and cf. P. 12,13). The vocal sacs act only as resonators to increase and prolong the sound and appear like balloons when inflated.

The lungs are paired in the form of highly distensible oval thin walled sacs. They lie in the anterior part of the body cavity. Each lung is covered externally by the peritoneum i. e., the *pleural membrane.*

The walls of the lungs are thin and only slightly muscular. The inner surface of the lungs of frog is moderately folded in the form of ridges or folds which increase the area for exchange of oxygen and carbondioxide. The internal lining of the lung is richly supplied with blood capillaries. The structure of the lung thus presents a bubbly or foamy appearance when distended. The internal cavity of the lungs is quite spacious as the lungs of frogs are sac-like structures.

The Mechanism of Pulmonary Respiration :

If a frog is observed at rest, movements of the throat are visible at frequencies between 80 and 120 per minute. During these movements, the bucco-pharyngeal cavity is lowered and raised in a more or less regular manner 80 to 120 times per minute. During the depression and the elevation of the buccopharyngeal cavity, the **buccopharynx** acts as a powerful **buccal force pump** which drives the air into and out of the lungs.

The passage of air into and out of the lungs is sometimes called the **ventilation of the lungs**. The various stages recognisable during ventilation of lungs are as follows :

In the first instance, the premaxillae are lowered causing the external nares to open. The air from the external nostrils passes into the olfactory chamber and the internal nares. This part of the respiratory act is called **aspiration.**

Once the air enters the nostrils, the body of the hyoid in the floor of the buccopharyngeal cavity is lowered due to which the air enters the buccopharyngeal cavity via the nostrils.

The premaxillae are later raised due to which the external nares are closed. Soon after this, the floor of the buccopharyngeal cavity is elevated by the raising of the hyoid apparatus. Because of the raising of the floor of the buccopharyngeal cavity, the pressure

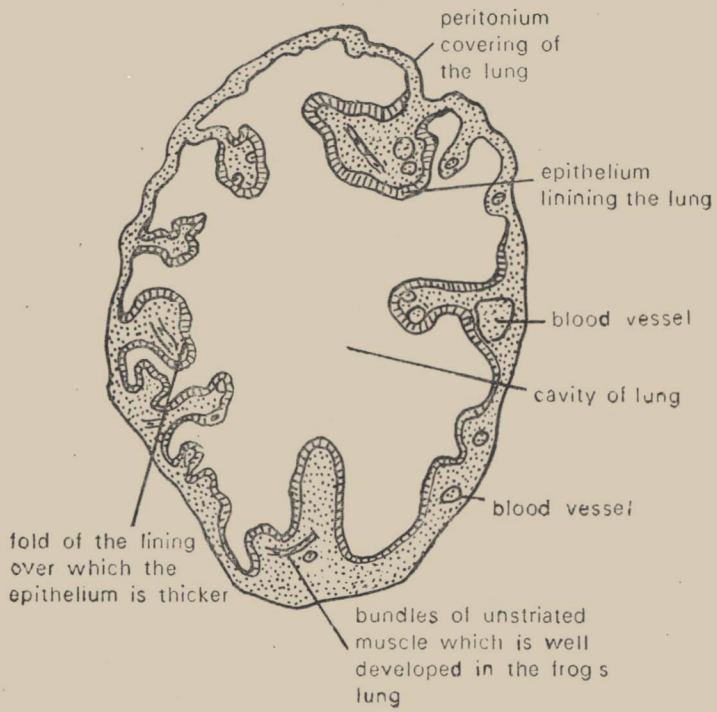


Fig. 8.5 Internal structure of the lung of frog.

on the air inside the buccopharyngeal cavity is increased. There being no other outlet for the air, it consequently forces open the glottis which ordinarily remains closed. The entrance to the oesophagus is kept closed by muscular contraction. The air through the glottis passes into the laryngotracheal chamber and eventually enters the lungs which are thus inflated. The buccopharyngeal cavity acts as a force pump driving the air into the lungs. This phase of respiratory act when the air enters the lungs is called **inspiration.** During all these operations, the mouth is kept closed so as to make the buccopharyngeal cavity an air tight chamber. If the mouth is forcibly kept open the frog will not be able to breathe.

To empty the lungs the procedure described above is reversed. The air after giving up its oxygen in the lungs, is forced back into the buccopharyngeal chamber partly by the contraction of the muscles of the body wall and partly by the elasticity of the walls of the lungs. The glottis opens to allow the air to pass but closes immediately afterwards. At the same time the buccopharyngeal chamber is lowered so as to enlarge the buccopharyngeal cavity to accommodate the air coming from the lungs.

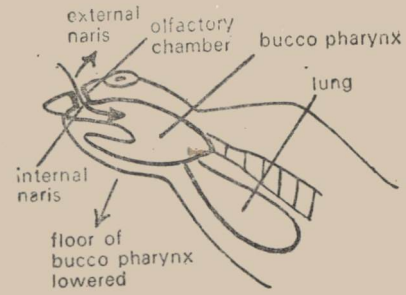


Fig. 8.6 Diagram indicating the mechanism of pulmonary respiration-aspiration.

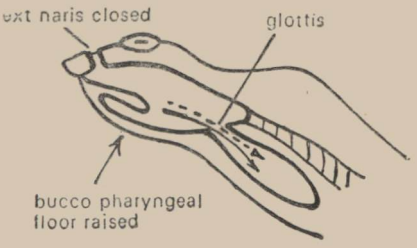


Fig. 8 7 The mechanism of pulmonary respiration—inspiration i.e., the air entering the lungs through the glottis.

Finally, the air is drawn out by the elevation of the floor of the buccopharyngeal cavity through the opening of the external nares. This part of respiration during which the used up air from the lungs is expelled through the external nostrils is known as **expiration.**

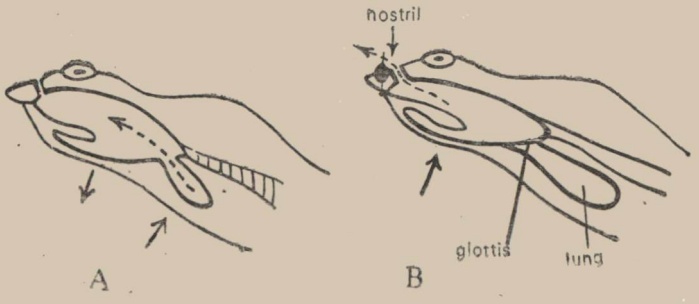


Fig. 8.8 A and B—The mechanism of pulmonary respiration—Expiration i.e , the used up air is expelled from the lungs through the external nares.

The frog appears to use its lungs only when the need for oxygen is greater. Ordinary requirements for oxygen seem to be met by the use of **buccal mucous membrane** and **the skin.** The details about the **buccal respiration** and the **cutaneous respiration** are described below.

Buccal Respiration :

In the case of buccal respiration, the exchange of oxygen and carbondioxide takes place in the mucous membrane lining the buccal cavity. The lungs do not take any part. As described, in pulmonary respiration, the air is drawn into the buccal cavity through the external nares by the lowering of the floor of buccopharyngeal cavity. The air is expelled like-wise from the buccal cavity by the elevation of the floor of it. Due to alternate lowering and raising of the floor of the buccopharyngeal chamber, the air is inhaled and exhaled through the external nostrils. *The exchange of gases occurs in the mucous lining of the buccal cavity.* During the buccal respiration, the mouth and the glottis are kept closed.

Cutaneous Respiration :

Cutaneous Respiration occurs in the skin. *In this case, the exchange of gases takes place in the skin which is richly supplied with blood vessels and is always kept moist.* As mentioned, the frog now and then plunges into water to keep its skin moist. The significance of keeping the skin moist is that the thin film of water which covers the skin, contains oxygen dissolved in it. The oxygen of water is exchanged with the carbondioxide in the blood which flows through the capillaries of the skin. Cutaneous respiration differs from buccal and lung respiration as regards the source of oxygen. In the case of cutaneous respiration the source of oxygen is water. On the other hand, in buccal and lung respiration oxygen is obtained from the air. When a frog is in a state of *hibernation*, it exclusively depends on cutaneous respiration for the supply of oxygen.

The Significance of the Process of Respiration in Living Organisms :

As described earlier, respiration is the most vital process which provides energy to the body. The oxygen brought to the tissues or cells through the respiratory system is utilised in cellular respiration or tissue respiration.

At the level of the cells a complicated process of cellular respiration takes place during which, step-wise breakdown or degradation of food molecules occurs. This results in the release of energy at several steps, which is stored in the form of a chemical substance called **adenosine triphosphate (A.T P).** The readily available fuel substances at the level of cells are carbohydrates e. g , glucose. Other food substances like amino acids and lipids are also used and undergo step-wise degradation in the process of cellular respiration.

In a laboratory, **glucose** can be burnt to give carbondioxide and water with the release of energy and the same can be explained by the following equation.

$$6O_2 + C_6H_{12}O_6 \longrightarrow 6\,CO_2 + 6H_2O + 690{,}000 \text{ cals. of energy per g mol.}$$

In the living cells during cellular respiration, oxidation takes place in the presence of **respiratory enzymes.** Besides the other enzymes, the **cytochrome complex system** contains the **important respiratory enzymes.** It has been estimated that one gramme molecule of glucose during **cellular respiration**[1] yields **38 A.T.P molecules**[2] **besides producing CO_2 and water.** The same can be explained by the following equation.

$$C_6H_{12}O_6 + 6O_2 + 6H_2O + 38 \text{ A.D.P.} + 38 \text{ P} \xrightarrow[\text{enzymes}]{\text{respiratory}}$$

$$6CO_2 + 12H_2O + 38 \text{ A.T P.}$$

The formation of each gramme molecule of A.T.P. from inorganic phosphate and A.D.P. involves the capture of 10,000 calories of energy. The total output of A.T.P. from the degradation of a single molecule of glucose amounts to 38 molecules of A.T.P. as is illustrated by the equation. Each A.T.P. molecule as stated captures 10,000 calories of energy as such 38 A.T P. molecules produced, will thus incorporate in them 380,000 calories of energy.

By burning glucose in laboratory it is shown in the equation, that 690,000 calories of energy are released. In cellular respiration 38 A.T.P. produced, capture 380,000 calories of energy out of a total of 690,000 calories. The net energy capture efficiency of the whole process of cellular respiration is thus at

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1. It should however be remembered that the oxygen brought to the tissues in the oxyhaemoglobin of the blood, in the final stages of cellular respiration combines with the hydrogen atoms to form water. The oxygen thus brought to the tissues serves as the final acceptor for hydrogen atom and forms thereby water.

2. The energy released during cellular respiration at various steps is used primarily for the transformation of A.D P. to A.T.P. This is referred to as oxidative phosporylation of A.D.P. to A.T.P.

least 50%. This is thus an efficient performance when it is remembered that engineers are reasonably satisfied when they are even able to convert one-third of the heat of combustion of a fuel into mechanical work.

In the process of respiration, the chemical energy of A.T.P. thus obtained is converted by the organisms into various forms of energy to perform useful **biological work, such as active transport**[1] (chemical energy) **motion**, (mechanical energy), **bioluminescence**[2] (light energy), **bioelectricity**[3] (eletrical energy) and **biosynthesis**[4] (chemical energy).

Revision questions

1. Describe in detail the respiratory organs of frog.
2. Define the terms, *external respiration* and *cell respiration* and mention in brief the significance of respiration to the life of an animal.
3. Describe in detail the mechanism of plumonary respiration in frog.
4. Give an account of buccal respiration and cutaneous respiration in frog.
5. Write notes on the following :
   (a) The internal structure of the lung of frog.
   (b) Larynx of frog.
   (c) A.T.P.

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1. The transfer of substances against a gradient.
2. The emission of light by a living organism.
3. The power of certain living organisms to give electric shocks through their electric organs. The electric activity is used for defensive purposes and it also serves to capture the prey. Various fishes have electric organs. The electric eel, found mostly in the Amazon has been extensively studied.
4. It is a cellular function during which complex compounds are synthesised from simpler ones e. g., the synthesis of complex body proteins from amino acids.

CHAPTER IX

THE FROG - NERVOUS SYSTEM

The life activities of vertebrates like the frog are controlled and co-ordinated by two well organised regulating systems called (1) **The nervous system** and (2) **The system of endocrine glands.**

The nervous system of frog will first be discussed.

The nervous system consists of three parts—(A) the **central nervous system** which includes **the brain** and the **spinal cord.** (B) **The peripheral nervous system** consisting of the nerves given off from the brain **(the cranial or cerebral nerves)** and the spinal cord **(the spinal nerves)** and (C) **The autonomic nervous system** consisting of the **sympathetic** and **parasympathetic nerves.**

(A) The Central Nervous System:

The **brain** of the vertebrates is lodged in the cranial cavity of the skull. The posterior continuation of the brain, called the **spinal cord** is similarly concealed in the canal of the vertebral column.

The brain is enclosed by the investing membranes or **meninges.** These are two in number. The membrane which invests the brain is called the **pia mater.** It is delicate and highly vascular. It is this layer which forms the vascular part of the choroid plexuses. The second membrane is tough. It is called the **dura mater** which lines the cranial cavity. The spinal cord like-wise is covered by two investing membranes.

In the higher vertebrates, a third layer, i e , the delicate **arachnoid layer** may be present between the dura mater and the pia mater.

The spaces between these meninges and within the cavity of the spinal cord and ventricles of the brain are filled up with a serous fluid which serves to absorb shocks to the central nervous system.

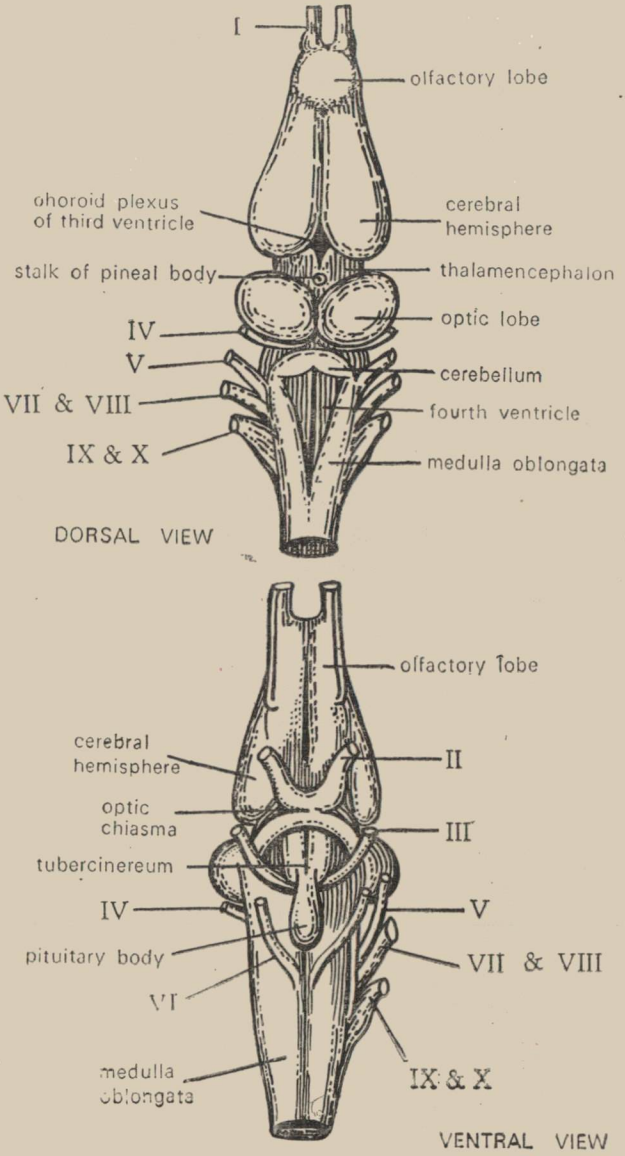


Fig. 9.1 Brain of Frog—Dorsal and ventral views showing the origin of the cranial nerves.

The Brain of Frog :

The brain of frog like the other vertebrates has three main divisions which arise during development from three primary brain vesicles called the **fore-brain** or **prosencephalon; the mid-brain** or **mesencephalon** and the **hind-brain** or **rhombencephalon.**

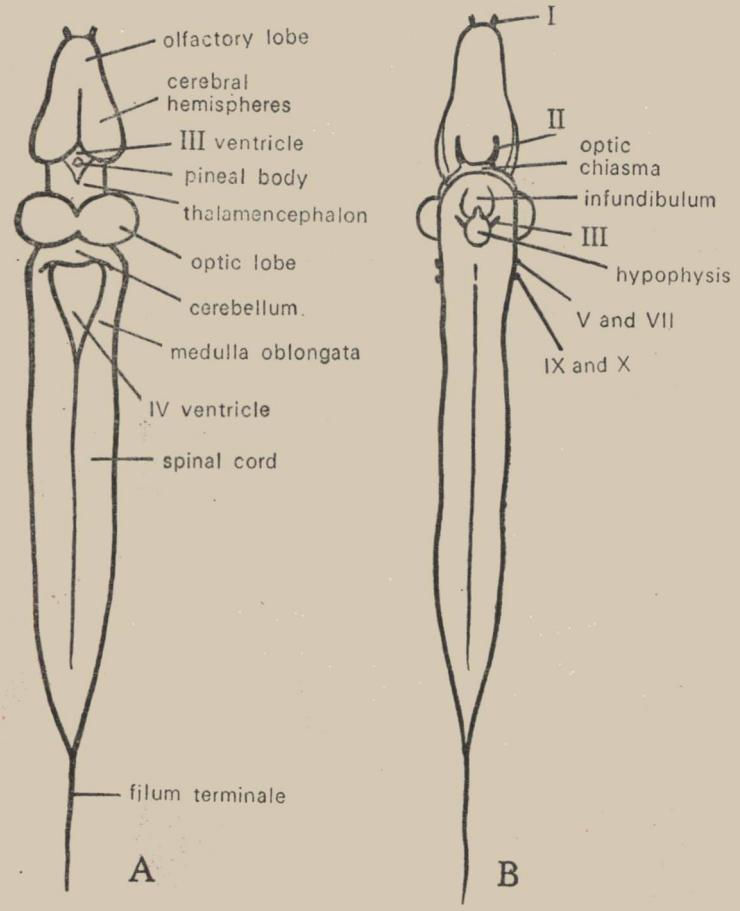


Fig. 9.2 Brain of frog—(A) Dorsal surface, (B) Ventral surface

The fore-brain or the **prosencephalon** consists of two divisions the anterior **telencephalon** and the posterior **thalamencephalon** or **diencephalon.**

The telencephalon distinguishes anteriorly into relatively smaller **olfactory lobes** and posteriorly into a large mass of **cerebral hemispheres**. A shallow transversely running groove separates the olfactory lobes with the cerebral hemispheres. The cerebral

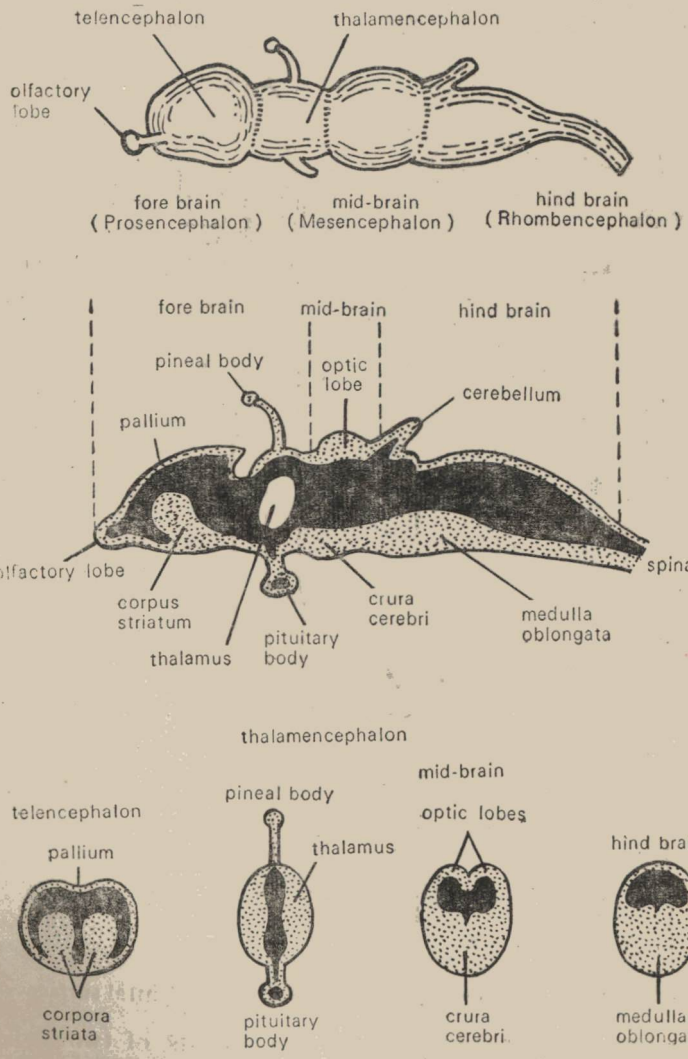


Fig 9.3 Diagrams representing the differentiation of brain from three primary brain (cerebral) vesicles.

hemispheres and the olfactory lobes together form the large mass in front. The olfactory lobes are the undivided part of this mass at its extreme anterior end, and from them the large olfactory nerves run forward. The cerebral hemispheres possess a well marked fissure separating them into right and left halves. The two halves of the cerebral hemisphere are collectively referred to as the **cerebrum**.

The roof of the telencephalon forms the **pallium** whilst the ventro-lateral walls thicken to form the **corpora striata**.

Behind the telencephalon is **the thalamencephalon** or **diencephalon** or **tween brain**. It is situated between the optic lobes and the cerebral hemispheres. On the ventral side of the thalamencephalon lies **the optic chiasma**. It resembles a wide X. It is formed by the crossing of a few of the nerve fibres of optic nerves of each side. Just behind the optic chiasma on the ventral side of the thalamencephalon is a swollen lobe called the **infundibulum**. Attached to the

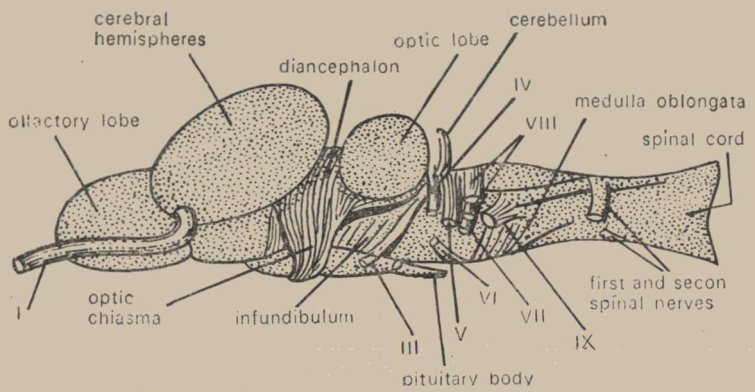


Fig. 9.4 Brain of frog seen from the side.

infundibulum is found the sac-like **pituitary body** or **hypophysis cerebri**. The pituitary body is an endocrine gland. The roof of the thalamencephalon is covered by a puckered membrane which is very rich in blood vessels and consequently of a deep red colour. This vascular membrane is known as the anterior **choroid plexus**. Lying over the choroid plexus on the dorsal side of the thalamencephalon is the remains of the **pineal body**. The side walls of the thalamancephalon are called the **optic thalami**.

The mid-brain or **mesencephalon** consists of two prominent rounded swellings, the **optic lobes** or **corpora bigemina** on the dorsal side of the brain. These lobes project laterally; hence are visible from the ventral aspect of the brain as well. The floor of the optic lobes is formed by two longitudinal ridges, the **crura cerebri.**

The hind-brain or **rhombencephalon** is distinguished into an anterior **metencephalon** and a posterior **myelencephalon** or **'after brain.'**

The metencephalon consists of the **cerebellum** lying immediately behind the optic lobes. It is very small and is reduced to a narrow transversely running ridge on the anterior dorsal region of the hind-brain. The myelencephalon consists of the **medulla oblongata** which is continued posteriorly into the spinal cord.

The ventricles of the brain: The cavities of the brain are called the *ventricles*. The olfactory lobes and the cerebral hemispheres are hollow. The cavities of the cerebral hemispheres are

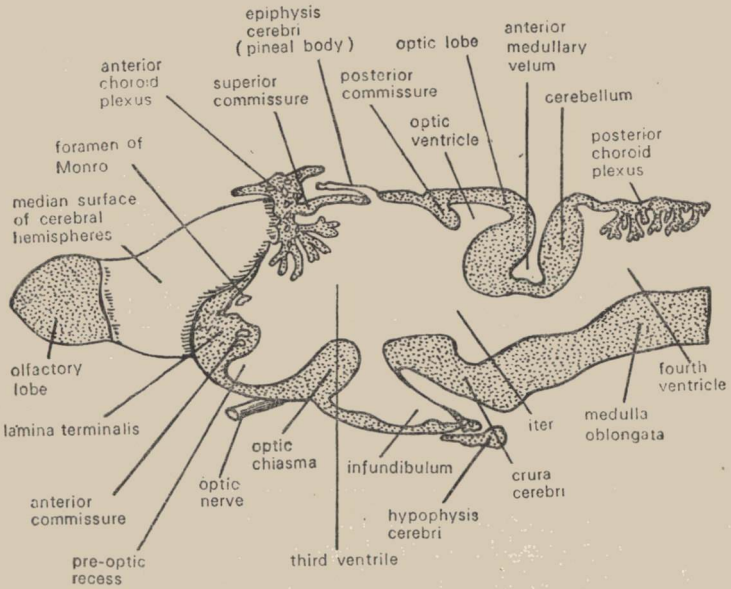


Fig. 9.5 Median longitudinal section passing through the brain of frog, *Rana*.

called the **lateral ventricles**. The cavities of the olfactory lobes also called **rhinocoels** are not clearly demarcated from the lateral ventricles and appear as forward prolongations of them in the olfactory lobes.

The cavity of the diencephalon or the thalamencephalon is known as the **third ventricle**. The two lateral ventricles communicate with the third ventricle through a common median aperture, the **foramen of Monro**. From the third ventricle, a duct called the **aqueduct of Sylvius, Sylvian duct** or **iter** (in full, *tertio ad quartum ventriculum*) passes backwards through the mid-brain and into it open the ventricles of the optic lobes. The cavity of the medulla oblongata is called the **fourth ventricle** which is connected with the third ventricle through the aqueduct of sylvius. Projecting into the fourth ventricle is found the **posterior choroid plexus** formed by the thickening and folding of the pia mater. The ventricles and passages of the brain and also the sub-arachnoid space are filled with **cerebrospinal fluid**[1], which is a form of lymph produced by a network of blood vessels called the **choroid plexuses** (The anterior and posterior choroid plexuses). These choroid plexuses as mentioned earlier are found in the roofs of the third (anterior choroid plexus) and the fourth (posterior choroid plexus) ventricles.

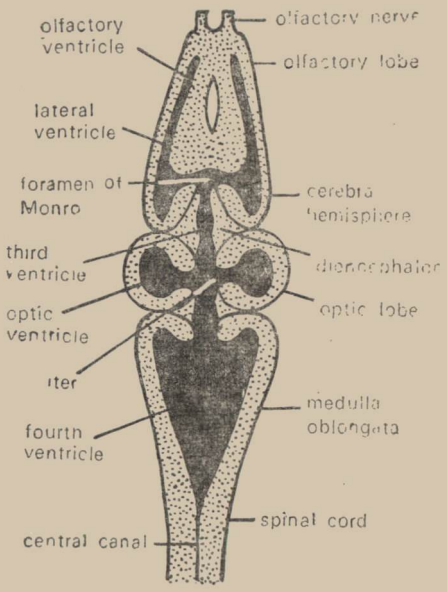


Fig. 9.6 Diagrammatic horizontal section passing through the brain of frog showing the ventricles.

1. It is a clear colourless fluid, slightly viscous with a low specific gravity (1.004 to 1.006). It contains inorganic salts in small quantities chiefly sodium chloride and potassium chloride. It has also small amounts of dextrose and proteins in traces. In an adult man, its quantity is 100 to 150 cu. cm.

The Functions of the Various Parts of the Brain of Frog:

The *olfactory lobes* are concerned with the sense of smell.

The *cerebral hemispheres* are the seats of intelligence and voluntary control of various activities. In the case of frog, the surface of the cerebral hemispheres is however smooth. This accounts for the relatively low intelligence of the animal.

The *optic lobes* exert an inhibiting influence on the reflex activity of the spinal cord. Each lobe controls the opposite side of the body. The removal of the optic lobes therefore makes the animal irritable.

The *cerebellum* is concerned with equilibrium and coordinated movements. The poor development of the cerebellum in the frog may be explained by the fact that the animal in its normal squatting position is very stable and requires practically no balancing.

The *medulla oblongata* regulates most of the important functions of the body that are not directly under the control of the will. It controls e.g., the snapping reflex of catching the prey, croaking, protrusion of tongue, swallowing, respiratory movements, locomotion etc. The nerves originating from the medulla oblongata are supplied to the heart and the alimentary canal. The medulla through these nerves as such controls the heart beat and the processes of digestion. Removal or serious injury to medulla oblongata leads to the death of the animal.

The spinal cord: As described, the medulla oblongata continues posteriorly into the spinal cord. It is slightly flattened, roughly cylindrical in shape and lies in the neural canal of the vertebral column. The end of the spinal cord rapidly tapers and eventually terminates in a thread-like portion called the **filum terminale**, which is enclosed by the urostyle. The spinal cord is slightly enlarged opposite the fore and the hind-limbs to form the **brachial** and **sciatic enlargements** respectively. Throughout the length, the spinal cord shows in its mid-region a well marked **dorsal fissure** at its dorsal surface and along its mid-ventral surface a less marked **ventral fissure**. These fissures look like streaks from the outside. A microscopic study of its cross-section reveals the general structure of the spinal cord as shown in figure 9.7.

The spinal cord is invested by a thin pigmented membrane, the *pia mater* and the neural canal in which the spinal cord lies is lined by a thick and tough membrane, the *dura mater*. The space between these two membranes is filled up with a lymphatic arachnoid fluid which serves to protect the cord from shocks.

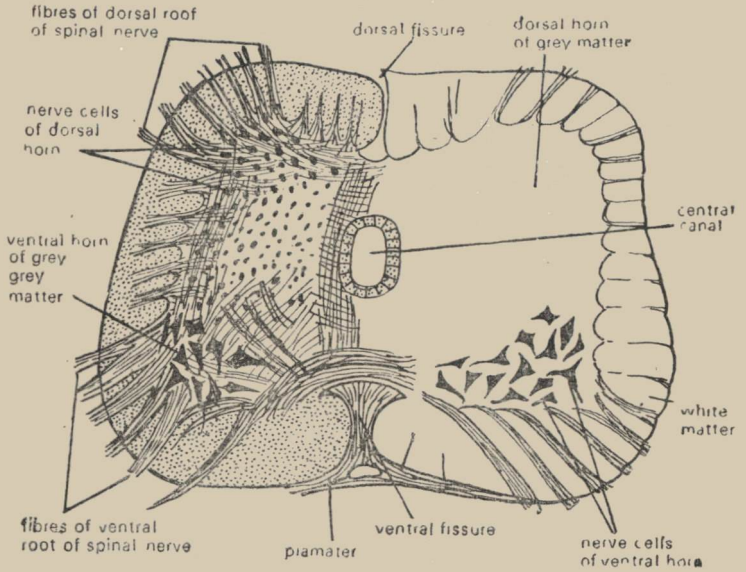


Fig. 9.7 Transverse section passing through the spinal cord of frog.

In the centre of the spinal cord is found a longitudinal cavity, the **central canal** which runs along its axis and is lined by a layer of epithelial cells. The central canal is continuous in front with the cavities of the brain and ends blindly behind. The section also reveals that the cord is made up of two kinds of nervous tissue, the **grey matter** on the inner side immediately surrounding the canal and the **white matter** on the outer side. The grey matter is squarish in outline and is produced at the edges into **dorsal and ventral horns.** The grey matter consists chiefly of nerve cells while the white matter is made up largely of nerve fibres.

Arrangement of Grey and White Matter in Brain :

The brain, like the spinal cord, is made up of both *grey* and *white matter*; their arrangement however is not uniform. In the

case of medulla oblongata and the optic lobes the grey matter is mainly internal and the white matter external. In the thalamencephalon, cerebral hemispheres and the olfactory lobes, the white matter is internal and the grey matter forms a thin outer covering called the **cortex**. The **cerebral cortex** consists of nerve cells.

(B) **The Peripheral Nervous System:**

Under the peripheral nervous system we discuss the distribution of nerves which arise from the brain and the spinal cord. The nerves arising from the brain are called the **cerebral** or **cranial nerves** and those arising from the spinal cord are called the **spinal nerves.**

According to the functions they perform, the nerves may be distinguished into **sensory, motor and mixed nerves. Sensory nerves** are those which bring impulses from sense organs (e. g., nose, eyes and ears) to the central nervous system. **Motor nerves** are those which carry messages from the central nervous system to the muscles and effect their movements. **The mixed nerves** perform both sensory and motor functions.

The cranial nerves of frog: In frog, *ten pairs of cranial nerves* arise from the brain. They emerge from the cranial cavity through the apertures or foramina in the wall of the cranium and in general innervate the sense organs or other parts of the head. Some of the cranial nerves are entirely *sensory*, some *motor*, while others are *mixed.* The details pertaining to the distribution of the cranial nerves of frog are as follows:

The first or *olfactory nerves* are very short. The olfactory nerve of either side, originates from the anterior end of the olfactory lobe and passing through a foramen, in the transverse portion of the sphenethmoid, innervates the mucous membrane lining the olfactory chamber. The sensation of smell is conveyed through the olfactory nerve to the brain. It is therefore purely a *sensory nerve.*

The second or *optic nerve*: Optic nerves are also paired. Each optic nerve arises from the side of diencephalon. On the ventral side of the diencephalon some of the optic nerve fibres cross over each other to form the **optic chiasma.** The crossing of optic fibres at the

chiasma is however not complete as some fibres remain on their own side. Each optic nerve leaves the cranial cavity through the optic foramen and then the nerve spreads out over the retina of the eye. This is purely *sensory*.

The third or *oculomotor nerve* arises from the crura cerebri beneath the optic lobe. It arises from the skull through a small foramen behind the optic foramen and innervates four out of the six muscles of the eye-ball. The muscles innervated by this nerve are *inferior oblique, internal rectus, superior rectus and inferior rectus.* It is entirely a *motor nerve.*

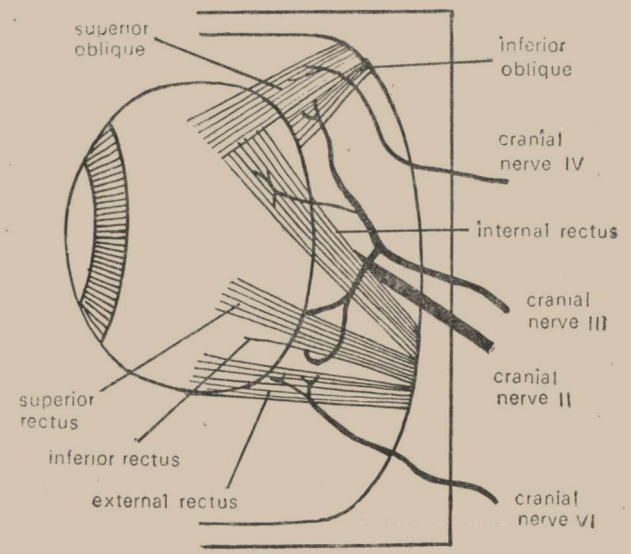


Fig. 9.8 Muscles of the eye-ball with their nerve supply.

The fourth or *pathetic (trochlear) nerve* is a slender nerve. It originates from the dorsal surface of the brain between the optic lobe and the cerebellum and leaves the skull above the third nerve. It innervates the *superior oblique* muscle of the eye-ball and is exclusively *motor.*

The fifth or *trigeminal nerve* arises from the side of the anterior end of the medulla oblongata. Before leaving the cranial

cavity through a large aperture in the pro-otic bone, this nerve is dilated to form a large swelling, the *Gasserian ganglion.* As the name implies, this nerve divides into three main branches called (a) *the opthalmic,* (b) *the maxillary* and (c) *the mandibular.*

(a) The *opthalmic branch of the fifth cranial nerve* can be seen on the inner side of the orbit by moving the eye-ball away from that side. It innervates the skin of the snout.

(b) The *maxillary branch of the V* supplies to the upper jaw.

(c) The *mandibular branch of the V* innervates the lower jaw.

The trigeminal is a *mixed nerve.*

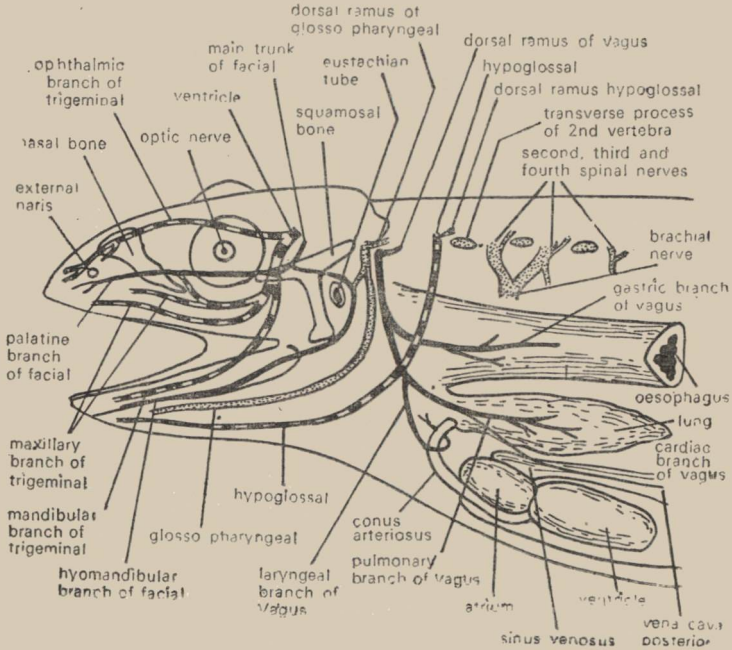


Fig. 9.9 The diagram indicating the distribution of the fifth, seventh, ninth, and tenth cranial nerves of frog.

***The sixth* or *abducent nerve*:** The *sixth* or the *abducens* arises from the ventral side of the medulla oblongata close to the mid-ventral line. It emerges from the cranium through the same aperture as the fifth and innervates the *external rectus muscle* of the eye-ball. It is a *motor nerve.*

The seventh or *facial nerve* arises from the side of the medulla oblongata just behind the origin of the *V* nerve. It runs forward and unites with the *Gasserian ganglion*. Later, it leaves the skull by the same aperture as the fifth and the sixth nerves and soon gives off two branches.

The dorsal branch is called *VII palatine* which innervates the mucous membrane of the roof of the buccal cavity.

The ventral branch is referred to as the *hyomandibular* which innervates the muscles and skin of the lower jaw and also the muscles of the hyoid.

The *VII* or *facial nerve* is a *mixed nerve*.

The eighth or *auditory nerve*, arises from the side of the medulla immediately behind and touching the root of the seventh nerve. It soon enters the auditory capsule in its inner wall through an aperture and innervates the internal ear. It is therefore purely a *sensory nerve*.

The ninth or *glossopharyngeal nerve* originates from the side of the medulla oblongata behind the eighth nerve and leaves the cranial cavity through an aperture situated on the outer side of the occipital condyle. It sends a branch which joins the hyomandibular branch of the facial nerve and later runs downward and forward to innervate the mucous membrane of the tongue and pharynx and also the muscles of the hyoid. It is a *mixed nerve*.

The tenth or *vagus nerve*: The vagus nerve arises in common with the *IX* and leaves the cranial cavity by the same aperture. Outside the skull, the *vagus* swells into the *vagus ganglion*. It is separated from the *IX* by a strand of muscles running parallel to both the nerves. Along side the tenth nerve is the cutaneous artery, and sometimes the internal jugular vein partly covers the nerve.

The *X nerve* divides into two branches.

(a) *The laryngeal branch*, which runs immediately anterior to the cutaneous artery, under the hypoglossal nerve, and eventually loops over the pulmo-cutaneous arch just

where this vessel divides into the pulmonary and cutaneous arteries, and then takes a forward course to the larynx.

(b) *The cardiac branch* of the vagus at the base of the lung divides, and one portion of it goes to the lung where it is seen to divide into several pulmonary branches. The other portion of the cardiac branch passes beneath the pulmonary artery and continues to the heart. In the proximity of the oesophagus, two or three slender branches called the gastric branches—will be found leaving the main cardiac branch (which may as well be called merely, the *X* nerve giving off the cardiac, pulmonary and gastric branches) to innervate the walls of the oesophagus and stomach.

The vagus nerve as such has a wide distribution supplying its branches to the larynx, heart, lung, oesophagus and stomach. It is therefore referred to as the *pneumogastric nerve*. It is as such a *mixed nerve*.

The spinal nerves: Nine or ten pairs of spinal nerves are found in frog. The spinal nerves arise from the sides of the neural canal through the intervertebral foramina between the successive

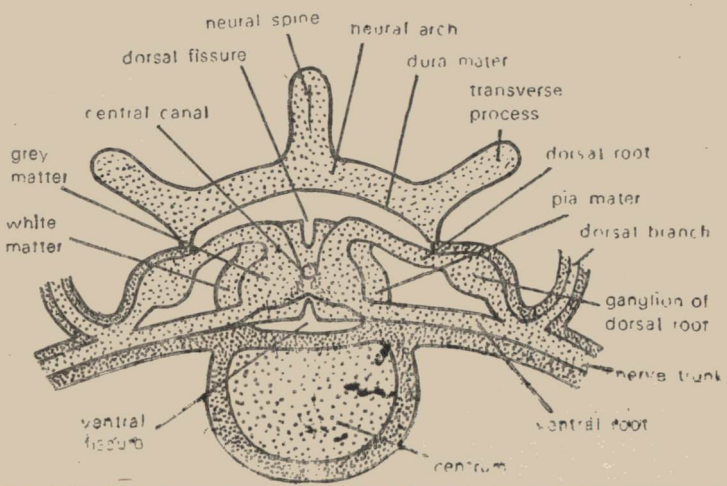


Fig. 9.10 Transverse section passing through the vertebral column of frog showing the origin of spinal nerves.

vertebrae. Each spinal nerve arises from the spinal cord by two roots. The **dorsal root** originates from the dorsal horn of the grey matter of the spinal cord and the **ventral root** arises from the ventral horn of the grey matter of the spinal cord. The dorsal and the ventral roots however lie in the neural canal only. The dorsal root bears a swelling or ganglion called the **dorsal root ganglion**. There is however no ganglion on the ventral root.

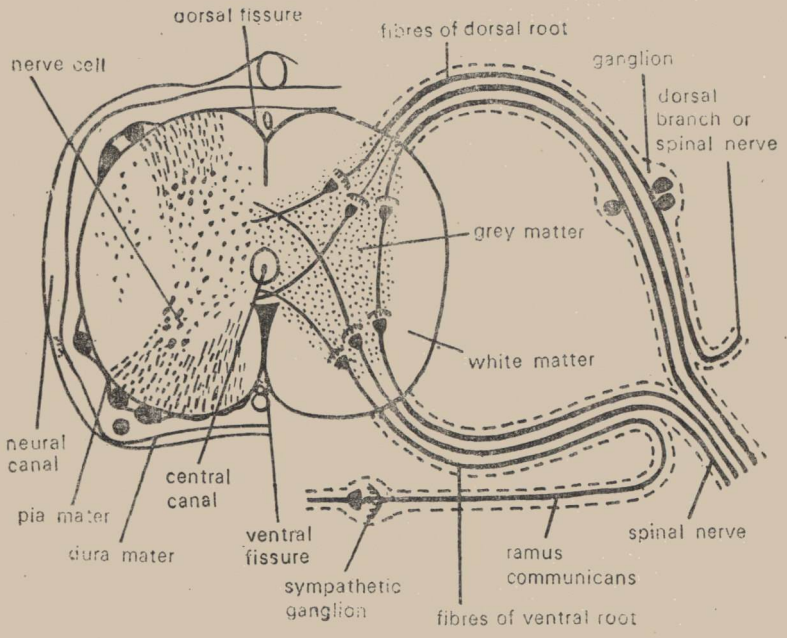


Fig. 9.11 A transverse section passing through the spinal cord of frog, showing on one side the emergence of dorsal and ventral roots.

Just outside the vertebral column, the dorsal and the ventral roots unite with each other and the nerve so formed divides immediately into a small **dorsal branch** and a large **ventral branch.** The small **dorsal branch** immediately passes into the dorsal muscles (muscles of the back) and the skin innervating these structures as such. The **ventral branch** is large which innervates the skin and muscles of the ventral side. Some of the ventral branches also innervate the limbs. *The large ventral branches are usually referred*

to as the **spinal nerves** *which in frog, as mentioned, are nine or ten arising in pairs one from either side of the spinal cord.*

The details of the ten pairs of spinal nerves are as follows :

The first spinal nerve or *the hypoglossal nerve* leaves the neural canal through the intervertebral foramen between the first and second vertebra. It passes forwards into the floor of the mouth and innervates the tongue.

The second spinal nerve is a very large nerve which arises between the second and the third vertebrae.

A small *third spinal nerve* leaving between the third and the fourth vertebrae joins the large *second spinal nerve*. From the combined nerve, a number of small nerves are given off, and the whole structure constitutes the **brachial plexus**. The brachial plexus so formed by the union of second and third spinal nerves continues along the arm in the form of a *brachial nerve*. The brachial nerve gives off a very thin branch to the shoulder region. This branch of the brachial nerve is known as the *coraco-clavicular nerve*.

The *4th*, *5th* and *6th spinal nerves* emerge from between the fourth and the fifth, fifth and sixth, and sixth and seventh vertebrae respectively. These nerves go diagonally backwards to the muscles of the body wall.

The *seventh*, *eighth* and *ninth nerves* leave the neural canal between the seventh and eighth vertebrae, eighth and ninth and the ninth vertebra and urostyle respectively. These are large nerves which proceed backwards. They are closely associated and form by connections and branches the **sacral plexus** or the **sciatic plexus.**

The seventh spinal nerve divides into two branches i. e., (i) the *ilio-hypogastric nerve* supplying the muscles of the abdomen and (ii) the *crural nerve* supplying the muscles of the thigh. The *eighth* and the *ninth spinal nerves* join to form the largest **sciatic nerve**, but before this union, the eighth spinal nerve sends a connection to the crural

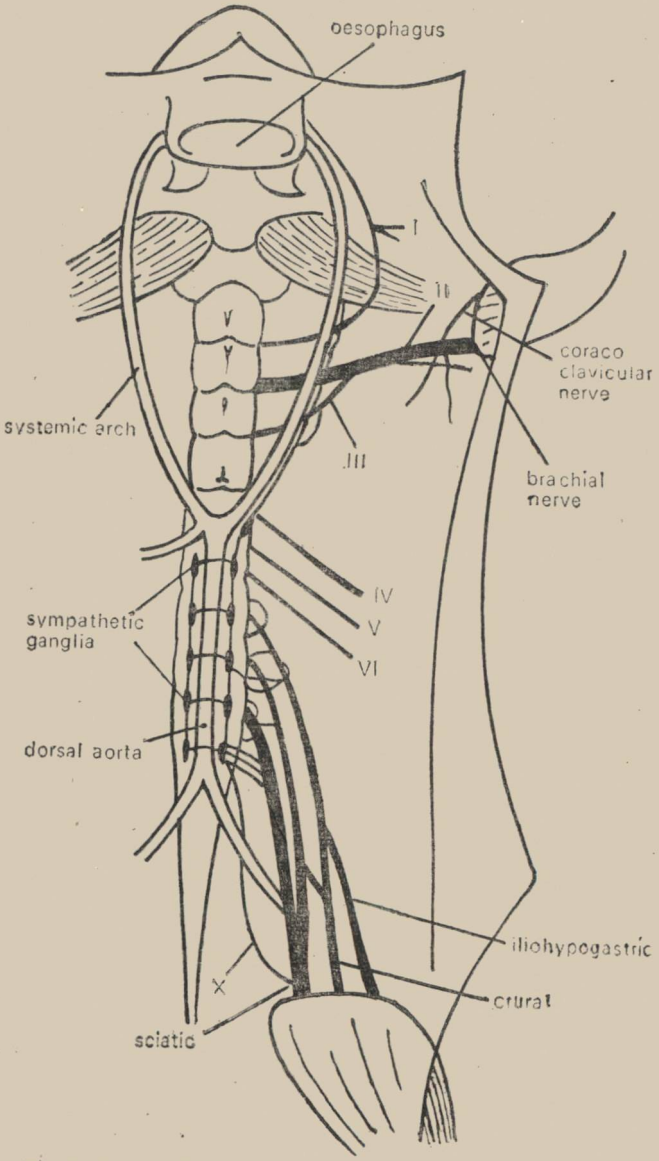


Fig. 9.12 The spinal nerves of frog — shown on one side.

nerve. The large *sciatic nerve* runs down the thigh and divides into *tibial* and *peroneal branches*, supplying the muscles and skin of the leg and foot.

The *tenth spinal nerve* which leaves the urostyle is a slender nerve which eventually joins the sciatic nerve. It is sometimes called the *coccygeal nerve*. It branches over the bladder, cloaca and the surrounding tissue. In *Rana tigrina*, the *X spinal nerve* is usually absent or is present only on one side. Inside the neural canal the *7th, 8th and 9th spinal nerves* together with the *tenth and the filum terminale of the spinal cord*, run downwards in a bush-like group known as **cauda equina**.

The first spinal nerve, the hypoglossal is a *motor nerve* as it supplies to the muscles only. The rest of the spinal nerves are the *mixed nerves* which innervate the muscles and the skin. They contain both sensory and motor fibres.

(C) The Autonomic Nervous System :

The term **autonomic nervous system** (Gk. *autos* : self ; *nomos* : law i. e., self governing) is applied to all those parts of the nervous system which control the involuntary activities i. e., the activities which are not under the conscious control of the animal. The autonomic nervous system is associated with the peripheral nervous system and innervates the smooth muscles of heart, lungs, digestive system, endocrine and other glands and such other organs which function continuously without conscious control. The **cerebro-spinal system** controls the relations between the animal and the outer world; the **autonomic nervous system** as mentioned regulates events within the animal.

The autonomic system can be divided into **sympathetic system** (consisting of paired chains of sympathetic ganglia and nerves) and **para-sympathetic system** which consists of nerves arising from the cranial and sacral regions of the central nervous system.

The para-sympathetic and sympathetic components of the autonomic nervous system always act *antagonistically*. This opposite

action results in a balance which produces smooth changes in the tone of smooth muscles and the activity of glands. *The sympathetic and para-sympathetic systems act in the opposite ways to one another, much as the reins and whip of a rider oppose one another.* The activity of the viscera thus is determined by the balance of these opposed forces. An example of such action may be quoted by the heart beat. The stimulation by sympathetic fibres, accelerates and strengthens the heart beat, while the vagus (para-sympathetic fibres) makes the heart weaker and slower. The resultant balance of these opposite actions is the normal beating of heart.

The reactions controlled by the autonomic nervous system are closely related to the emotions. Grief, anger, excessive joy, fear, and sexual stimulation, all result in profound changes in the functioning of the organs under the control of the autonomic nervous system.

The Sympathetic Nervous System of Frog:

In frog, the sympathetic nervous system consists of a pair of delicate *sympathetic nerve cords* which lie one on either side of the dorsal aorta and continue forward along the outer sides of the systemic arches. At the anterior end each sympathetic cord enters the skull through the vagus foramen and eventually terminates in the *Gasserian ganglion.* The sympathetic cord on each side may therefore be said to begin in the corresponding *gasserian ganglion.* All along the entire length of the sympathetic cord are found at regular intervals altogether *nine* or *ten small sympathetic ganglia.* Each sympathetic ganglion is connected with the corresponding spinal nerve (ventral branch) by a branch of nerve called the *ramus communicans* (See also Figs. 9·11 and 9·14).

The sympathetic ganglia and the cords are usually covered with a layer of black pigment which make them easy to follow. From the sympathetic ganglia arise the nerves which supply the heart, blood vessels and other internal viscera e. g., alimentary canal, (i. e., stomach, intestine), kidneys, gonads and the urinary bladder. The activities of these organs in frog as such is regulated by the autonomic nervous system.

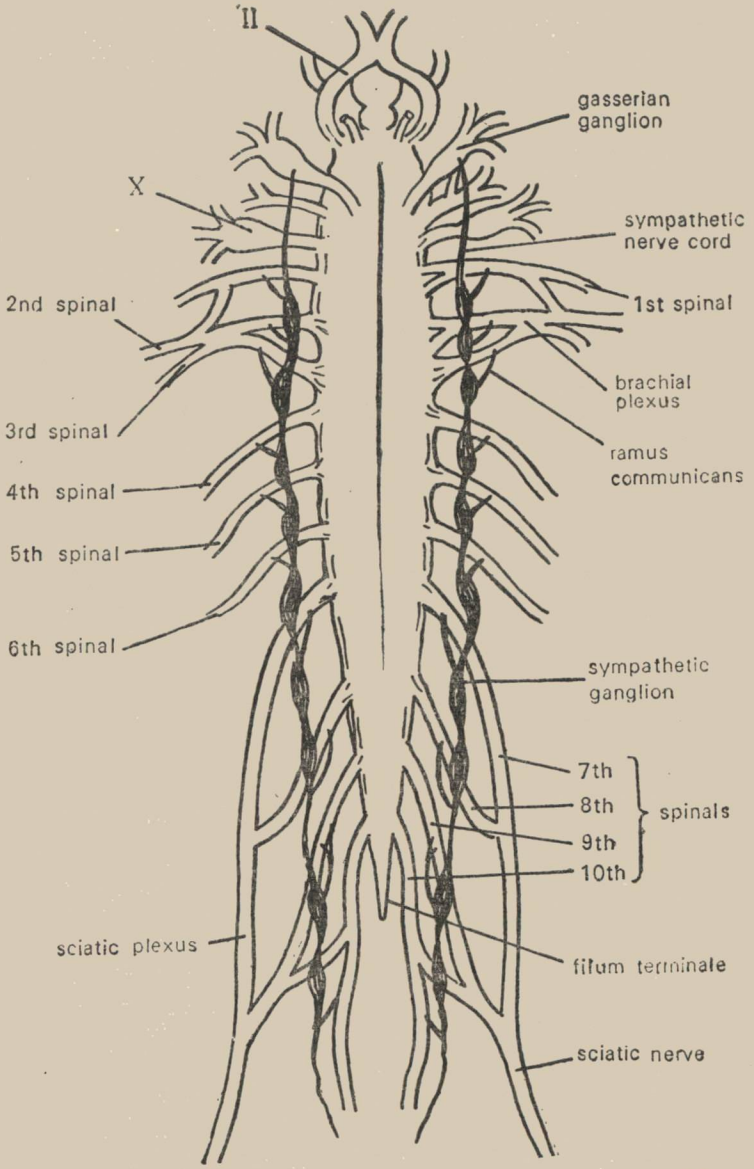


Fig. 9.13 Spinal nerves and the sympathetic nervous system of frog showing a chain of sympathetic ganglia.

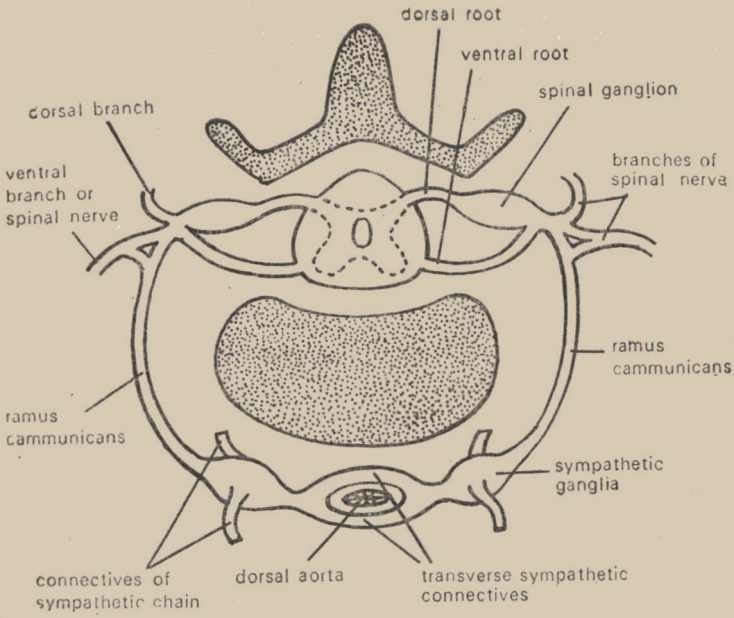


Fig. 9.14 A diagram of a pair of spinal nerves and their connections with the sympathetic system.

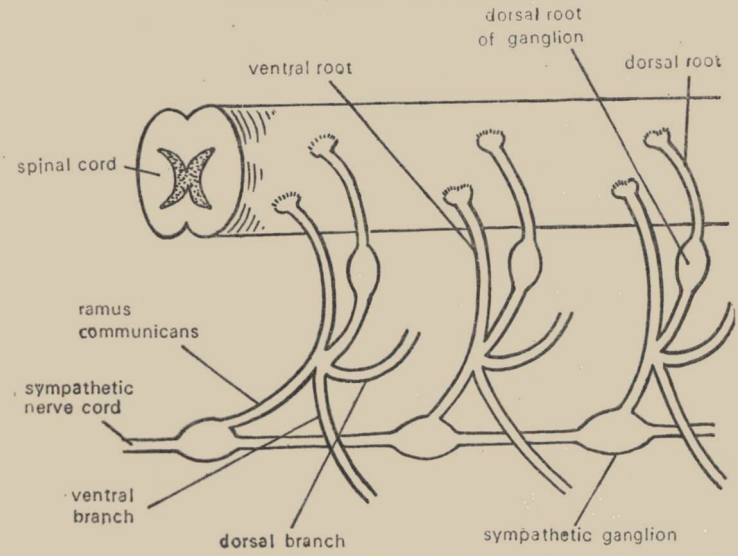


Fig. 9.15 Frog — Sympathetic cord and the spinal nerves showing relationship.

REFLEX ACTION

If you put a drop of weak acid on the body of a frog whose brain is removed or destroyed it will be noted that even in this condition the frog is still able to react to this stimulus. The frog may even use the other leg to wipe off the irritating substance. In the above example, as the brain of frog is removed or destroyed, the response given by the frog to the acid is not brought about by the exercise of free will. Such type of action is called a **reflex action.** *The reflex action as such can be defined as an automatic response by the animal, to a stimulus, without the intervention of the will.* The actions that are performed by the will of the animal, as a result of free choice, are called **voluntary actions.** The reflex actions on the other hand are involuntary. Men and the animals, perform different types of reflex actions in their daily life. Few such examples are as follows :

A strong light held in front of the eyes makes them shut. Whenever anything is passed rapidly in front of the eyes, blinking of the eye-lids takes place. If our hand comes in contact with a hot or a cold object we suddenly draw the hand away. The retort of a gun startles us.

The vital functions of the important organs of the body are also the examples of reflex actions, such as the action of gastric glands when food reaches the stomach and the flow of bile from the gall bladder when the food reaches the duodenum. The above vital actions, we know, occur without our knowledge.

The reflex action is produced in the following way:

A stimulus on the skin (epidermis), or the sensory receptor is translated into a nerve impulse. This nerve impulse travels centrally to the sensory neuron *A* which is located in the dorsal root ganglion or the spinal ganglion. From neuron *A* later, the nerve impulse passes over its axon into the grey matter of the cord to terminate in the ventral horn or a **relay centre**. Here it connects with the dendrites of motor neuron *B*. From motor neuron *B*, the impulse travels into the axon which extends outward in the spinal nerve to muscle

tissue (**an effector organ**) and stimulates the muscle to contract. Many reflex reactions involve more than two neurons.

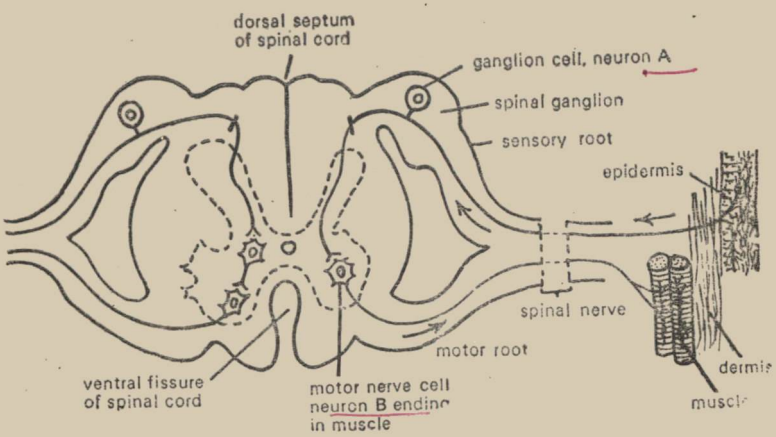


Fig. 9.16 Diagram illustrating a simple reflex arc.

The path followed by an impulse during the reflex action is called ***a* reflex arc.**

The essential parts of a simple **reflex arc** described above are as follows:

Parts of a Simple Reflex Arc :

(1) **A sensory receptor** which may be a naked nerve ending, or a specialized sensory cell.

(2) **A sensory neuron**, whose cell body is located in the dorsal root ganglion of one of the spinal nerves or the corresponding ganglion of one of the sensory cranial nerves.

(3) **A relay centre** located in the central nervous system which may involve one or more **association neurons.**

(4) **A motor neuron**, whose cell body is in the grey matter of the spinal cord or the centres of the origin of the motor cranial nerves.

(5) An **effector organ** which may be a muscle or a gland.

The series of structures involved in the reflex path i.e., sensory receptor, sensory neuron, relay centre, motor neuron and effector organ constitute the *reflex chain.*

Conditioned reflexes are those which are produced as a result of training, experience or repeated performance of the same activity. The conditioned reflexes were first demonstrated by **Pavlov**, the Russian physiologist. The famous experiment of Pavlov was on dogs which were fed a number of times during and shortly after the ringing of a bell. By repeating this process of ringing the bell at the time of giving food to the animal — there developed a *conditioned reflex* amongst them. In such animals, even without food, a secretion of the saliva occured merely upon ringing the bell. The sound of the bell here acted as a conditioned stimulus which resulted in the secretion of saliva. In conditioned reflexes, the activity of the cerebral cortex plays an essential role.

Nervous Tissue:

The chief functional units of the nervous system are the **neurons** i. e., nerve cells. There are however other cells also, called **neuroglia**, which make up as much as half the substance of the nervous tissue. The neuroglia are generally thought of as supporting cells but they also play an important role in the nutrition of the neurons. In all, the nervous system of man comprises some 3000×10^6 cells.

Units of Nervous Function — Neurons:

A neuron may well be defined as a **nerve cell with all its processes.**

A neuron consists of a **cell body** or a **cyton** or **soma** which contains a large nucleus and many mitochondria and other granules (Nissl granules). The striking feature of the neuron is the length of its cytoplasmic processes.

Two types of processes may be distinguished in a neuron. One type of process, known as the **axon (axis cylinder** or nerve fibre process) is long, has few processes and has relatively uniform and narrow diameter. The other type of process known as the **dendrite**

(or the protoplasmic process) is generally short, has numerous branches, with a rough contour, and tapers from a broad diameter where it joins the cyton to slender processes where it terminates.

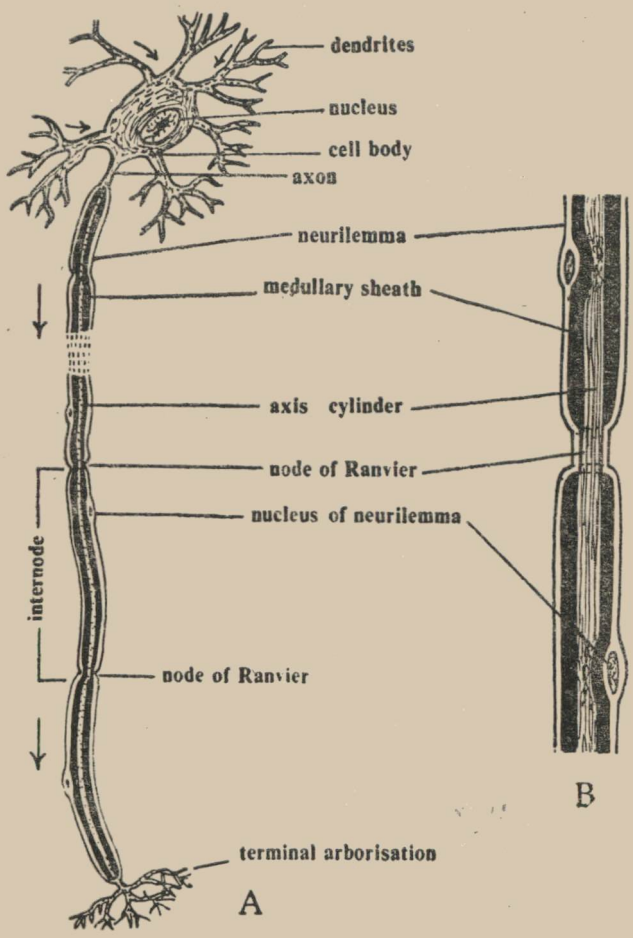


Fig 9.17 (A) Nerve cell. (B) The structure of an axon.

The Synapse: The neurons are associated with each other through the synapse. Synapses as such are the regions where two neurons are functionally connected. At this point, a nerve impulse is transmitted from one neuron to another. The synapses transmit impulses in one direction. The nerve fibre however is capable of

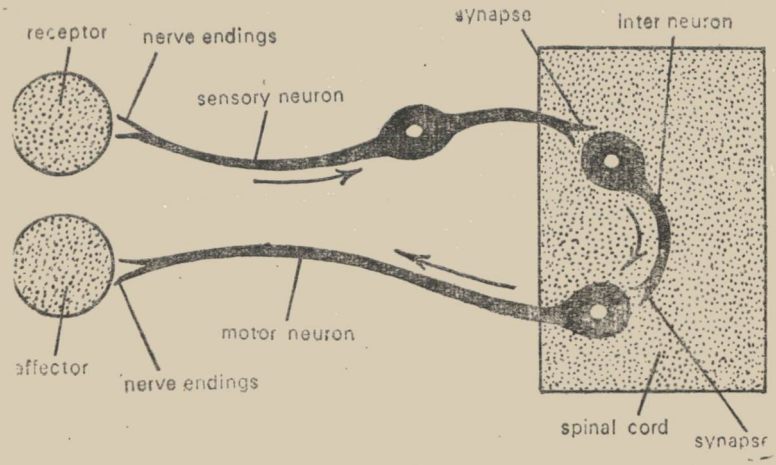


Fig. 9.18 The functional connections of the neurons across the microscopic spaces called the synapses.

conducting a nerve impulse in either direction from a point of stimulus. The synapse is a point at which the terminals of the axon of one neuron come into contact by contiguity with the dendrites or cell body of another neuron. Such association may be effected by basket work of neuro-fibrillar processes from the terminal end of one

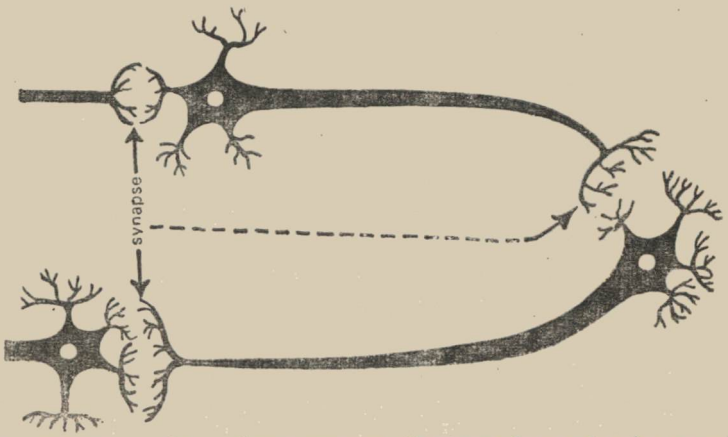


Fig. 9.19 The end to end arrangement of neurons from extensive neural paths. A synapse separates one neuron from the next structurally; but not functionally.

neuron fitting against the dendrites or cyton of the neuron receiving the impulse.

At a synapse, the two cell membranes (of the axon and dendrite or cyton) are usually somewhat thickened, and the gap between the two may be as small as 100 Å and as such it is only visible by means of an electron microscope.

Neuroglia :

The neurons as described are the outstanding components of the nerve tissue. Besides the neurons, other essential elements associated with them are the **neuroglial elements.** These form the interstitial tissue of the nervous system. The **neuroglia** (Gr. *neuron* : nerve; *glia* : glue) forms an important part of the central nervous system, ganglia and the peripheral nerve fibres.

The functions of the neuroglia are as follows :

Neuroglia is an interstitial, proliferative auxillary tissue of the central nervous system. *Ependymal cells* of neuroglia subserve a supporting role at least in the foetal brain and the cord of man. Neuroglial cells react in different ways when the neurons are affected by a pathological process. *Astrocytes* of the neuroglia provide the *blood-brain barrier* that regulate exchanges between the blood and the brain. *Oligodenroglial cells* substitute as sheath cells to the nerve fibres of the brain and the cord. The *microglia* are the macrophages (phagocytic elements) of the nervous system.

The Nerve Fibre (Axon and its Sheath) :

All axons of the peripheral nervous system are covered for most of their course by *cells arranged end to end, forming a sheath known as the* **neurilemma.** The cells of the neurilemma are also known as the **cells of Schwann.** A majority of the axons also have an observable heath of fatty material known as **myelin sheath** located between the superficial surface of the axon and the neurilemma membrane. The **myelin is actually formed by the Schwann cells.**

The axon with its neurilemma is called a **nerve fibre.** Those nerve fibres possessing a myelin sheath are known as the **myelinated**

nerve fibres. In the central nervous system, some fibres appear to be embedded in neuroglia but lack neurilemma and myelin. Such fibres are called **unmyelinated fibres.**

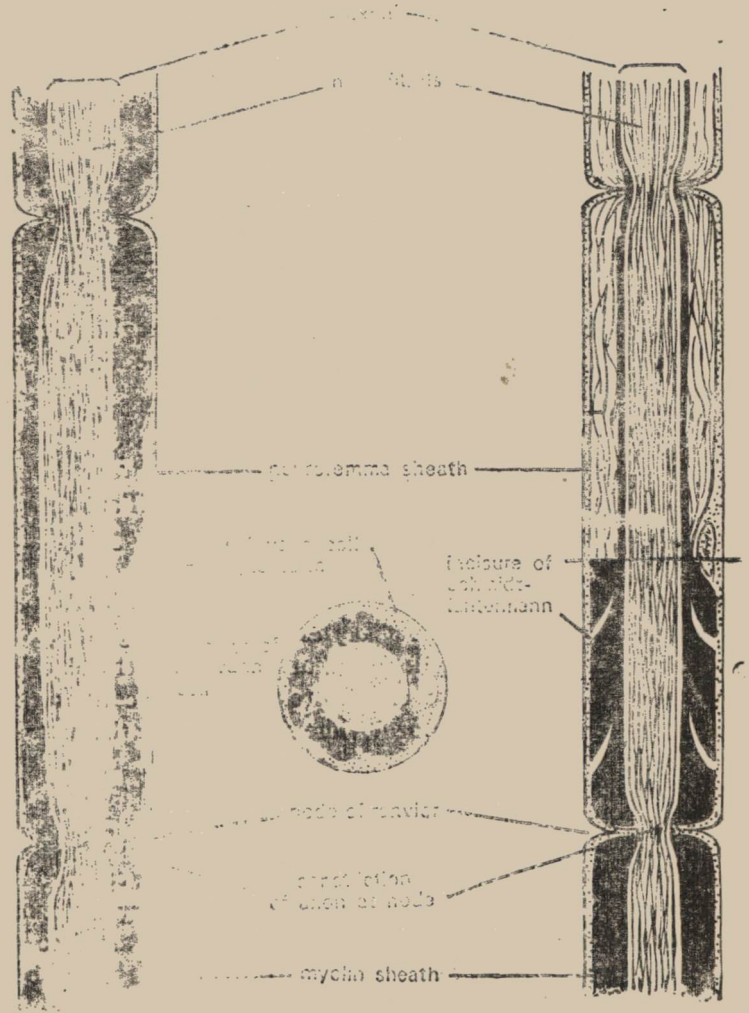


Fig. 9.20 The structure of the myelinated nerve fibres.

Myelinated nerve fibres: The myelinated fibres of the peripheral nervous system are thus composed of (i) an axon, (ii) a myelin sheath and (iii) a neurilemma sheath. The axon consists of neuro fibrils continuous with those of the cell body. These are

embedded in axioplasm which has a superficial covering of its plasma membrane called the axolemma—that is not to be confused with the neurilemma. The neurofibrils of the axons are probably concerned with metabolism or mechanical support of nerve fibres.

The myelin sheath consists of a fatty material called **myelin**. In fresh state, the myelin has a glistening, homogenous, white appearance which gives the name 'white matter' to these parts of the central nervous system having a predominance of myelinated fibres. In fixed condition, the myelin sheath looks brown or black.

The myelin sheath is not continuous but is interrupted at intervals of 80 to 600μ by depressions called the **nodes of Renvier**. At these depressions, the ends of neurilemma cells meet and are in direct contact with the axon. The portion between the two adjacent nodes of Ranvier is called the **internode**. In the middle of each internode, at some place on the internal periphery of the neurilemma is the **nucleus of Schwann** (i.e., neurilemma cell nucleus) surrounded by a small amount of granular protoplasm.

In addition to the above mentioned sheaths which enclose a nerve fibre, it should also be remembered that the fibres of the peripheral nerves, have outside the neurilemma, a connective tissue sheath of mesodermal origin known as the **endoneurium**. This does not however form a part of the nerve fibre proper. The endoneurium is composed of delicate connective tissue fibrils, connective tissue cells and a homogenous inter-fibrillar ground substance. The fibrils are disposed chiefly in a longitudinal direction and are closely adherent to the neurilemma sheath.

The Histology of a Peripheral Nerve :

Each peripheral nerve consists of a great many hundreds of nerve fibres. Each nerve fibre as stated is composed of an axon, myelin and a neurilemma. The single fibre is enclosed further by a connective tissue sheath of mesodermal origin, the **endoneurium**. The nerve fibres are arranged in bundles or **fascicules** of varying size, bound together by loose fibro-elastic connective tissue and the entire nerve is supported by similar tissue.

The connective tissue surrounding all the fascicules is called the **epineurium** or the **external perineurium**. This continues in between

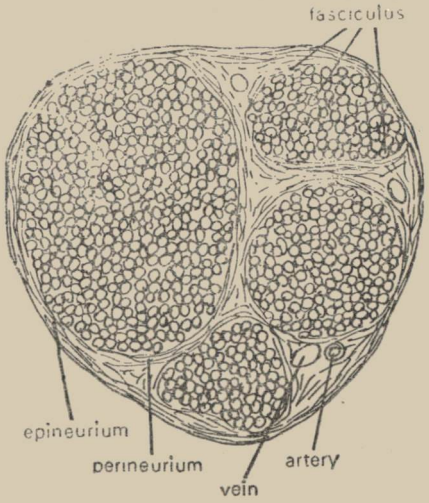


Fig. 9.21 Transverse section passing through a peripheral nerve.

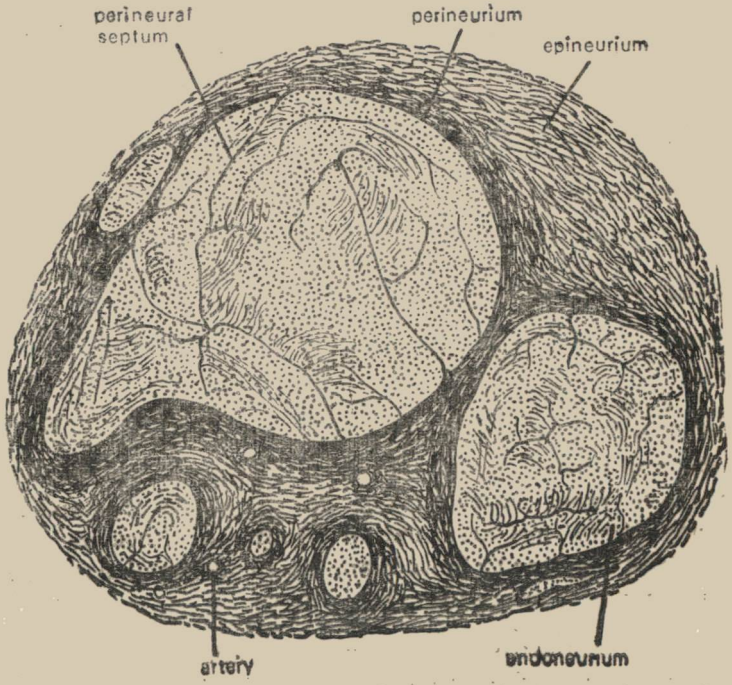


Fig. 9.22 Transverse section passing through the sciatic nerve of a monkey.

the bundles to merge with a connective tissue around each bundle. This part of the connective tissue surrounding each bundle is called the **internal perineurium** or **perineurium.** There is, as stated earlier, a loose delicate extension of the connective tissue which surrounds the single fibres to form the **endoneurium.**

Nerve Ganglia : A ganglion is a small aggregation of neurons (cyton and processes) outside the central nervous system. Each dorsal root of a spinal nerve possesses a **spinal ganglion** or **dorsal root ganglion.** Outside the cord and brain, several sympathetic ganglia of varying sizes and locations are found and have received as such different anatomical names. The connective tissue surrounds the ganglion and penetrates among the fibres and cells. Myelin does not usually surround the sympathetic fibres but a neurilemma sheath is present.

The Nerve Impulse :

A **stimulus** may be defined as an environmental change capable of initiating activity within the living substance of a cell. When a nerve receives a stimulus, a wave of irritability sweeps through the entire neurone and its processes This property is referred to as **conductivity.** The wave of irritability is the *nerve impulse.* The **nerve impulse,** upon reaching the end of a nerve fibre, is capable of initiating through a synapse, an impulse in the adjoining neuron or it can bring about a response in an effector organ, such as a gland or a muscle.

The rates of nerve impulse conduction in certain nerves of man and frog are given below :

In large fibres of sciatic nerve—

in frog	100 – 150 ft. per sec.
in man	280 – 300 ft. per sec.

In thin unmyelinated fibres—

in frog	50 ft. per sec.
in man	3 ft. per sec.

Revision questions

1. Describe in detail the structure of the brain of frog as revealed by its dorsal and ventral aspects.
2. Describe the structure of the spinal cord of frog.
3. Give an account of the distribution of the spinal nerves of frog.
4. Describe the distribution of the cranial nerves of frog.
5. Describe in detail the role of autonomic nervous system in vertebrates.
6. Describe in detail the sympathetic nervous system of frog.
7. What is a reflex action? Give examples. Describe the chief components of a simple reflex arc.
8. Describe the structure of a nerve tissue and also describe neuroglia and its functions?
9. Write notes on the following :
   (a) Choroid plexuses.
   (b) Cerebro-spinal fluid.
   (c) Meninges.
   (d) Synapse.
   (e) The distribution of *V*, *VII*, *IX* and *X* cranial nerves of frog.
   (f) Conditional reflexes.

CHAPTER X

THE FROG–SPECIAL SENSE ORGANS

Special Sense Organs:

Associated with the nervous system are the **special sense organs** through which the animal is able to detect **five special senses.** These are the senses of **touch, smell, taste, sight and hearing.**

The details of these special sense organs of frog are given below.

Organs of touch: The receptors for the sense of touch are lodged in the dermis of the skin which is richly supplied with the sensory nerve fibres. The cells concerned with the sense of touch are in the form of groups of flattened cells called the **tactile cells.** Each group of tactile cells forms a **tactile corpuscle.** These are sensitive to t o u c h . The tactile corpuscles are innervated by the nerve endings of a sensory nerve. These sensory nerves convey the impulses to the central nervous system. The touch corpuscles are even sensitive to chemical stimuli and also to variations in temperature and humidity.

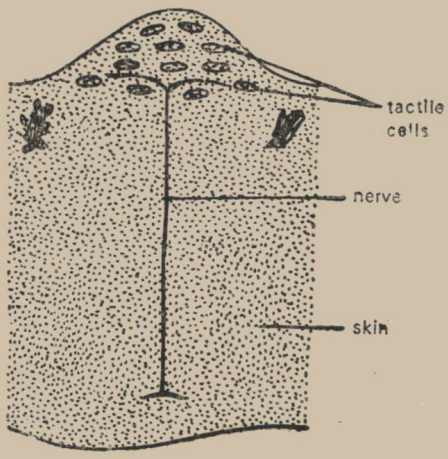


Fig. 10 1 A tactile corpuscle as seen in a vertical section of the skin of frog.

Organs of taste: The receptors for the sense of taste are located in the mucous membrane of the mouth, especially on the tongue and in the vicinity of the vomerine teeth, and can even extend as far back as the gullet. The taste cells are the modified epithelial cells having an elongated form and are arranged in groups to form the taste buds. The taste buds in the tongue are situated on papillae (fungiform papillae) of the mucous membrane. The taste buds are innervated by the fibres of ninth and palatine branch of the seventh

cranial nerve. The taste buds are stimulated by coming in contact with food and the impulse is carried to the brain (through the nerves mentioned) where sensation of taste becomes manifested.

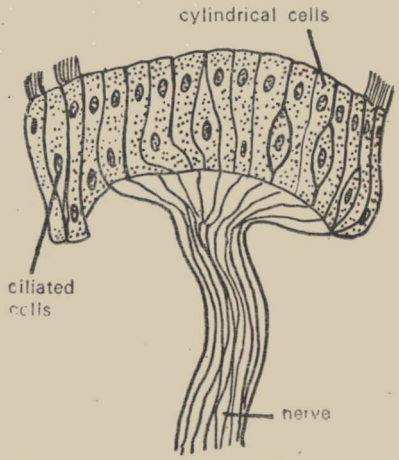


Fig. 10,2 A vertical section passing through a fungiform papilla.

Organs of smell: The receptor cells for the sense of smell are lodged in the **nasal** or **olfactory sacs.** The olfactory sacs are enclosed in the olfactory capsules of the skull and are separated from one another by a partition, the **nasal septum.** Each olfactory sac has two apertures, the **external nostrils** opening on the surface of the snout, and the **internal nostrils** opening into the mouth cavity.

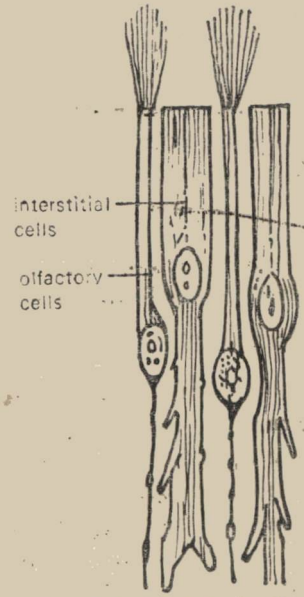


Fig. 10.3 Epithelial cells of the olfactory mucous membrane

The olfactory sacs are lined by a delicate mucous membrane. Some of the cells of this mucous membrane are of the ordinary columnar type, also called **supporting** or **interstitial cells**, while others are extremely slender and are produced into delicate processes at their free ends. These are called the **olfactory cells.** The part of the olfactory cells is swollen where the nucleus is situated. The fibres of the olfactory nerves innervate the olfactory cells. The olfactory cells are affected by the minute particles given off from the odorous bodies. The contact of these particles with the olfactory cells acts as a stimulus, which is transmitted by the olfactory nerves to the brain giving rise thereby to the sense of smell.

Organs of sight: The frog has a pair of eyes, which as already described are more or less globular structures lodged in an orbit of the skull.

The outer exposed part of the eye-ball is clear and transparent while its concealed part i. e., the portion lodged in the orbit is opaque. Each eye ball has three eye-lids which have already been described (See pages 9 and 10).

The structure of the eye can well be understood by it's vertical section.

The wall of the eye-ball is composed of three layers, namely, **sclerotic, choroid** and **retina**.

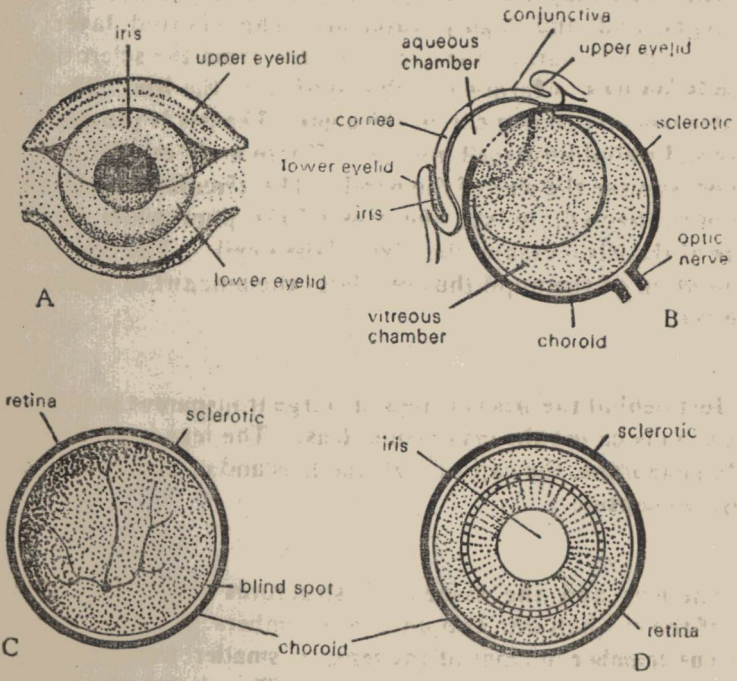


Fig 10 4 The eye of the frog.—(A) Eye as seen in the living animal. (B) Median longitudinal section of the eye passing through the plane of the optic nerve. (C) and (D) The two halves of the eye, bisected equally

The outermost covering of the eye ball is the **sclerotic** It is formed chiefly of connective tissue and cartilage.

The *sclerotic layer* is continued at the exposed part of the eye in the form of transparent layer called the **cornea.** The cornea, in turn, is covered by a thin transparent epithelial layer, the **conjunctiva.** The conjunctiva is continuous with the lining of the eye-lids. The conjunctiva is kept moist by the secretion of a lacrymal gland known as the **Harderian gland**, situated between the eye-ball and the orbit in the antero-ventral region. Any excess secretion of the Harderian gland is carried away into the olfactory chamber by means of a tube, the **naso-lacrymal duct**.

The middle layer of the eye-ball is called the **choroid.** It is darkly pigmented and highly vascular. The choroid layer as it enters the exposed part of the eye separates from the sclerotic layer and bends inwards to form a circular partition, the **iris.** The iris in the centre has an opening called the **pupil.** The iris is provided with circular and radial unstriped muscles. These muscles of the iris can reduce or increase the size of the pupil. The circular muscles of the iris when contracted, reduce the size of the pupil while the radial muscles of the iris increase the size of the pupil. The constriction and dilatation of the pupil thus regulates the amount of light entering the eye.

Just behind the iris is found a large transparent more or less spherical body called the crystalline **lens.** The lens is enclosed in a delicate membrane, the capsule of the lens and is also held in position by this capsule.

The lens and the associated structures divide the internal cavity of the eye-ball into two unequal chambers. An outer chamber or **aqueous chamber** in front of the lens, is smaller and is filled with a clear watery fluid, the **aqueous humour.** The chamber behind the lens called the **vitreous chamber** is large and is filled with a gelatinous substance known as the **vitreous humour.**

The innermost layer of the eye-ball is the **retina** which lines the vitreous chamber. It is the most sensitive part of the eye. The retina is easily detachable from the choroid. At one place however, where the optic nerve enters the eye. the retina becomes continuous with the fibres of the optic nerve, which pass through the sclerotic and choroid. The inner part of the eyes where the optic nerve fibres are found distributed is called the **blind spot**. The retina is the only part of the eye sensitive to light except at the blind spot.

A vertical section passing through the retina reveals its very complex structure under the microscope.

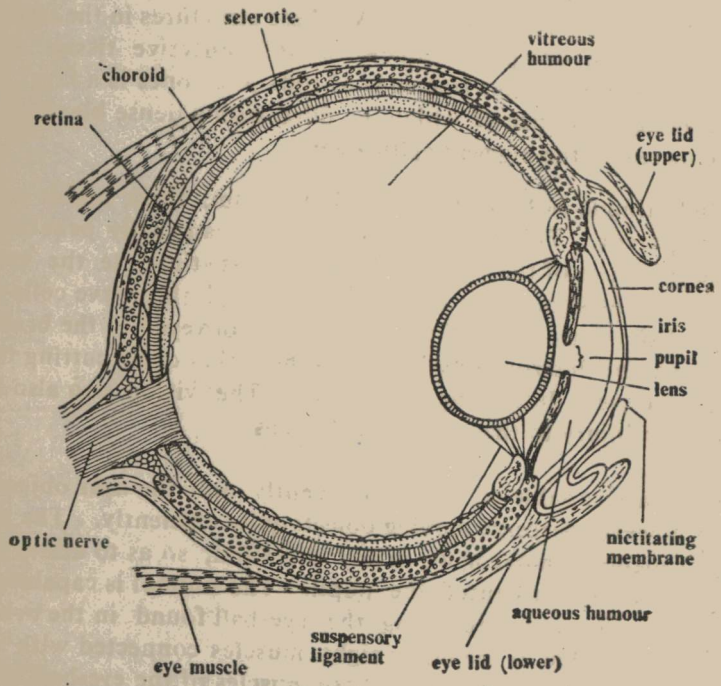


Fig. 10.5 Vertical section passing through the eye ball of frog revealing its internal structure.

The inner surface of the retina is covered with the nerve fibres which converge at the back of the eye-ball and form the optic nerve.

Next to the nerve fibres can be seen a layer of nerve cells and then the layers of fibres and nuclei. Finally, the outer part of the retina is formed by a layer of light sensitive cells. These cells according to their form and shape are referred to as **rods** and **cones.** The rods are capable of perceiving the twilight vision. The cones on the other hand are associated with daylight vision. The cones are said to contain a pigment iodopsin or visual violet. The ability of an animal to differentiate between light of various wave lengths is called **colour vision.** Bees. butter flies, teleosts, reptiles, birds and mammals are able to discriminate colour.

The rods and cones as their development reveals are the modifications of the epithelial cells. All these structures in the retina are supported by a complex framework of connective tissue. In close contact with the outer free ends of rods and cones is a layer of cells, the living substance of which is filled with a dense black pigment. It is called the **pigment epithelium.**

The retina is not much more than $\frac{1}{4}$ mm. thick and is perfectly transparent. The rays of light as such can easily penetrate the whole thickness of the retina. The rays thus stimulate the **rods** and **cones** and the stimulus is transmitted through the nerve cells to the fibres of the optic nerve, from where it is conveyed to the brain. The sight may be destroyed by injury to the retina or by cutting the optic nerve or even destroying the brain. The vision can also be affected by an injury to the cornea or the lens.

Frogs are capable of seeing efficiently only the near objects. They can however perceive moving objects quite efficiently. The eye of frog is capable of movement, in any direction, so as to allow the light from any object to enter the pupil. The animal is capable of rotating, elevating and depressing the eye-ball found in the orbit. This is made possible by means of eight muscles connected with the eye-ball in the orbit. The role of these muscles of the eye-ball is as follows:

The *levator bulbi* muscle raises the whole eye, causing it to project farther on the surface of the head. The *retractor bulbi* withdraws the eye-ball due to which it bulges into the mouth cavity. Four other muscles i. e., the superior, inferior, anterior (internal)

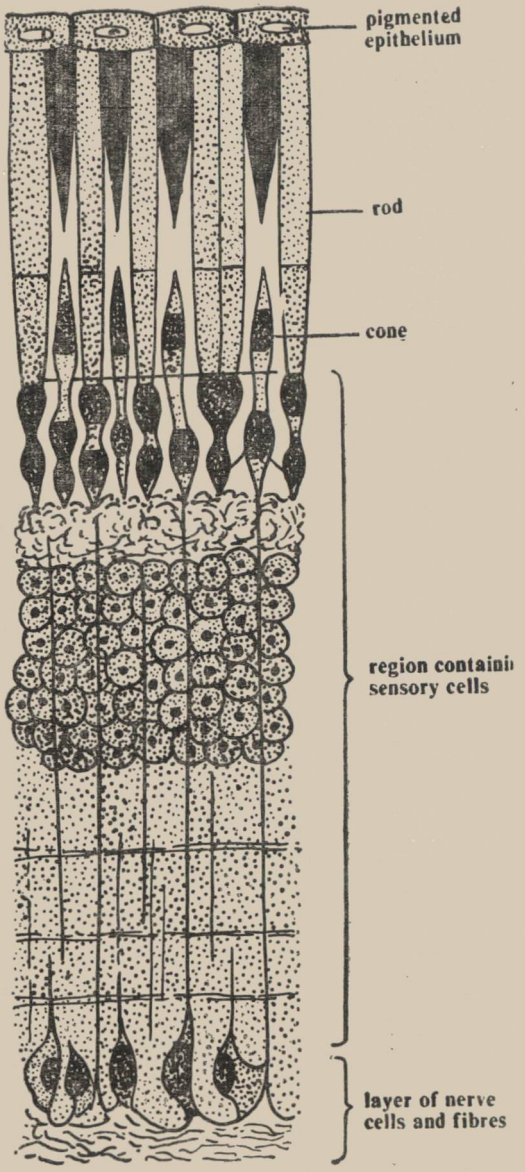


Fig. 10.6 Vertical section passing through the frog's retina.

and posterior (external) recti, rotate the eye-ball respectively, upwards, downwards, forwards and backwards. Two other eye-ball muscles, i.e., the superior and inferior oblique muscles produce a rotation along an axis joining the optic nerve with the middle of the cornea (See Fig. 9.8).

The entire eye as such works more or less like a photographic camera. The cornea, aqueous humour, lens and the vitreous humour are a series of transparent media arranged in such a fashion that the rays of light from an external object are refracted and brought to a focus on the **retina** where they form a greatly diminished and inverted image of the object. The **iris** as mentioned is provided with muscles which by their action can enlarge or diminish the size of the **pupil**. The iris, therefore, acts like a diaphragm which regulates the amount of light entering the eye. Attached to the capsule of the lens are delicate muscles by means of which the lens can be shifted to some extent towards the cornea. The focus of the entire apparatus can thus be altered according to whether the object in view is nearer or farther from the eye. This arrangement for accommodation is however poorly developed in frog.

The various parts of the eye as such are so adjusted that they bring the images of the external objects at various distances to an accurate focus on the back part of the interior of the eye-ball, i.e., on the retina.

Organs of hearing and equilibrium : The organs of hearing and equilibrium are a pair of ears. Each ear is composed of two parts—the **middle ear** and the **internal ear.**

The middle ear : The middle ear receives the sound waves and transmits them to the internal ear. The middle ear is bounded externally by a circular tightly stretched **tympanic membrane** or the **tympanum** or **ear-drum.** The tympanic membrane in the form of a circular area can be seen externally behind each eye. Inside the tympanic membrane lies the cavity of the middle ear called the **tympanic cavity** or **chamber.** Attached to the inner surface of the tympanic membrane is a rod of bone, **columella** which extends through the tympanic cavity. The other end of the columella is attached to a small nodule of cartilage called the **stapedial plate** or

stapes. The stapes lies over an **oval aperture** called the **fenestra ovalis.** The oval aperture is found in the wall of the auditory capsule or ear capsule in which lies the internal ear.

The tympanic cavity, communicates ventrally with the buccal cavity through a passage called the **eustachian tube.** The eustachian tube maintains equal pressures on both the sides of the tympanum.

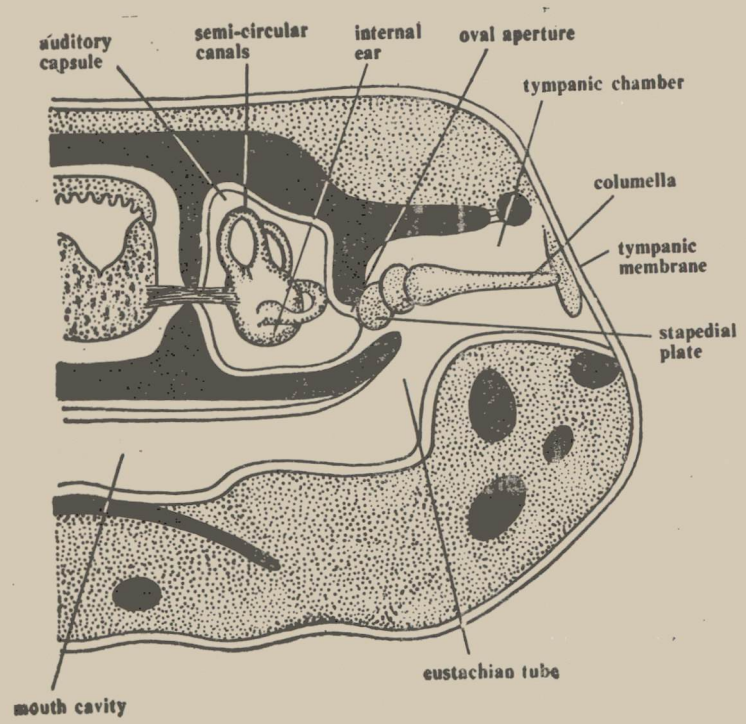


Fig. 10.7 Transverse section passing through the head at the level of the tympanic membrane. Only one half of the section is revealed.

The internal ear of frog, like other vertebrates lies within the auditory capsule of the skull. It is in the form of a kind of bag of a very peculiar and complicated form. It is also known as the **membranous labyrinth.** It is made up of two somewhat ovoid sacs separated by a constriction. The dorsal sac is called the **utriculus** and the ventral one the **sacculus.** A small out-growth in the form of three swellings, arises from the sacculus and projects backwards.

This outgrowth is called the **cochlea** (lagena). With the utriculus are connected three tubes which on the basis of their form are referred to as **semi-circular canals.** These three semi-circular canals lie at right angles to each other. Two of the semi-circular canals according to their position are referred to as the **anterior** and **posterior vertical semi-circular canals** (i. e., *canalis ant.* and *canalis posterior*) respectively. The third semi-circular canal lies horizontally and is as such referred to as the **horizontal semi-circular canal** (*canalis horizontalis*). The anterior and posterior vertical canals are united

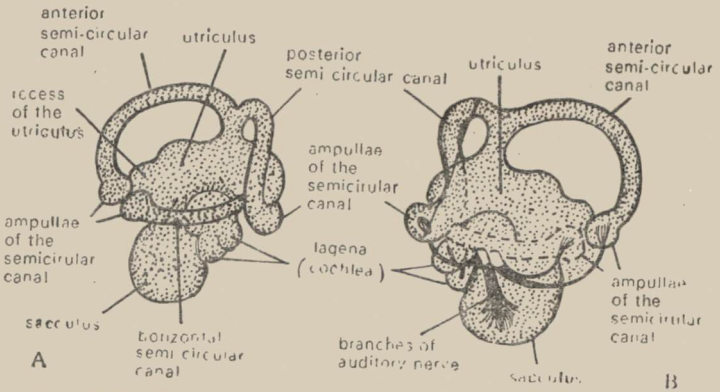


Fig. 10.8 The internal ear or membranous labyrinth of frog. (A) Outer and (B) Inner views.

to one another at their adjacent ends. Further, each canal has one end dilated into a bulb-like swelling called **ampulla.** The ampullae of the anterior vertical semi-circular canal and the horizontal semi-circular canal are at their anterior ends. The ampulla of the posterior vertical semi-circular canal is at its posterior end.

The entire membranous labyrinth is filled up with a fluid called the **endolymph.** In this fluid are to be seen floating, many minute calcareous particles called the **otoliths.** The membranous labyrinth does not fit tightly into the cavity of the auditory capsule in which it is found. The space in the auditory capsule left between the membranous labyrinth and the surrounding bone and cartilage of the auditory capsule is filled by loose connective tissue and a fluid called the **perilymph.** The perilymph surrounding the membranous labyrinth protects it from shocks.

As regards the internal structure of the membranous labyrinth, it should be noted that each semi-circular canal is lined by cubical epithelium. There are found in the membranous labyrinth a number of **acoustic spots.** The acoustic spots consist of greatly elongated cubical cells which bear at their free ends sensory processes called **the auditory hairs.**

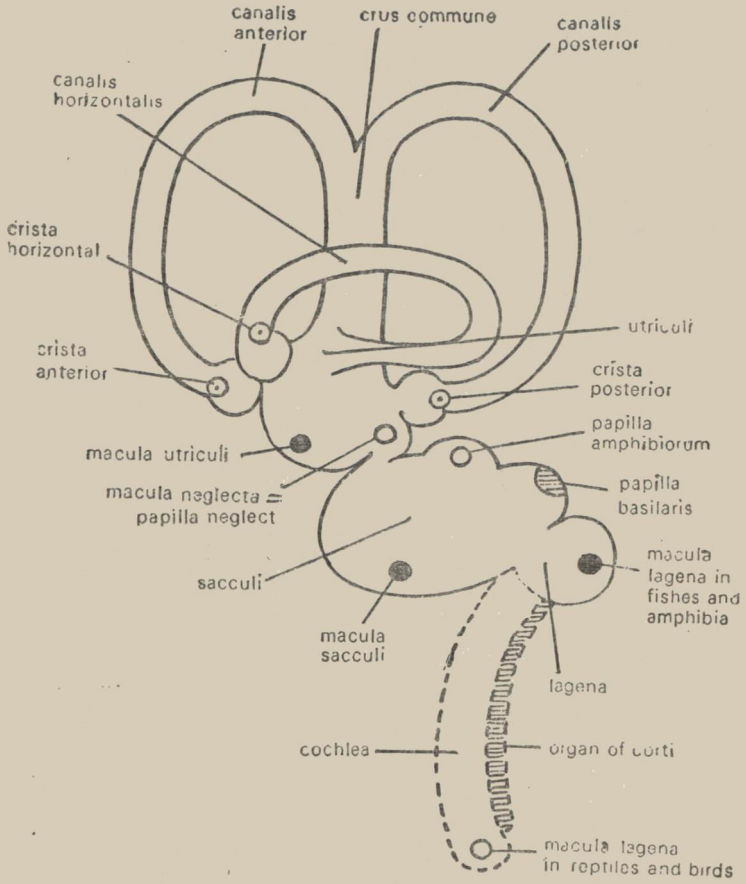


Fig. 10.9 The membranous labyrinth representing structures found in all vertebrates. (Diagrammatic).

A few of such acoustic spots or sensory endings are as follows:

In each ampulla is located a sense ending called the **crista ampullaris**[1]. An axillary jelly-like structure is attached to the crista called the **cupula**. The cupula encloses sense hairs which protrude from the surface of the crista.

There is also found a sense ending called the **macula** in the utriculus and the sacculus. The sense cells which constitute the maculae are similar to those of the cristae with one exception, that the sense hairs are shorter. The sense hairs are embedded in an otolith membrane covering the macula. These membranes are always encrusted with lime, which is found either in the form of solid stones called **otoliths** or in the form of concretions of lime, called **otoconia**. In frog, however otoliths are found. The cochlea is really a small process called the **papilla basilaris**. In the utriculus, there is a sense ending in the form of papilla called **papilla neglecta**. This is however absent in the ear of frog but there is found in the sacculus a sense ending known as **papilla amphibiorum**.

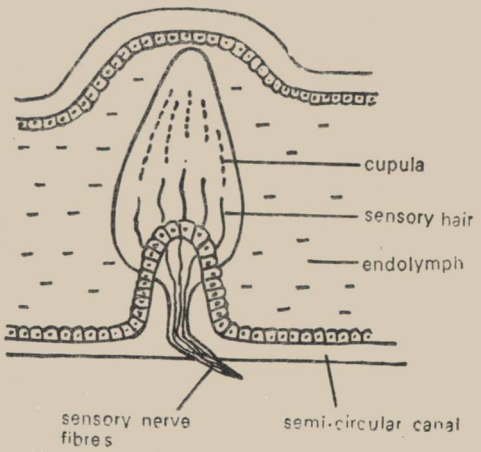


Fig. 10 10 Section of an ampulla.

The membranous labyrinth serves the double function of **hearing** and **equilibrium**. The sound waves strike the tympanic membrane. The vibrations of these sound waves striking the tympanic membrane are transmitted by the columella to the stapedial plate and so to the perilymph. From the perilymph, they are

1. Cristae ampullaris found in each ampulla of the respective semicircular canals are referred to as (1) Crista ant. (2) Crista post. and (3) Crista horizontalis as shown in Fig 10.9.

transmitted to the endolymph contained in the membranous labyrinth. These vibrations after reaching the endolymph act as stimuli to the sensory cells of the acoustic spots and then the impulses are carried by the nerve fibres of the auditory nerve to the brain. This gives rise eventually to the sensation of sound. The sense of sound can however be destroyed by an injury to the membranous labyrinth, by cutting the auditory nerve, by destroying the brain or also to a great extent by a damage to the tympanic membrane or the columella.

The semi-circular canals of the internal ear are particularly concerned with the maintenance of the equilibrium of the body both during rest and movement. The change in the position of the body causes the otoliths to press upon the sensory hairs of the acoustic spots found in the internal ear. The impulses thus set in from the sensory hairs are communicated to the brain and the animal can readjust to a normal position. The fluid in the semi-circular canals directly stimulates the sensory hairs. In addition to the maintenance of balance, the semi-circular canals are also responsible for the sense of direction and velocity of movement.

Revision questions

1. What are special sense organs? Mention in brief the special sense organs of frog concerned with the senses of touch, smell and taste.
2. Describe in detail the structure of the eye of frog.
3. Give a detailed account of the ear of frog. State in what way it serves the two important functions of hearing and the maintenance of the equilibrium of the body.
4. Write notes on the following:
   (a) Blind spot
   (b) Acoustic spots
   (c) Otoliths
   (d) Membranous labyrinth
   (e) Harderian gland

CHAPTER XI

THE FROG – ENDOCRINE GLANDS

We have learnt in the previous chapters that the coordination of the activities of the various organs of the body of animals may either be brought about through nervous impulses transmitted along the nerve tissue or by certain chemical substances set free in circulation. These chemical substances are secreted by the **endocrine glands**[1]. The secretions of the endocrine glands are called the **hormones**[2]. The endocrine glands differ from the exocrine glands in

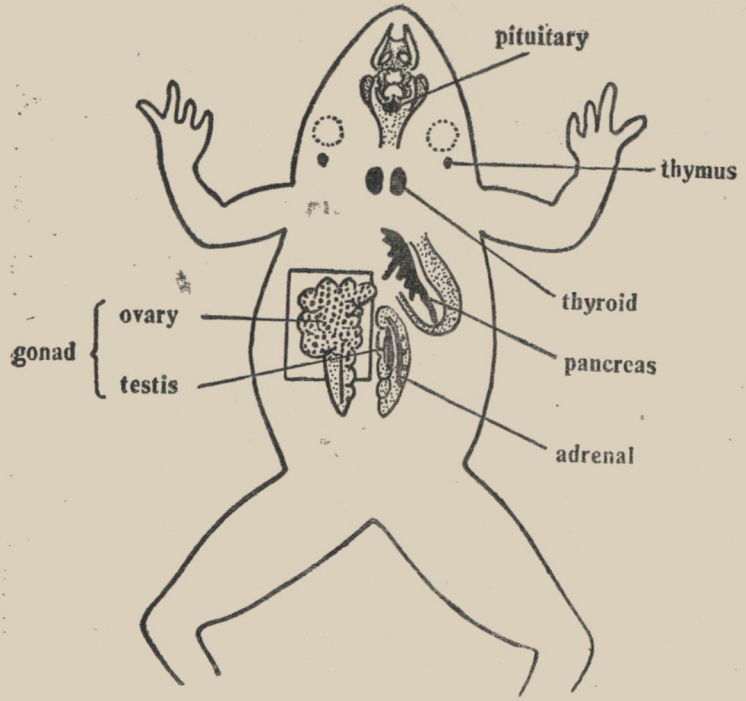


Fig. 11.1 The diagrammatic representation of the location of endocrine glands of frog.

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1. The word is derived from the Greek meaning 'inside separation.'

2. The word hormone from Greek means 'Excite' was first used by the famous English physiologist, E. H. Starling in 1905, while referring to the newly discovered 'secretin.'

the absence of ducts. They are as such referred to as the **ductless glands.**

The endocrine or ductless glands are the **glands of internal secretions,** which regulate and coordinate the functions of the different organs of the body. The hormones directly secreted in the blood are carried through the circulatory system to the distant regions of the body where they stimulate various physiological processes.

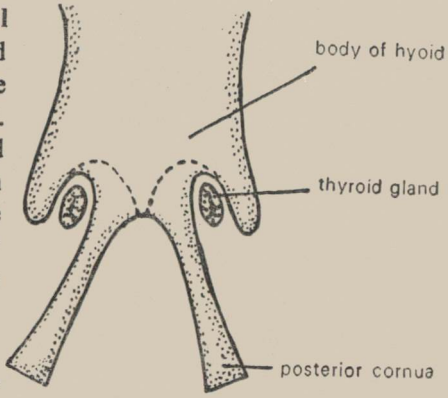


Fig 11.2 Diagram illustrating the position of the thyroid glands of frog.

The role, functions and the structure of the various types of endocrine glands found in the body of frog will now be discussed.

The Endocrine Glands of Frog :

The endocrine glands found in the body of frog are as follows :

The thyroid glands : The thyroid glands are paired structures in an adult frog. Each thyroid gland lies one on either side of the hyoid apparatus just posterior to it's postero-lateral processes. The hormone secreted by the thyroid glands is called *thyroxine* which contains large amounts of iodine. The thyroxine stimulates metamorphosis in frogs.

Parathyroids develop as epithelial growths from the ventral portion of the third and fourth visceral slits. It is suggested that just like in mammals, the parathyroids in amphibia as well, produce hormones which play an important part in calcium metabolism especially by controlling the concentration of calcium salts in blood.

The thymus glands in adult frogs are paired. Each thymus, beneath the skin, lies behind the tympanic membrane, partly covered

by muscles. The functions of the thymus have not been clearly defined. Thymus feeding has had a variable effect both on pigmentation and growth of tadpoles. The thymus gland however is proportionately larger during the larval than adult life. In amphibia, the thymus functions in producing lymphocytes, granulocytes and also erythrocytes to a certain extent. The specific effects of thymus are however not established in amphibia.

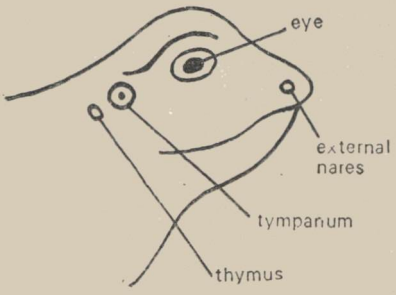


Fig. 11.3 Diagram indicating the position of the thymus in frog.

Pineal organ: The pineal arises in the embryos of both frogs and salamanders, as a diverticulum of the thalamus which extends towards the integument of the fore-head. Here it is indicated by a pigmentless, transluscent spot. The tip of the pineal enlarges to produce a vesicle which in Ambystoma may assume the form of a rudimentary retina. Sense cells appear in the pineal organs of many amphibia and there are also ganglion and supporting cells. The pineal organ is believed to represent a median eye which was probably functional in the ancestors of modern amphibia.

The specific functions, of the secretions of the pineal, are not clearly understood in amphibia. **McCord** and **Allen** (1921), found that feeding of pineal caused a temporary contraction of the melanophores of *Rana pipiens* and the skin became lighter in colour. The pineal body produces a substances called *metatonin* which when injected into the body of amphibia as mentioned, causes the skin to become lighter in colour. **Schulze** and **Holldobler** (1926), have observed that implantation of pieces of beef pineal in tadpoles causes an acceleration of body growth and further, **Addair and Chidester** (1928), report that feeding desiccated pineal organ, would hasten metamorphosis. Further investigation is required before any specific function can be assigned to the pineal gland of the amphibia.

Adrenal organ : In Salientia, the adrenal glands are paired. Each adrenal gland forms an irregular strip of yellow tissue attached to the ventral surface of each kidney, usually near the middle line and closely associated with the renal veins. It is formed of two kinds of tissues of different origin and function. **The inter-renal**

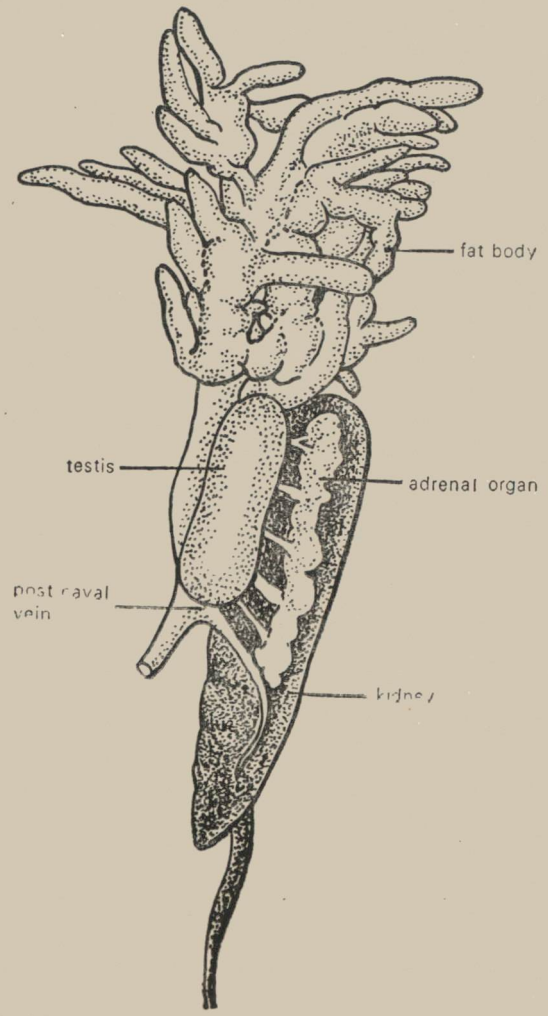


Fig. 11.4 The left kidney of *Rana cotesbiana*, viewed from the ventral side showing the left adrenal gland and the associated structures.

tissue of the organ consists of fatty inclusions having yellow colour. The second is the **chromaffin tissue** with cells containing granules. The inter-renal tissue is more abundant than the chromaffin tissue in amphibia. In mammals, the inter-renal tissue forms the *adrenal cortex* and the chromaffin tissue, the *adrenal medulla.*

The function of the inter-renal tissue in amphibia is obscure but in mammals its secretions influence the growth of the gonads. The chromaffin tissue releases a hormone, *adrenalin.* In amphibia, as in mammals adrenalin affects those organs innervated by the sympathetic neurons and stimulates them in the same way. The adrenalin, in amphibia may have an influence on the normal metabolism, by increasing the amount of glucose in the blood by stimulating the liver to discharge. Adrenalin thus increases the amount of sugar in the blood, while insulin decreases it. The release of adrenalin may also have some effect on pigmentation, for in some species injection of adrenalin causes a contraction of the melanophores. Injection of adrenalin into frogs induces a contraction of the skin melanophores and rise in blood pressure due to the constriction of the arterioles. Feeding of adrenal tissue to tadpoles increases their growth rate but has no effect on metamorphosis.

The pituitary gland: The pituitary gland of amphibia arises from a solid ingrowth of ectoderm between the fore-brain and the fore-gut forming thereby the *hypophysial ingrowth.* It later becomes applied to the *infundibulum*, a ventral diverticulum of the thalamus.

The hypophysial ingrowth of the pituitary distinguishes into three different parts, namely **pars anterior**, **pars intermedia** and **pars tuberalis**. The infundibulum is sometimes described as the **pars posterior** or **pars nervosa** of the pituitary.

The various hormones secreted by different parts of the pituitary along with their effects are described below :

Pars anterior secretes a hormone which stimulates growth. Removal of this part from the tadpoles results in a considerable retardation of their growth. **Gigantism** has been produced in tiger salamanders by feeding the anterior lobe substance. The anterior

lobe of the pituitary exerts a remarkable control over metamorphosis, as the hormones of this lobe influence the growth and development of the thyroid gland. The pars anterior besides influencing the body growth and metamosphosis of the amphibian larvae also has a specific effect on the growth and liberation of the sex products of the adults. The pars anterior thus produces the gonad stimulating hormone as well.

Pars intermedia of an amphibian pituitary exerts an important control over the pigmentation. The hormone produced by this lobe induces both an expansion of the melanophores and a constriction of the lipophores and possibly of the guanophores. The pigment cells no doubt are under the nervous control and may respond directly to light. The pituitary hormone from pars intermedia nevertheless, plays the main role of colour-tone regulator in some species of salientia.

Pars posterior secretes more than one hormone. It has an important influence on the water equilibrium of both the larva and the adult. The implantation of the posterior lobe in adult frogs causes a contraction of the body walls lasting several days. **Spaul** (1930), reported that extracts of the posterior lobe inhibit metamorphosis.

It can be said in brief that all parts of the pituitary have functions of great importance in the life of the amphibia.

Pancreas as stated earlier is a dual organ with its exocrine and endocrine portions. Its endocrine parts is the **'islets of Langerhans.'** The role of the islets of langernans in amphibia is already discussed on pages 131 to 133.

Gonads or sex organs: Gonads i.e., the testes and the ovaries are primarily the organs of reproduction. They also, however, release certain hormones into the blood stream which have an important role in stimulating the growth and maintaining the development of *secondary sexual characters*. In the secondary sexual characters of amphibia one can mention the familiar *nuptial pads* of male frogs, the broad *tail crests* of male newts etc.

The removal of *testes* from the male newts results in a rapid loss of secondary sexual characters. It seems to be established, that the testis induces and maintains the secondary sexual characters of

the male. The source of testicular hormone in amphibia is found in the sperm or in the sertoli cells (cf. structure of testis).

The *ovary*, in frogs, apparently controls the growth of skin papillae and also influences the development of the oviducts. As already mentioned, it should be remembered that the growth and liberation of the sex products is under the control of a hormone from the pars anterior of the pituitary.

The Mucous Membrane of the Stomach :

The first products of gastric digestion stimulate the cells of the lining epithelium of the stomach to produce a hormone **gastrin**— which after circulation in the blood stream again reaches the stomach and stimulates a flow of digestive juice.

The Mucous Membrane of the Small Intestines :

The mucous membrane of the small intestine also secretes various hormones e. g., **secretin** stimulates the pancreas via the blood stream and evokes a copious secretion of the pancreatic juice. The acid contents of the stomach coming into contact with the intestinal mucosa, act as a stimulus, for the release of **secretin. Cholecystokinin** is the hormone which brings about the emptying of the gall bladder. **Pancreozymin** is a hormone responsible for the liberation of digestive enzymes into pancreatic juice.

The Endocrine Glands of Mammals and other Vertebrates :

The principal endocrine glands of mammals and other vertebrates are given in the following pages in the form of a table, along with the hormones secreted, and their effects.

Endocrine Glands and Hormones

GLAND	HORMONE	EFFECTS
Pituitary gland		
Posterior lobe	Synthesizes no hormones. These hormones actually originate in **hypothalamus** which are as follows.	
	1. Oxytocin.....	Ejection of milk from the mammary glands. Contraction of uterine muscle, parturition.
	2. Vasopressin.....	Conservation of water and reduction of urine secretion.
The intermediate lobe	(MSH) Melanophore - stimulating hormone (Intermedin)	Dispersion of melanophores; darkening of skin in fish, amphibians and some reptiles. Synthesis of melanin in all vertebrates.
Anterior lobe	1. Thyroid stimulating hormone, (Thyrotrophin TSH)	Synthesis and secretion of thyroid hormones. Growth of thyroid gland.
	2. Adrenocorticotrophic hormon (ACTH, corticotrophin)	Synthesis and secretion of adrenal cortex hormones; growth of adrenal cortex.
	3. Follicle stimulating hormone (FSH)	In females, growth of ovarian follicles.
	4. Luteinizing hormone (LH; interstitial cell—stimulating hormone)	In females secretion of oestrogens and progesterone. Ovulation, formation and function of corpus luteum.

GLAND	HORMONE	EFFECTS
	5. Prolactin (Luteotrophic hormone, LTH; Lactogenic hormone).	Mammals: milk synthesis and secretion; corpus luteum function in rodents.
	6. Somatotrophic hormone (STH; growth hormone).	Synthesis of protein. Growth particularly of bones of extremites and skull.
Adrenal glands Adrenal cortex	1. Glucocorticoids (Predominately cortisol and corticosterone).	Breakdown of proteins; glucose and glycogen synthesis. Stress adaptations; anti-inflammatory and anti-allergic effects.
	2. Mineralocorticoids (Predominately aldosterone)	Retention of sodium in kidney. Normal sodium and potassium ratios in extra cellular and intra-cellular fluids.
	3. Androgens.	
Adrenal medulla	1. Adrenalin (Epinephrine)	Rate and force of heart beat. Constriction of small arteries of the skin and viscera dilation of small cardiac arteries and skeletal muscles, rise in the blood glucose. Stimulation of oxidative metabolism.
	2. Noradrenalin (Norepinephrine)	General constriction of small arteries; rise of blood pressure.
Thyroid	Thyroxine, Triiodothyroxine	Growth and development of nervous tissue. Amphibian metamosphosis. Consumption of oxygen and heat production in birds and mammals only.
Pancreas (Islets of Langerhans)	1. Insulin.....	Lowering of blood glucose; glucose utilisation and synthesis of fats and proteins.

GLAND	HORMONE	EFFECTS
	2 Glucagon.....	Elevation of blood glucose; promotion of glucose secretion by liver.
Parathyroid	1. Parathyroid hormone (PTH)	Serum calcium elevation and lowering of serum phosphate.
	2. Calcitonin.	Lowering of serum calcium
Ovary (a) *Graafian follicle*	1. Oestrogens (i. e., oestradiol also oestrone and oestriol).	Female sex characteristics.
	2. Progesterone	Inhibition of ovulation and gestation.
	3. Relaxin.	Relaxation of cervix of the uterus and ligaments of pelvis during child birth.
(b) *Corpus Luteum.*	Progesterone and oestrogens	
Placenta	1 Oestrogens	
	2. Progesterone	
	3 Relaxin..	Relaxation of pelvic ligaments; and enlargement of birth canal.
	4 Chorionic gonadotrophin and possibly others.	Similar in effect to lutenizing hormone.
Testis	1. Androgens e g., Testosterone	Male sexual characteristics.
Pineal body	Adrenoglomerulotrophin (Tentative conclusion)	Regulates aldosterone secretion by zona glomerulosa of adrenal cortex.

GLAND	HORMONE	EFFECTS
Kidney	Renin	Converts blood protein, angiotensinogen to angiostensin. The angiotensin stimulates aldosterone secretion and elevates blood pressure.
Mucous membrane of stomach	Gastrin	Secretion of gastric juice.
Mucous membrane of small intestine. (Duodenum and jejunum).	1. Secretin.....	Secretion of pancreatic juice.
	2. Cholecystokinin..	Emptying of gall bladder.
	3. Pancreozymin.....	Release of digestive enzymes into pancreatic juice.

For the sake of information, the location of the principal endocrine glands in man are shown below diagarmmatically.

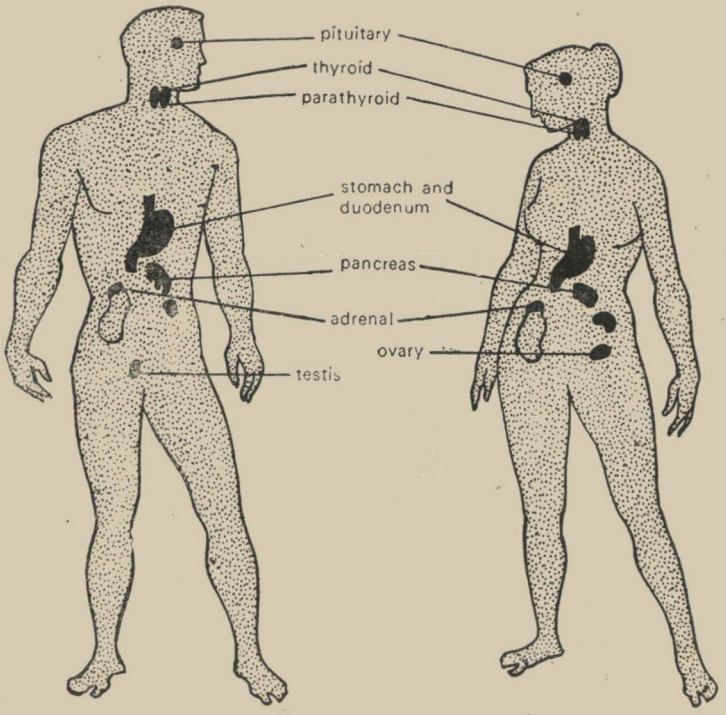


Fig. 11.5 Diagrammatic representation of endocrine glands in human body.

Further, the disorders due to the dysfunctioning of the endocrine glands in man are illustrated with suitable diagrams along with a legend pertaining to the disorder in each case.

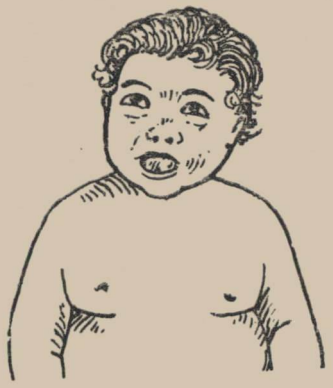


Fig. 11.6 A case of **infantile cretinism** due to imperfect development or early atrophy of the **thyroid** Characterised by dwarfism, sub-normal body activities, thickened skin and retardation in mental development and sexual maturation.



Fig. 11.7 *Myxoedema* : The hypofunctioning of the thyroid in adults leads to **myxoedema** (accumulation of mucous containing fluid in skin). It is a condition characterised by a subnormal metabolic rate, retarded nervous activity, coarsened and rounded features and thickened nostrils, roughened skin and loss of hair. Lethargy and obesity are common features. The figure on the right depicts a case before treatment. Left side the same after treatment with thyroid extract.



Fig. 11 8 Exophthalmic goitre. The protrusion of the eye-balls and staring eyes. A case of hyperthyroidism.

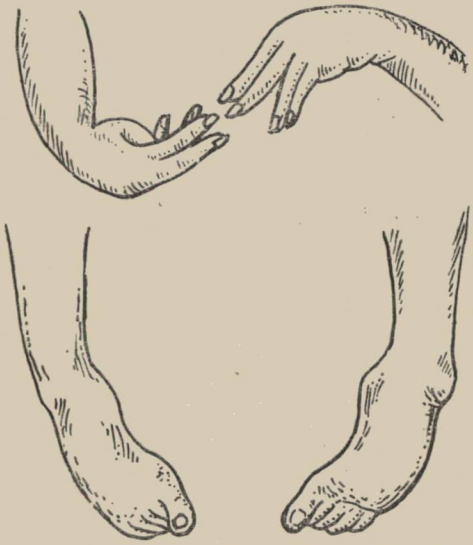


Fig. 11.9 The diagrams representing the positions of hands and feet in tetany. This occurs due to hyposecretion of parathyroid hormone, resulting in a rapid fall in the concentration of calcium in blood, characterised by intermittent tonic muscle spasms, muscle cramps and hyper irritability of both the central and the peripheral nervous systems.

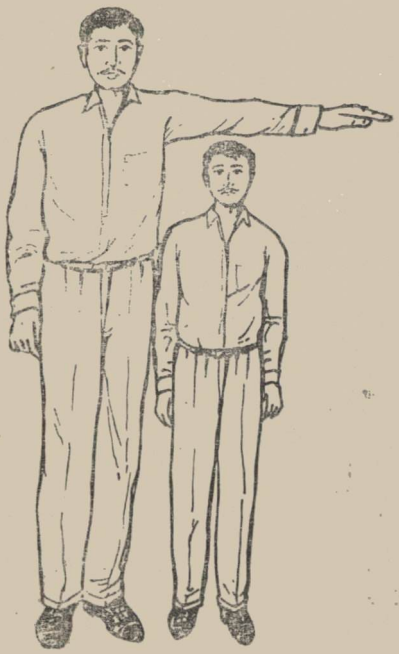


Fig. 11.10 An example of gigantism due to excessive secretion of the growth stimulating hormone from the anterior lobe of the pituitary. Left side : A person with an extraordinary height. Right side : A tall person within normal limits of height.



Fig. 11.11 A case of **acromegaly**. (A) Front or facial view of a person suffering from **acromegaly**. (B) Side view of a man suffering from acromegaly. In adults the hypersecretion of the anterior pituitary growth stimulating hormone leads to acromegaly. (Gk. *acron* : extremity, *megas* : large).



Fig. 11.12 In women the changes which come with pub rty are controlled by oestrogens produced in the ovaries.



Fig. 11.13 The secondary sex characteristics of a man, his broad shoulders, deep voice, beard and chest hair—are all produced by androgens secreted in the testes.

Revision questions

1. What is an endocrine gland? Describe in brief the endocrine system of frog.

2. Give an account of the structure and functions of the thyroid gland of frog.

CHAPTER XII

THE FROG - URINOGENITAL SYSTEM

The *urinogenital system* includes the *urinary* or *excretory organs* concerned with excretion and the genital organs or *reproductive organs* belonging to the reproductive system. Each system is concerned with the different activity of the animal and during development arises separately. In an adult animal, however, the two systems become intimately related, that is why these two systems are studied together under the common heading the **Urinogenital System** In the case of an adult female the two sets of organs are separate and so present a some-what simpler condition than the male.

The excretory system of frog will first be described.

The Excretory System of Frog :

The paired *kidneys* and other associated structures namely a pair of **ureters**, a **urinary bladder** and the **cloaca**, constitute the main parts of the urinary system or the *excretory system* of frog.

The kidneys : The kidneys of frog are paired structures. They are dark red, some-what ovoid, elongated and flattened structures. They are located just beneath the vertebral column, one on each side of the dorsal aorta in the abdominal cavity. The internal margins of the kidneys (i.e., the margins towards the dorsal aorta) are irregularly lobulated. As the kidneys are flat, they do not project into the coelem but lie in the **sub vertebral lymph space** or **sinus** (See Fig. 2.7), covered over by the peritoneum, only on their ventral surface. On the ventral surface of each kidney there is an irregular patch in the form of a yellow stripe called the **adrenal body** which as described is an important ductless gland.

From the posterior outer edge of each kidney arises a duct called the **ureter** which passes directly back to the cloaca, into which it eventually opens at the lip of the **urinogenital papilla.** As the

ureter in the male also conveys the genital products, it is as such a **urinogenital duct**, also called the **vas deferens.**

Arising from the floor of the cloaca and extending forwards into the abdominal cavity is a large thin-walled sac called the **urinary bladder**. The urine is stored in the urinary bladder. The

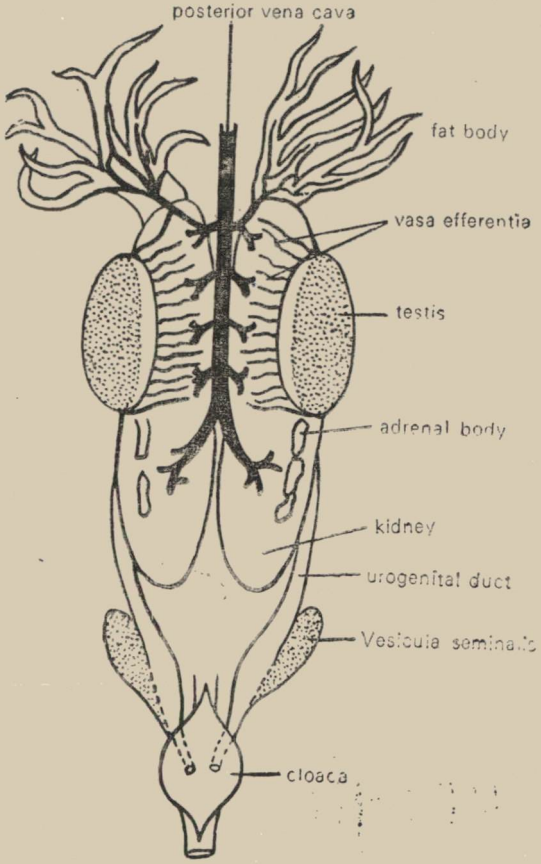


Fig. 12.1 Male frog — Urinogenital system.

opening of the bladder into the cloaca is provided with a **cloacal sphincter**. At times, when the animal is roughly handled, the urine from the bladder is suddenly discharged.

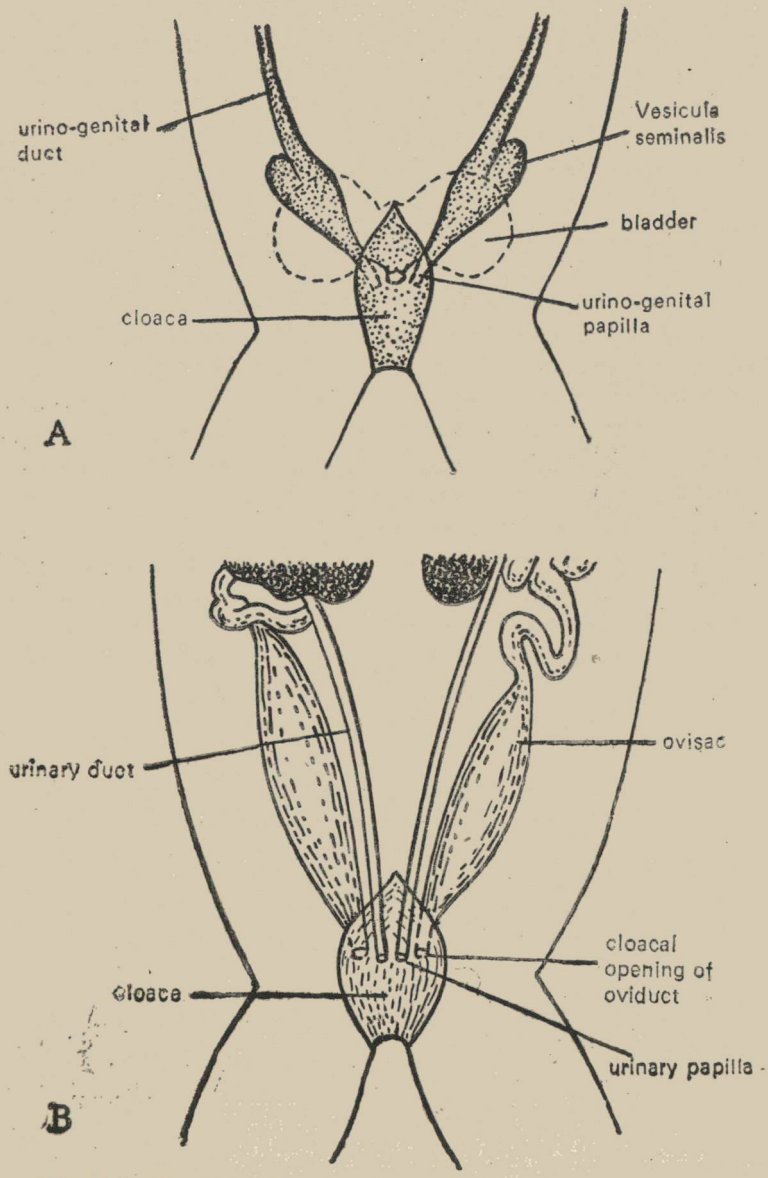


Fig. 12.2 The Frog — Posterior part of the urinogenital system (A) Male. (B) Female.

The Internal Structure of the Kidney of Frog :

A section passing through the kidney of frog reveals, that it is made up of a tangled mass of highly twisted microscopic tubules called the **urinary tubules** or **uriniferous tubules.** In a section, the urinary tubules are cut in various planes, some transversely and appear as circles, others longitudinally or obliquely. All the uriniferous tubules are interwoven with a net work of blood capillaries and are held together by the connective tissue.

At one end of each urinary tubule is found a globular or bulb-like swelling called the **Malpighian body.** Malpighian bodies of the urinary tubules are located on the ventral surface of the kidney. Each malpighian body is composed of a double walled **Bowman's capsule,** within the cavity of which, is found a little rounded bunch or knot of blood capillaries, called the **glomerulus.** The two walls of the Bowman's capsule are lined with thin flattened cells of pavement epithelium. The delicate inner-wall of the Bowman's capsule is in intimate contact with the glomerulus so that the blood in the glomerular capillaries is separated from the renal cavity of the Bowman's capsule only by two exceedingly thin membranes i. e., the inner layer of the Bowman's capsule and the walls of the glomerular capillaries. The Bowman's capsule is connected posteriorly to the neck of the urinary tubule or the **proximal part of the tubule.** The proximal part of the urinary tubule is lined by columnar cells provided with cilia. The proximal part of the tubule later continues behind in the form of a much coiled urinary tubule which winds through the substance of the kidney. This part of the urinary tubule consists of a single layer of glandular epithelium which is also at places provided with cilia. The course of each urinary tubule is complicated. To start with, each urinary tubule runs dorsally and forms more or less a complicated coil. Later it runs towards the ventral side where it forms a second coil and finally it runs dorsally again and joins one of the **transverse collecting tubules** The transverse collecting tubules extend transversely across the dorsal surface of the kidney and open on the outer margin into the **ureter.**

The arrangement of the blood vessels in the kidney is characteristic. As described, the blood is brought to the kidneys by

the **renal arteries**, and the **renal portal vein** and is carried away by the **renal veins**.

The renal arteries on entering the kidneys break up into smaller and smaller arteries called the afferent vessels or **afferent arterioles**. The **afferent arteriole** or vessel instead of forming the general capillary network, passes to the malpighian body in the interior of which it breaks up into a little bunch of much coiled

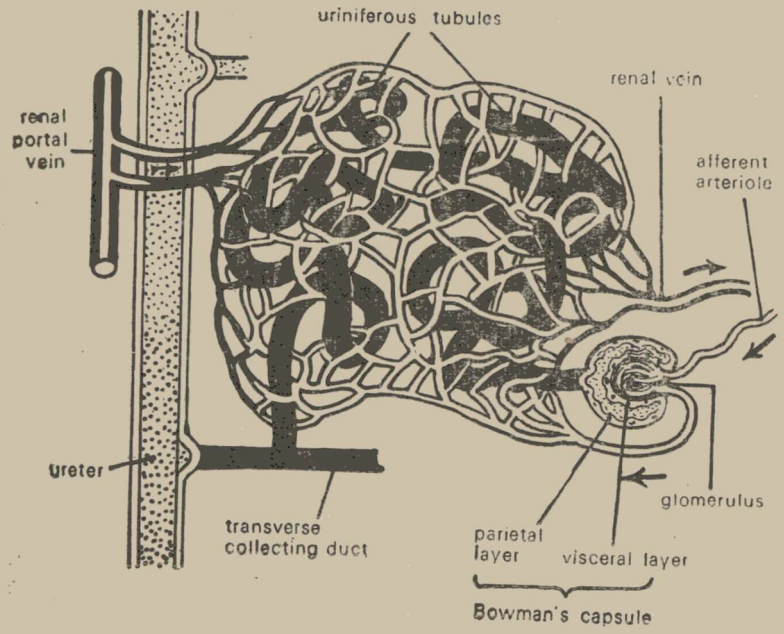


Fig 12.3 Diagrammatic representation of the course followed by the urinary tubule.

capillaries called the **glomerulus**. The capillaries of glomerulus reunite to form an **efferent arteriole**, which leaves the capsule by the same opening, and forms the general capillary network of the kidney. The renal portal vein after entering the substance of the kidney breaks up into the capillaries without approaching the malpighian body. The capillaries formed by the renal portal vein thus join the general capillary network formed by the efferent arteriole. The general capillary network thus unites to form the **renal veins** which discharge their blood ultimately in the **posterior vena cava**.

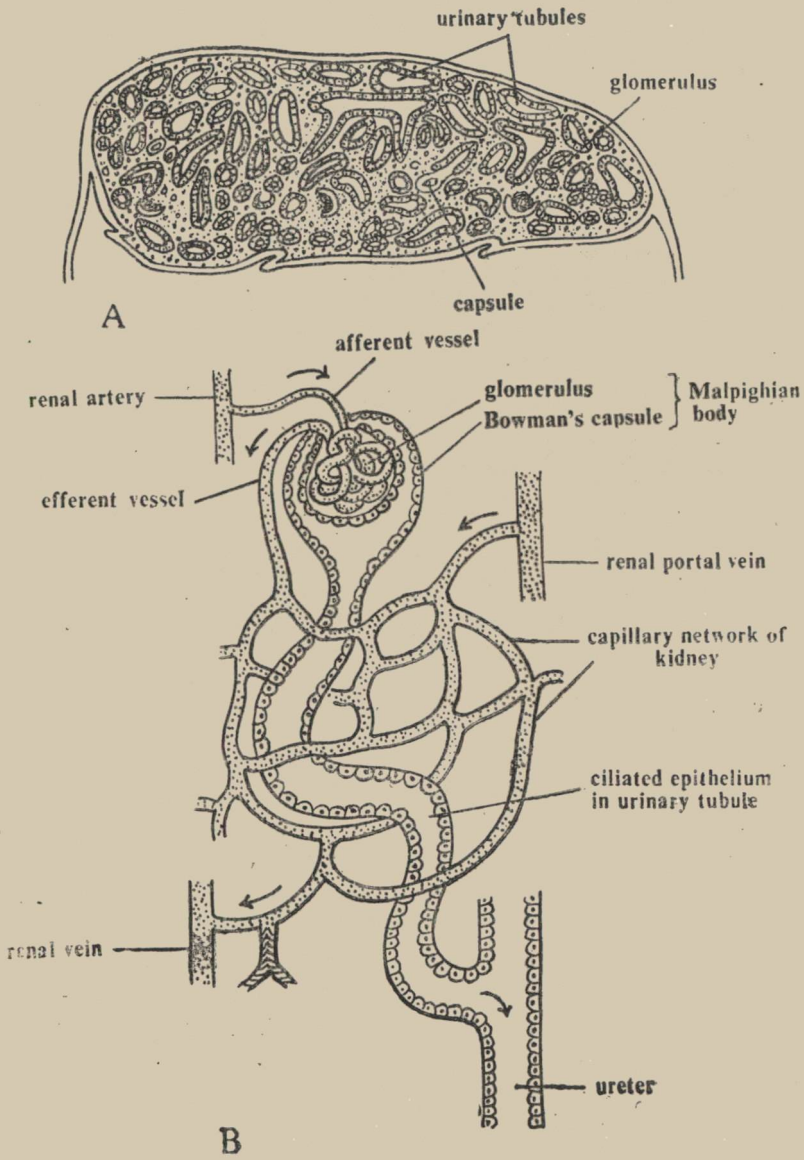


Fig. 12.4 The Frog — (A) T.S. passing through the kidney. (B) A urinary tubule with its blood vessels (Diagrammatic).

As mentioned, the capillaries of the glomerulus are entirely arterial. Further, the diameter of the efferent arteriole is lesser than that of the afferent arteriole so that the blood from the afferent arteriole via the glomerular capillaries, into the efferent arteriole, flows under great pressure. This facilitates **ultrafiltration** of substances from the glomerular capillaries into the Bowman's capsule.

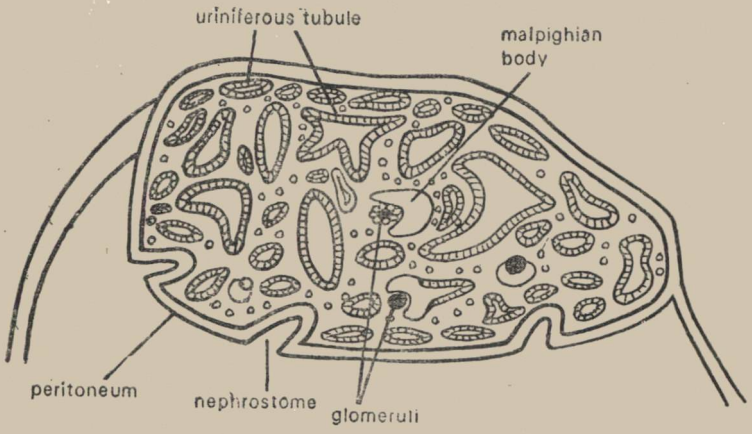


Fig. 12 5 T S. Kidney of frog showing the position of the nephrostomes.

Amphibian kidney is further characterised by the presence of open **nephrostomes.** Nephrostome is really the branch of the kidney tubule and not of the blood capillary. This branch of the kidney tubule pierces the peritoneum on the ventral side of the kidney and thus opens directly into the coelomic cavity. The nephrostromes as such are also referred to as the **nephrocoelomostomes.**

Renal Excretion :

The urinary tubules with their malpighian bodies are the functional units of the kidney. The waste substances, from the blood brought to the glomerular capillaries, are separated from the glomerulus, by a process of **ultrafiltration** i. e., **filtration under pressure.**

The blood corpuscles and the blood proteins like fibrinogen and fats are held back in the blood but the soluble excretory substances like urea, uric acid and salts of potassium, sodium, calcium

and magnesium are filtered through the glomerular capillaries into the Bowman's capsule in the first instance.

From the Bowman's capsules, the above **glomerular filtrate** passes into the urinary tubule. The main role of the urinary tubules is to reabsorb from the glomerular filtrate, the useful materials like sugar, salts of sodium, deproteinised plasma and some water. These reabsorbed substances in turn are passed into the general capillary network of the urinary tubules, from there into the general circulation. After the reabsorption of useful substances by the tubules, the remaining filtrate within the tubules, chiefly consists of urea, water and salts in small amounts. This fluid, called **urine**, is a waste product and is allowed to flow down the urinary tubule. The current for the flow of urine is kept up by the beating of the cilia found at intervals within the urinary tubules. The urine ultimately collects in the urinary bladder which empties at intervals. The kidneys while eliminating the nitrogenous substances from the body also regulate the quantity of water and other useful substances in the frog's body. The kidneys of frog as such also perform the function of **osmoregulations**.

THE REPRODUCTIVE SYSTEM OF FROG

Under the urinogenital system, the excretory system of frog has been discussed in detail. The **reproductive system of frog** will now be described. In frog the sexes are separate.

The Male Reproductive Organs:

The male reproductive organs consist of a pair of **testes** or **spermaries.** Each testis is a yellow ovoid body lying ventral to the kidney of its own side and is placed behind the fat bodies.

Each testis is enclosed by a sheath of peritoneum which continues on the dorsal side to form a double fold called the **mesorchium.** The testis is attached to the body wall by the mesorchium. The **male gametes** or **sprems** are formed in the testes. Arising from the inner margins of each testis, are a number of fine ducts called the **efferent ducts** or **vasa efferentia.** These ducts run in the peritoneum and enter the kidney near its inner border. The spermatic fluid from the testis via vasa efferentia is thus carried to the cloaca by the ureters. In the male frog, each ureter just behind the kidney

The Female Reproductive Organs:

A pair of ovaries and a pair of oviducts are found in a female frog.

Each ovary is in the form of an irregular sac-like structure lying ventral to the kidneys. The ovary full of eggs is a lobulated hollow sac covered by the peritoneum which extends dorsally to form a double membrane, the **mesovarium.** The ovary is suspended from the dorsal body wall by the mesovarium. The blood vessels and nerves to the ovary pass between the two membranes of the mesovarium. In breeding season, the ovaries are seen studded with mature eggs, each of which is half black and half white. The **oviducts** are in the form of a pair of much coiled long tubes lying dorsal to the ovaries and extend in front to the roots of the lungs. At the root of the lung, each oviduct ends in a ciliated funnel called the **funnel of the oviduct** which opens into the coelom through its opening called the **ostium.** The posterior end of each oviduct is somewhat dilated to form the **'uterus'** or **ovisac.** The ovisac in turn opens into the cloaca through its dorsal wall in front of the opening of the ureter.

The ripe eggs from the ovary during the breeding season are shed into the coelom by the rupture of the ovaries. The release of eggs from the ovary is called **ovulation.** The eggs discharged from the ovaries float about in the coelomic fluid till they find their way into the ciliated funnels of the oviducts. The cilia lining the body cavity and funnels carry the eggs towards the mouth of the funnels, the ostia. From the ostia the eggs enter the oviducts. The eggs during their passage through the oviduct become covered in three distinct layers with an albuminous material or jelly secreted by the glandular walls of the oviduct. The ripe eggs with the above coatings are retained for sometime in the ovisacs and later they are finally passed out of the body through the cloacal aperture. When the eggs come out of the body, the jelly-like covering on coming in contact with water swells up enormously to form the **frog's spawn.** The main role of the jelly is to protect the eggs from mechanical injuries as well as from attacks of fungi, bacteria and other organisms.

Fat Bodies:

Associated with the gonads are seen the **fat bodies.** They are a pair of yellowish organs attached to the anterior ends of the

dilates into a **vesicula seminalis** and narrows again before joining the cloaca. The ureters in the male frog thus serve the purpose of conveying both the spermatic fluid and the urine to the cloaca. The ureters as such are referred to as the **urinogenital ducts.**

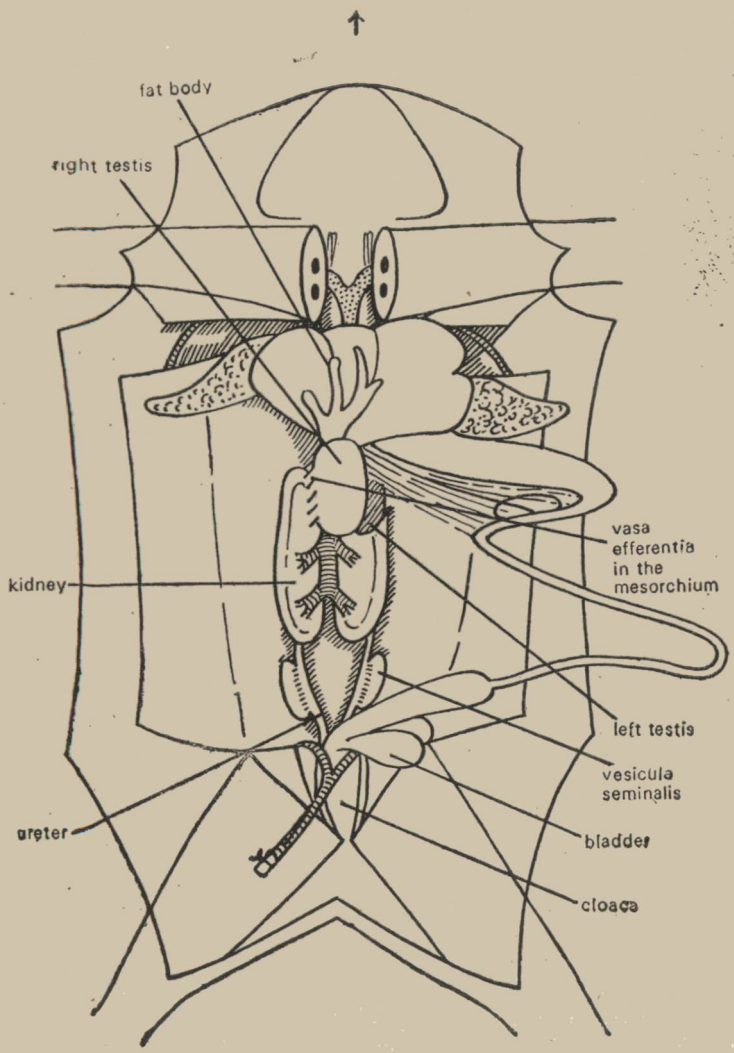


Fig. 12.6 The frog — Male reproductive system.

The Female Reproductive Organs:

A pair of ovaries and a pair of oviducts are found in a female frog.

Each ovary is in the form of an irregular sac-like structure lying ventral to the kidneys. The ovary full of eggs is a lobulated hollow sac covered by the peritoneum which extends dorsally to form a double membrane, the **mesovarium.** The ovary is suspended from the dorsal body wall by the mesovarium. The blood vessels and nerves to the ovary pass between the two membranes of the mesovarium. In breeding season, the ovaries are seen studded with mature eggs, each of which is half black and half white. The **oviducts** are in the form of a pair of much coiled long tubes lying dorsal to the ovaries and extend in front to the roots of the lungs. At the root of the lung, each oviduct ends in a ciliated funnel called the **funnel of the oviduct** which opens into the coelom through its opening called the **ostium.** The posterior end of each oviduct is somewhat dilated to form the **'uterus'** or **ovisac.** The ovisac in turn opens into the cloaca through its dorsal wall in front of the opening of the ureter.

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Fat Bodies:

Associated with the gonads are seen the **fat bodies.** They are a pair of yellowish organs attached to the anterior ends of the

gonads. Each fat body has a number of finger-like processes. The number and size of the finger-like projections of the fat bodies varies

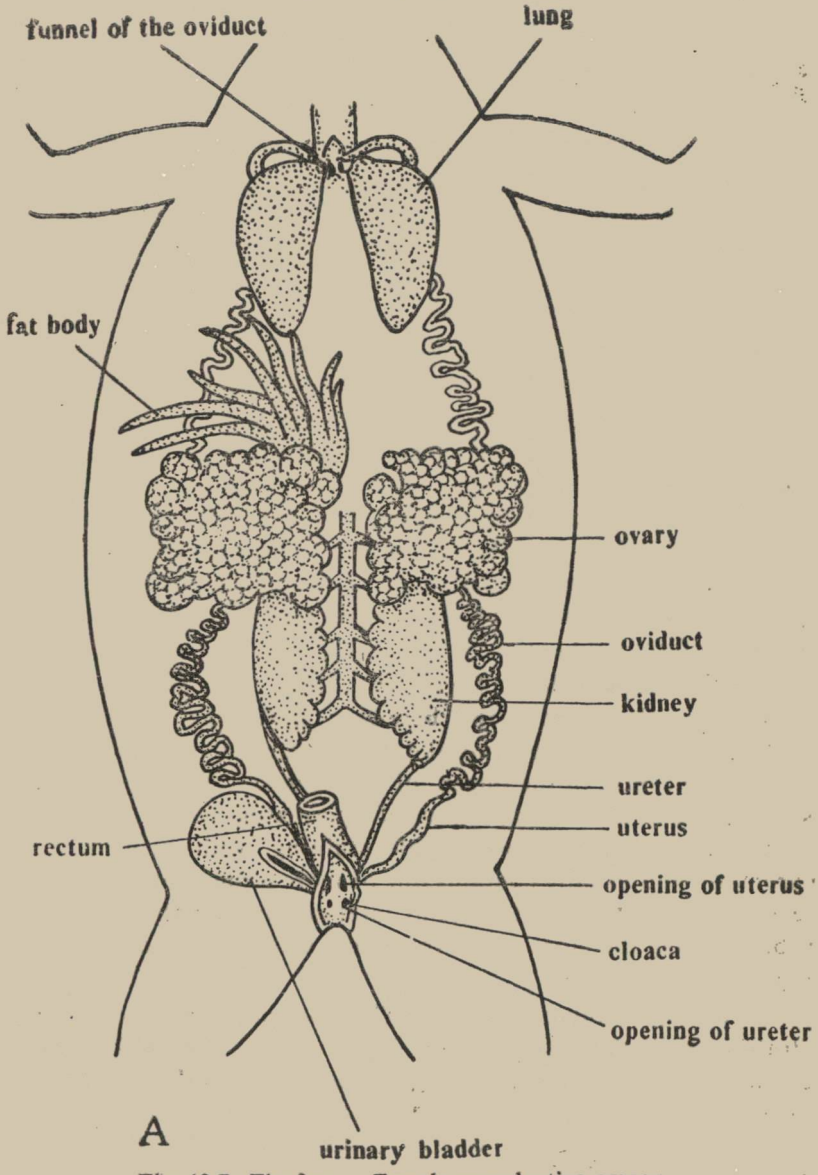


Fig. 12.7 The frog — Female reproductive organs.

in different individuals. In the same individual also their number is variable at different times of the year. The fat bodies serve as the storages of reserve food material.

The Histology of the Testis of Frog:

The testes of frog in their fine structure conform to the general pattern of the testes of other vertebrates.

Each testis consists of a number of fine convoluted tubules called the **seminiferous tubules.** These tubules are separated into small groups by membranous partitions called *septa*.

The seminiferous tubules lead into a smaller set of tubules, the vasa efferentia which converge to form the *vasa deferentia* or *sperm ducts* also referred to as the *urinogenital ducts* in male frog.

The wall of the convoluted seminiferous tubules consists of (a) an outer capsule composed of fibro-elastic connective tissue and flattened fibroblasts which closely invests the tubule (b) a thin homogenous **basement membrane** and (c) a lining of a complex startified epithelium. This complex stratified epithelium consists of two kinds of cells—(1) The supporting cells or **cells of Sertoli** and (2) the primary spermatogenic cells or **spermatogonia.** The spermatogonial cells alternate in location with sertoli cells in the walls of the seminiferous tubules.

1. Sertoli cells: These are long columnar cells having broad bases which rest on the basement membrane. The elongated portions of these cells extend like the spokes of a wheel, part way toward the centre of the lumen of the tubule. These cells are best seen before or after completion of spermatogenesis. The nucleus of the sertoli cell is ovoid, pale staining, with finely dispersed chromatin and usually contains one or more prominent nucleoli. The sertoli cells occur at quite regular intervals around the lumen of the tubule among the more numerous and smaller developing spermatogenic cells.

2. Spematogenic cells: The spermatogenic cells form a stratified epithelial tissue several layers deep. The epithelium rests on the basement membrane and its cells extend in toward the lumen of the tubule. The layer of spermatogenic cells is interrupted at regular intervals by sertoli cells. At sexual maturity, the spermatogenic cells can be seen in all stages of differentiation and are arranged in several, more or less, distinct layers.

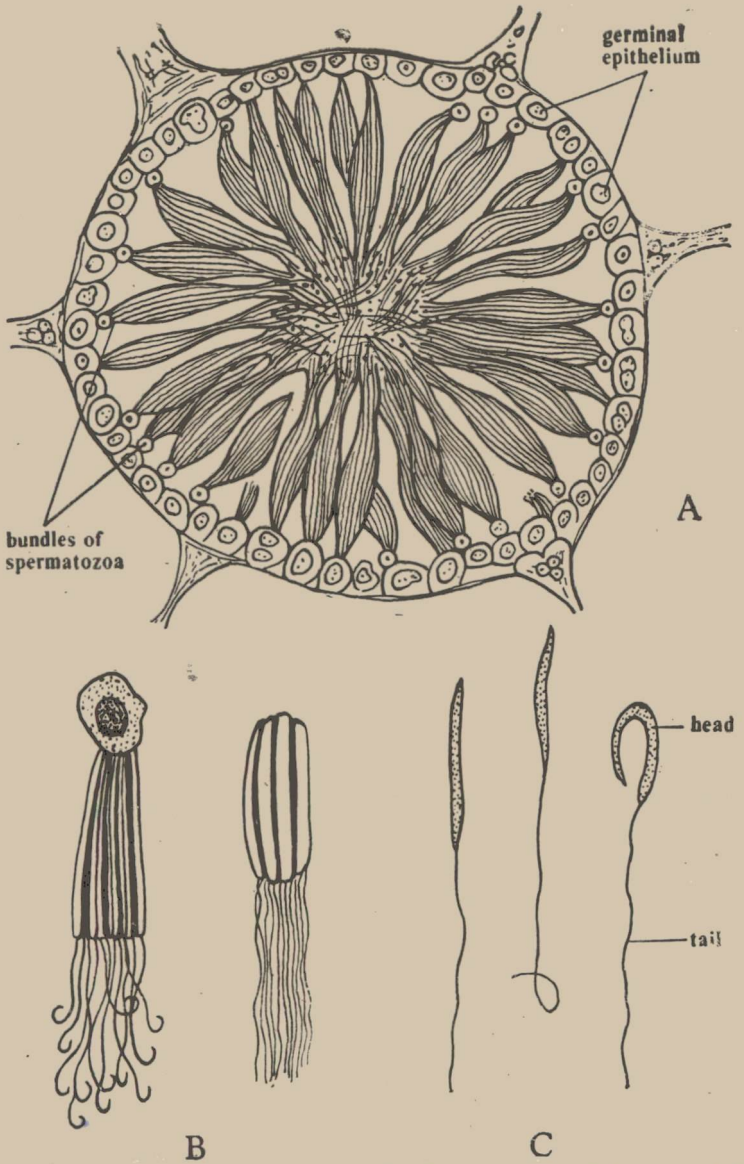


Fig. 12.8 (A)—Transverse section passing through one seminiferous tubule. (B)—Stages in development of sperms. (C)—A few spermatozoa.

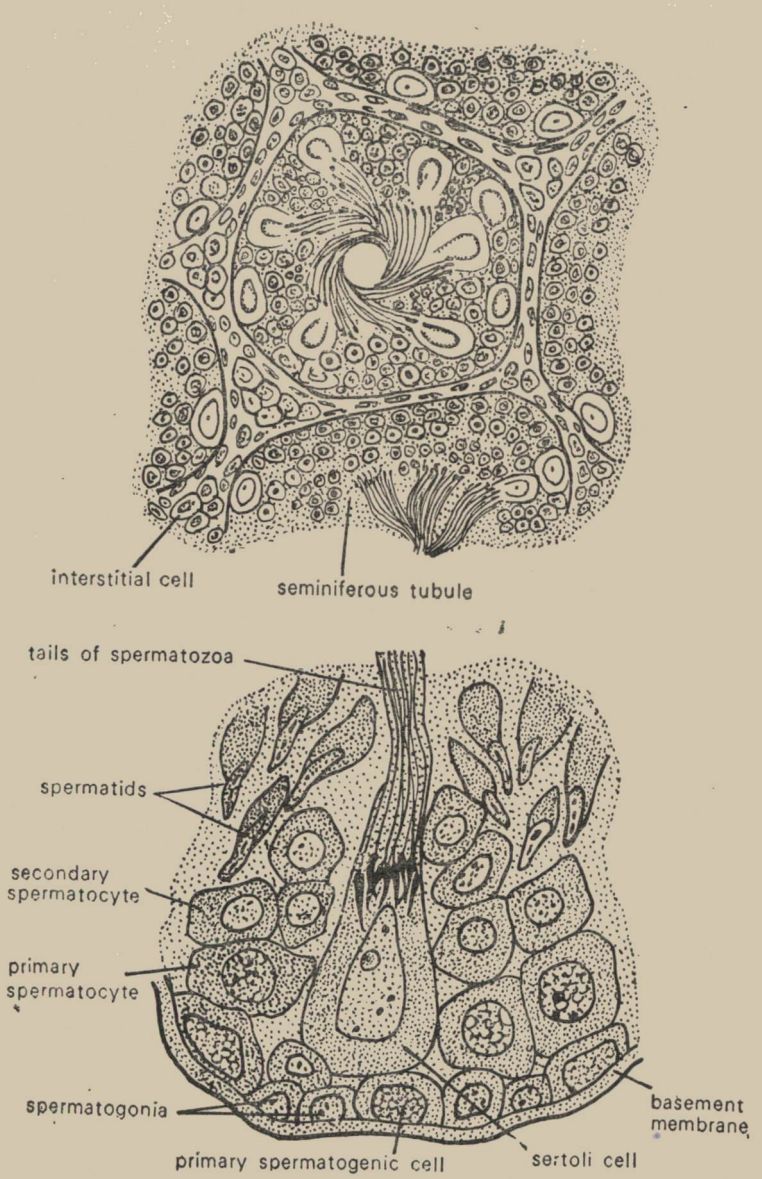


Fig. 12.9 Above : Transverse section passing through the seminiferous tubules of testis. Below : Part of a seminiferous tubule highly magnified to show the arrangement of cells in the seminiferous epithelium.

When the spermatogenesis starts, a series of mitotic divisions takes place in the spermatogonia. The cells obtained by repeated mitotic divisions of the spermatogonia are called the **primary spermatocytes**. The primary spermatocytes later undergo meiotic division and give rise to the **secondary spermatocytes** with a haploid number of chromosomes. The secondary spermatocytes with a haploid number of chromosomes undergo mitotic division and produce **spermatids**. These are small spherical cells with a haploid chromosome number. The spermatids arrange themselves in columns and later are seen in close attachment with the cytoplasm of the sertoli cells. The spermatids now undergo a process of transformation and become fully developed spermatozoa with *head*, *middle piece* and *tail*. Mature or nearly mature spermatozoa are frequently observed in the tubule, with their heads in close contact with the cytoplasmic processes of the sertoli cells, and their tails extending out into the lumen.

In a mature testis, the following cell types are distinguished passing from the periphery of the tubule toward the lumen i.e., spermatogonia, primary spermatocytes and spermatids, (the latter often in the process of transformation into spermatozoa).

3. **Interstitial cells**: The space between the adjacent seminiferous tubules is occupied by a loose fibro-elastic connective tissue similar to that forming the wall of the tubules. In this connective tissue are found certain groups of cells known as the **interstitial cells** or **cells of Leydig**. These cells arise from the fibroblasts and may revert to cells which are indistinguishable from the fibroblasts.

The internal secretion of the testes (testosterone) is elaborated by the interstitial cells. (Hormones of the testes see page 241).

The Histology of the Ovary of Frog:

The ovary is a thin walled hollow sac irregular in shape, lined internally by the germinal epithelium composed of primordial germ cells.

In the young ovary, the actively dividing primordial germ cells can be identified in small clusters. After sometime one of the cells in the cluster stops dividing and begins to increase in size, while its sister cells form a peripheral layer around it. The innermost

cell differentiates into **oocyte** and the surrounding ones constitute a layer of cells called the **follicle cells.** The entire group with its oocyte is now called an **ovarian follicle.** From now on the oocyte enters a period of rapid growth. It accumulates yolk and eventually when full grown, becomes the **primary oocyte**..

In a growing ovary, hundreds of ovarian follicles are found. The smaller follicles are seen in the form of clusters, the larger ones are found alone and separated from others by partitions which are composed of ovarian connective tissue called the **stroma**. Within the stroma, the blood vessels ramify throughout the entire ovary and supply the necessary food and oxygen. The waste products are also removed by the blood vessels. The oocytes gradually grow in size.

The smaller oocytes have no yolk or if present it is very little and evenly distributed. The nuclei of smaller oocytes are centrally placed. In the later stages, as the oocyte grows, the yolk becomes concentrated near one pole—the vegetal pole, while the nucleus moves in the opposite direction toward the animal pole. The oocytes thus have a typical **telolecithal** appearance i. e., the yolk is concentrated only at one pole. There is further, a progressive accumulation of black pigment granules in the peripheral *ooplasm* of the animal hemisphere which give a black appearance to this region, while the vegetal polar hemisphere remains creamy white.

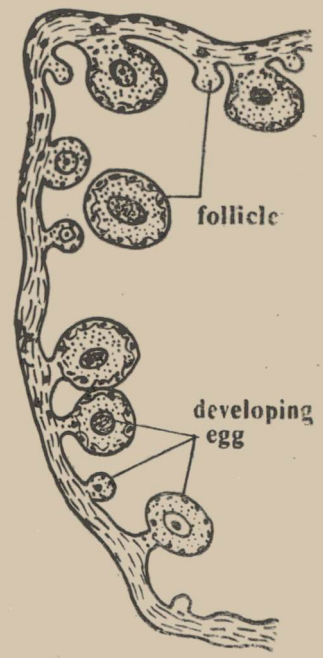


Fig. 12.10 A section passing through the ovary of frog showing the ovarian follicles and developing eggs

In future development as stated earlier, the animal pole side is destined to produce the anterior end of the embryo, while the vegetative polar portion forms the posterior end. It appears thus, that even when the ovum is still in the ovary,

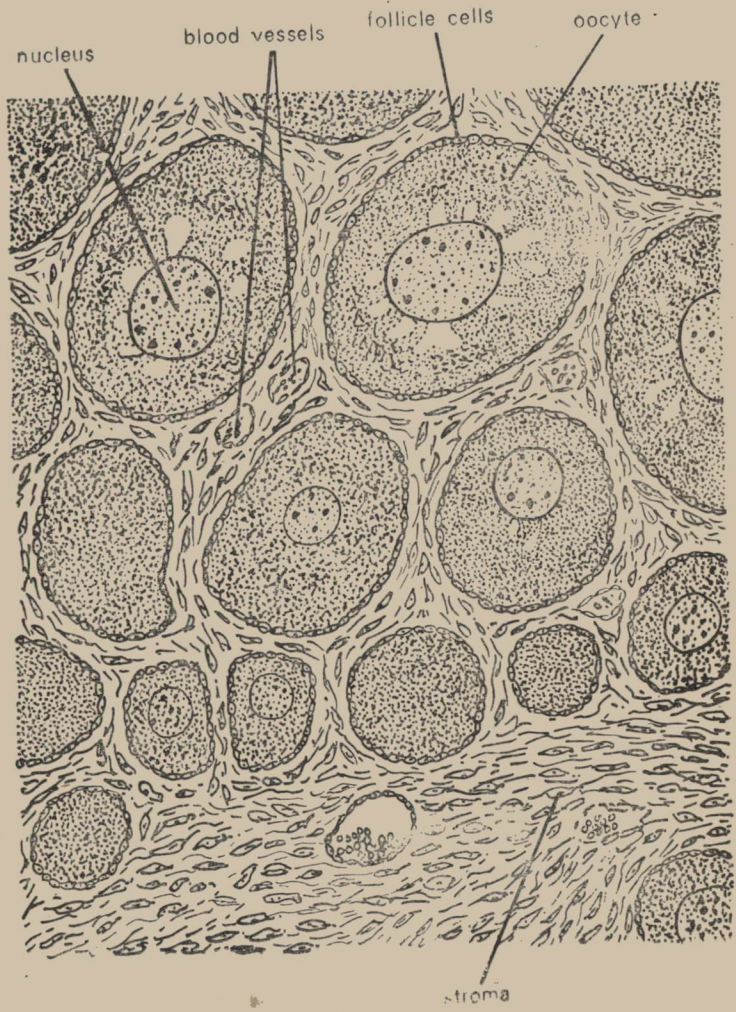


Fig. 12.11 A section passing through the ovary of frog containing young oocytes.

the primary axis or approximately the antero-posterior axis of the future embryo is established. With regard to germ layers, the materials for the ectoderm are derived from the animal hemisphere, while the endoderm comes from the vegetative hemisphere. The mesoderm, which differentiates later, originates from both.

During the period of growth of the oocyte, the follicle cells change gradually in form and arrangement. The follicle cells in the earlier stages are very distinct and closely packed together. Later they become flattened, and when the egg is ready for discharge, they form a thin, encapsulating sheath of cells.

Each amphibian egg as it comes from the cloaca of the female, is a single cell ¾ to 3 mm. in diameter. It is surrounded by the vitelline membrane and by several layers of adhesive jelly which are added as it passes through the oviduct (See Fig. 12·17).

The Structure of a Spermatozoan :

In male animals, the male gamate i. e., the mature spermatozoan is usually a greatly elongated vibratile cell. It consists typically of a **head, middle piece** and **tail**.

Head : Almost the entire mass of the sperm head is formed by the **nucleus** The nucleus may be flattened, greatly elongated, hooked or twisted into a spiral. The shape of the head is diverse and *species specific*. Many animals can be identified by the shape of the head alone. The nucleus is surrounded by a nuclear envelope which consists of two concentric membranes enclosing a greatly attenuated perinuclear space. Pore complexes rarely occur in the nuclear envelope. A thin layer of cytoplasm surrounds the nucleus in the sperm head. The usual cytoplasmic structures and organelles such as mitochondria, golgi complex, endoplasmic reticulum and ribosomes are absent from the thin layer of cytoplasm. During spermiogenesis the histones found in somatic cell nuclei are replaced in the sperm nuclei by more basic proteins late in spermiogenesis (The metamorphosis of spermatids into sperms is called spermiogenesis. It includes extensive changes in both nucleus and cytoplasm). At present, the significance of replacing histones by arginine rich proteins or protamine is unknown.

At the anterior end of the sperm head, just beneath the plasma membrane is the *acrosome*. The acrosome is a small cap-like

structure that arises from golgi complex (cf. p. 295 vol. 1 4th edition) during spermiogenesis. The acrosome functions in the penetration of the egg by the sperm during fertilization. It also shows wide variations in size and shape between different species.

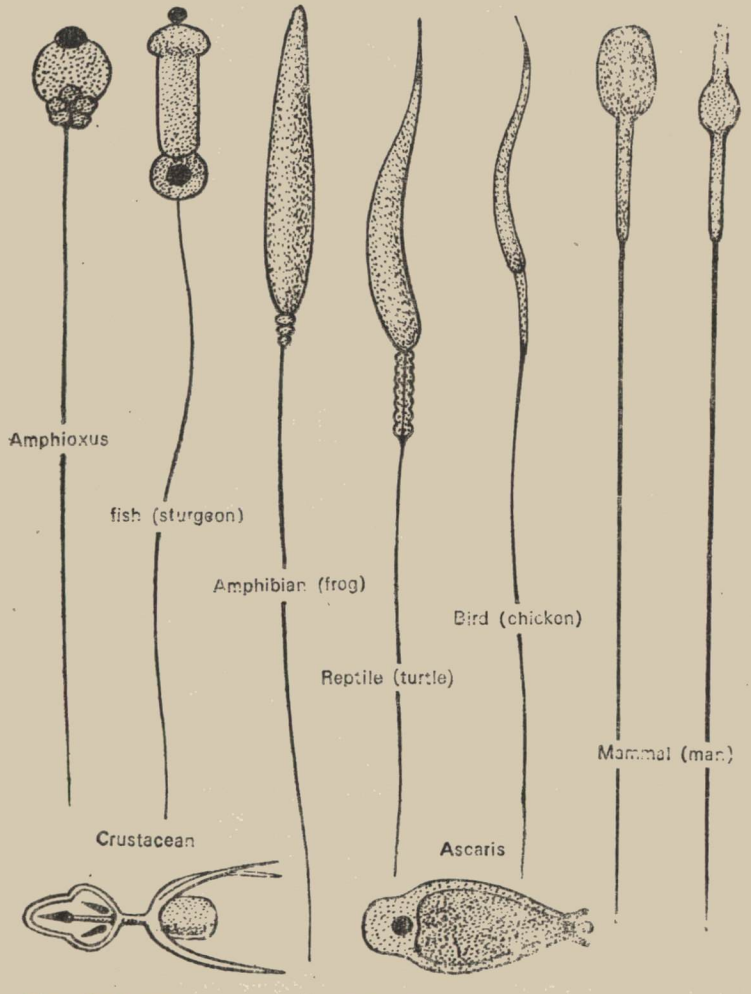


Fig. 12.12 The spermatozoa of chordates along with the sperms of the Crustacean and the Ascaris.

The plasma membrane surrounds the nucleus and acrosome; it extends posteriorly as a sheath around the middle piece and tail of the spermatozoan.

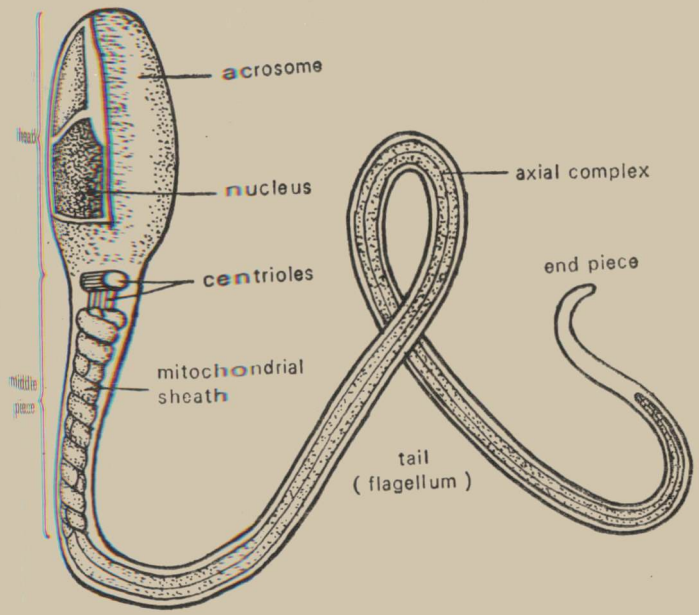


Fig. 12.13 The structure of a spermatozoan.

Middle piece : The head is followed by the middle piece. Middle piece consists primarily of a sheath of mitochondria surrounding the tail axis just behind the head. In some animals particularly the insects, the mitochondria fuse into a composite structure known as the *nebenkern* (neben = *near*; kern=*nucleus*.) In many vertebrates and some invertebrates, the mitochondria of the middle piece become arranged end to end in a tightly packed spiral of very shallow pitch. The other important organelles of the middle piece are the centrioles. Two centrioles are normally present. One lies close to the base of the nucleus just outside the nuclear envelope. It is called the *proximal centriole*. The second centriole is located immediately behind the first. It is called the *distal centriole*. It gives rise to the axial complex of the tail.

Tail: The tail extends from the distal end of the middle piece. It contains an axial complex (axoneme) and a sparse sheath of cytoplasm enclosed by the plasma membrane. The axial complex as stated arises from the distal centriole and extends from the base of the nucleus through the middle piece to the tip of the tail. In light microscope the axial complex appears as a central fibre running the length of the tail. It consists of a regular arrangement of microtubules (cf p. 300–302 vol. I 4th edition). In cross-section it appears as an outer circle of nine double tubules (peripheral doublets), surrounding a central pair of single micro-tubules (central singlets). The entire configuration is called 9+2 pattern. This arrangement of the micro-tubules of the sperm tail is remarkably uniform in animals and plants.

The above arrangement of the sperm cell into *head, middle piece* and *tail* is typical of all animals.

Sperms lacking a tail (non-flagellate types) occur in a few species of nematodes, some crustacean, few arachnids (mites) and some myriapods. In general, the absence of tail is correlated with the absence of the organelles of the middle piece including mitochondria and centrioles. Multiple sperm tails are found very rarely and appear in only a few species, such as flatworms (Rhabdocoels) and as abnormal types in the snail *Viviparus* and other animals normally bearing more typical sperms.

The Structure of an Ovum or Egg:

The egg (ovum) is one of the most highly specialised cells of the body. It reacts after fertilization and proceeds to the formation of an embryo and then an adult. The term ovum should be applied to the female germ cell after its completion of the entire maturation process.

A cell of the ovary can be recognizable as a definite oocyte when it enlarges and in many species begins to accumulate the materials known as the yolk in the form of various shapes and compositions.

The cytoplasmic organelles, the golgi complex and mitochondria play a part in the formation of the yolk. The materials for

the growth of the oocyte and for the deposition of the yolk are partly derived from the follicle cells that surround it. In birds and probably also in reptiles, portions of the golgi substance of these follicle cells can be seen actually entering the oocyte.

In the earlier stages of oogenesis, the golgi substances in the oocyte are usually concentrated around the centrioles to form a

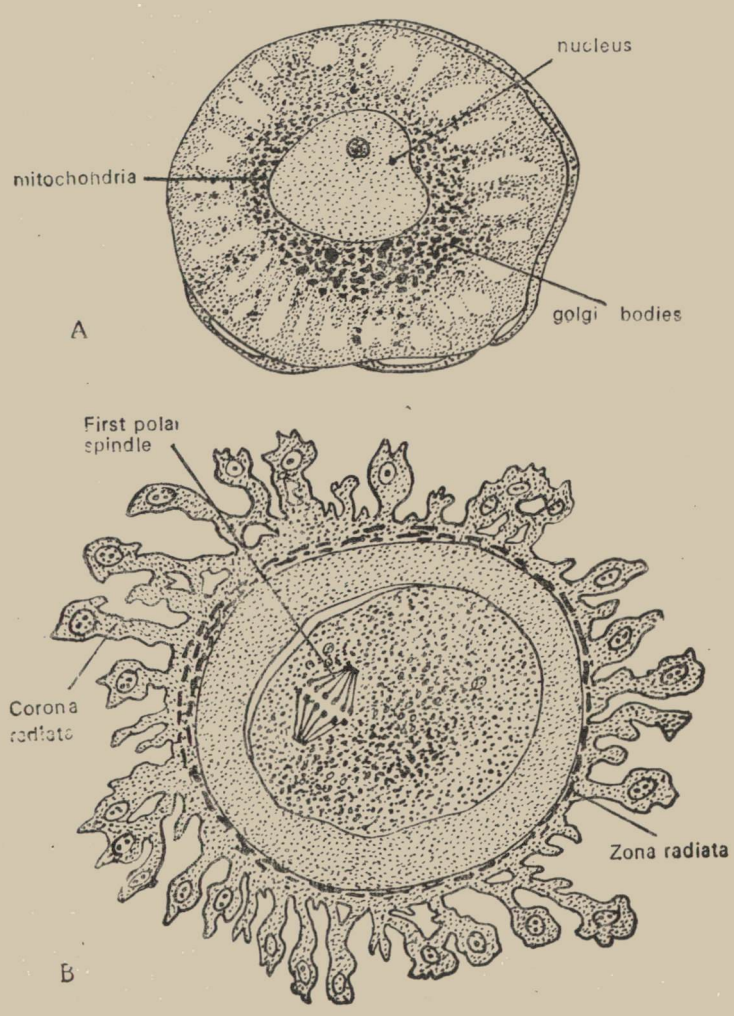


Fig. 12.14 (A) Young human oocyte.
(B) Ovum from mature follicle of guinea pig.

structure referred to as the *yolk nucleus*. The yolk nucleus lies from the start eccentrically on one side of the nucleus. The yolk nucleus enlarges and breaks up into pieces, which scatter throughout the cytoplasm and lay down the spherules of the yolk. Associated with the yolk granules are large mitochondria.

The nucleus of the egg in most ova moves towards one pole. The side towards which the nucleus ultimately lies is an area of yolk free protoplasm. It is called the *animal pole*. The region of the egg, opposite to the animal pole, is the yolk containing area referred as the *vegetative pole*. The axis of the egg is thus established and this is carried through into the embryo and adult; the animal pole being on the future dorsal side of the body. The presence of such an axis in the ovum is an indication that different parts of it now begin to have distinct properties. The unfertilised ovum is thus not by any means a homogenous system. Many of its contents differ along the animal vegetative axis.

Various Types of Eggs:

Eggs of various organisms differ considerably in the amount of yolk they contain, in the way it is distributed and in the time at which it is utilized.

Some eggs which are very small and the yolk evenly distributed, are called **Homolecithal** or **Isolecithal eggs** (equal yolk). In such eggs, there is little or no gradient in yolk distribution along the animal vegetal axis. The human egg (0·1–0·2 mm) is an example of isolecithal egg. The yolk gradient may not be detected, however the position of the animal pole may be determined easily. The germinal vesicle lies near the animal pole and when meiosis occurs, one polar body nucleus is extruded at this pole at each division. The eggs of *amphioxus* also contain little yolk and are said to be *oligolecithal.* The term oligolecithal is used for the eggs of mammals (other than monotremes).

Other eggs are larger and have noticeably greater concentration of yolk at the vegetal pole. They are called **Telolecithal eggs** (yolk at one end). Most amphibians have larger eggs (1-2 mm, *Rana*) and are also considerably heavily yolked and hence called the *Mesolecithal.* The eggs of amphibians have a strong yolk gradient. The

region of the animal pole shows small and scattered yolk platelets which grade progressively into the larger yolk masses occupying the vegetal pole almost to the exclusion of the cytoplasm.

In sharks, modern bony fishes, reptiles, birds and monotremes the telolecithal eggs contain relatively more yolk and are said to be *macrolecithal* or *megalecithal* eggs The great bulk of the bird's egg, consists of yolk, with only a thin disc of nucleated protoplasm at the animal pole. The eggs of birds are large, as well. The diameter of an egg of ostrich is 85 mm.

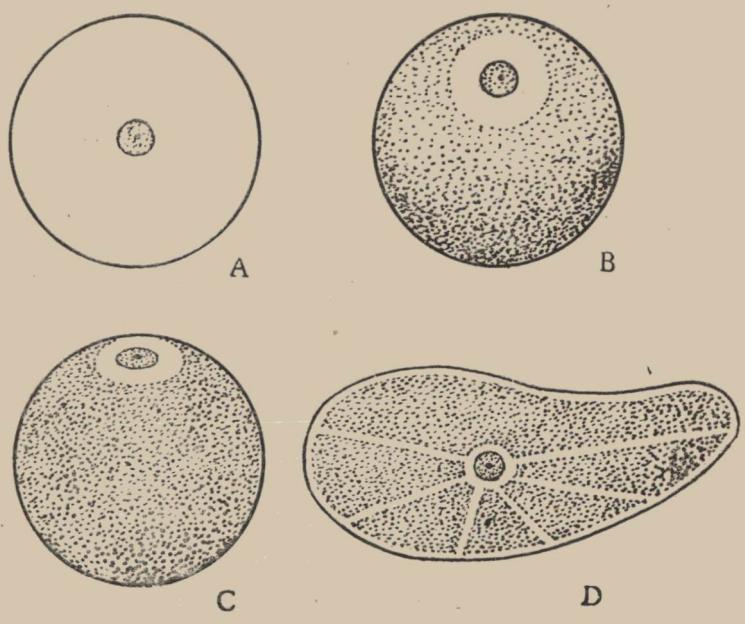


Fig 12.15 The distribution of yolk (stipples) and the position of the nucleus in various types of eggs (A) Isolecithal egg. (B) and (C) Telolecithal eggs. (D) Centrolecithal egg.

Eggs of many arthropods and some coelenterates are referred to as *Centrolecithal*. They are relatively large and usually elongate and have a very great amount of yolk. The nucleus lies near the geometric centre of the yolk mass, surrounded by a small amount of

cytoplasm. A thin cytoplasmic layer covers the surface of the yolk and sends fine threads into the zone occupied by the nucleus.

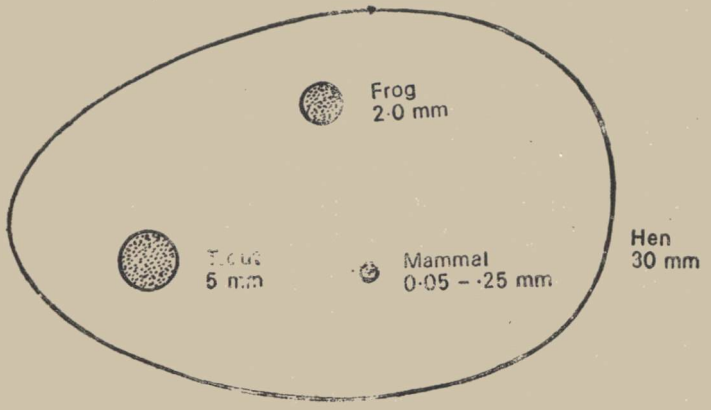


Fig. 12.16 The relative sizes of various types of eggs.

Egg membranes : The special feature of the oocyte is its protective membranes. The protective membranes as earlier described are of two kinds—the **primary** and the **secondary.**

The primary membrane is the plasma membrane of the egg itself, called the **Oolemma** and the surrounding **Vitelline membrane** that is added during the growth of the oocyte. The secondary membranes are sometimes added as the egg passes through the oviduct. Examples of such kinds are the shell membrane and shell of the hen's egg and the jelly membranes of the frog's egg.

The Structure of the Hen's Egg :

The term bird's egg is used in its more familiar sense, including the yolk, the albumen and the shell.

The ovum proper of the hen's egg consists of the central spherical yellow portion ordinarily referred to as 'Yolk' which inspite of its large size, is merely a single cell. A circular whitish protoplasmic area can be seen at the top of the yolk called the *blastodisc* or *blastoderm* composed of the dividing blastomeres.

In its passage through the oviduct towards the cloaca, the fertilized ovum or zygote undergoes cleavage and at the same time becomes surrounded with *albumen* or white of the egg and other accessory membranes.

The albumen or white of the egg is secreted by the glandular wall of the oviduct. Further, as the wall of the oviduct is provided with spirally arranged grooves and ridges, the egg rotates as it passes along the oviduct. Due to this, the albumen is covered

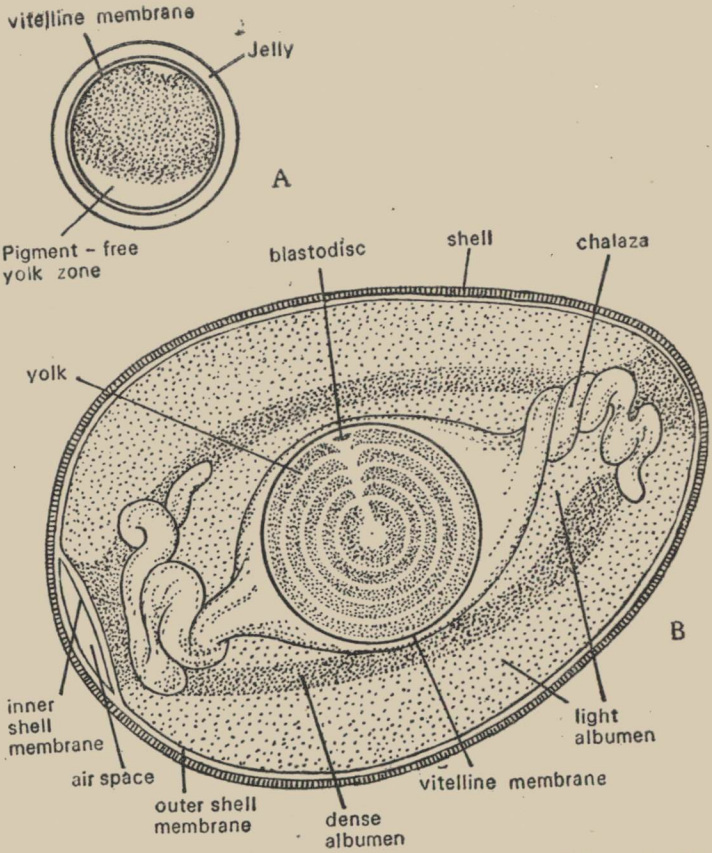


Fig. 12.17 (A) Primary and secondary egg membranes of the unfertilized egg of the frog. (B) The structure of hen's egg.

around the ovum in a layered sheet, having a more opaque twisted cord on each side, called the **Chalazae.** The chalazae are instrumental in keeping the ovum placed in the centre of albumenous mass after its complete formation. Albumen secreted in the grandular portion of the oviduct is of firmer consistency than that which is added further back.

The entire mass of albumen formed around the ovum, now becomes surrounded by a permeable membrane called the **shell membrane.** The shell membrane comprises an inner shell membrane immediately in contact with the albumen and the ovum and the outer shell membrane which lies in contact with the outer porous shell.

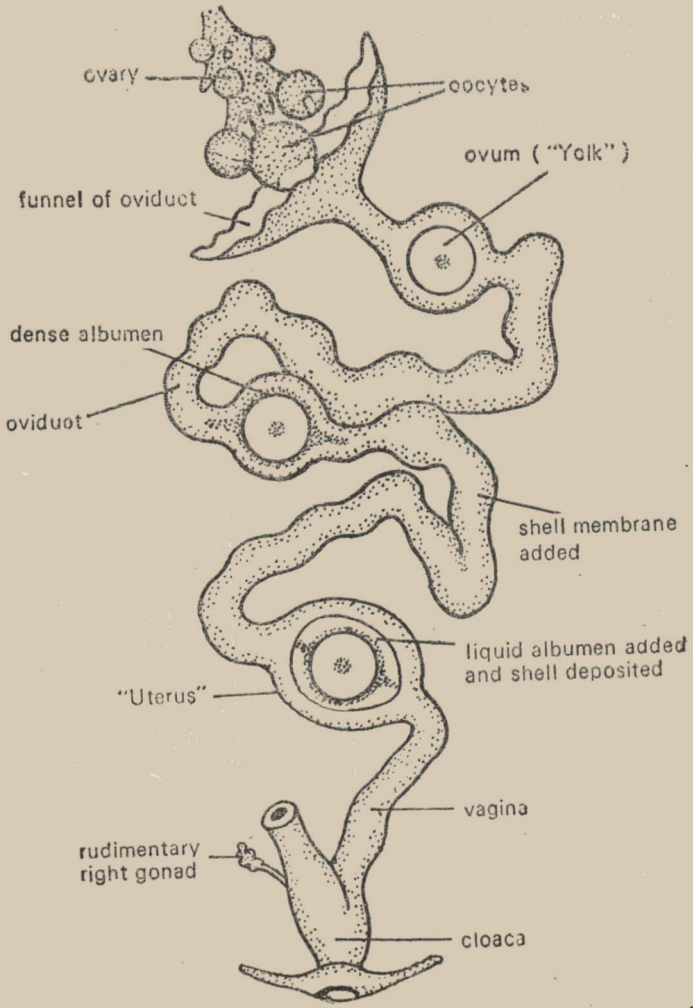


Fig. 12 18 The egg in the oviduct of the hen. Only one egg at a time normally descends the oviduct.

When the egg enveloped by the shell membranes reaches the posterior portion of the oviduct called the uterus, it becomes covered by a solid **porous calcareous shell.** This porous calcareous shell is chiefly composed of carbonates and phosphates of calcium and magnesium. The shell lends a typical 'Ovoid' contour to the egg, one end being slightly blunter than the other.

Within the egg at the blunt end, is a small space, the so called *air space*, which is formed as a cavity between the two closely apposed components of the inner and outer shell membranes. The dual composition of the shell membrane can be demonstrated to the best advantage at the site of the air space. In eggs that have been kept for sometime after laying, the volume of the air space increases. An easy method to test the freshness of an egg is to place it in water. A fresh egg always sinks, whereas an old one keeps floating due to the presence of a large volume of air inside.

The calcareous shell of the chick's egg may be white or more or less brown or may have dark brown circular patches interspersed in the lighter brown shell. On account of misinformation some people believe that white-shelled eggs are of better quality than brown ones; others believe the opposite to be true. The shell has nothing to do with the nutritive value of the eggs. Generally, brown eggs are laid by dark or brown feathered hens and white eggs are laid by white hens.

Revision questions

1. Describe in detail the excretory system of frog.
2. Give a detailed account of the microscopic structure of kidney of frog and also mention the physiology of *renal excretion.*
3. Describe in detail the male and female reproductive systems of frog.
4. Describe the microscopic structure of the testis of frog.
5. Give an account of the histology of the ovary of frog.
6. Describe the structure of a spermatozoan.
7. Describe the structure of an ovum with the details of the structure of hen's egg as well.

CHAPTER XIII

THE DEVELOPMENT OF FROG

The egg: The development of the eggs of frog is a slow process. Eggs require three seasons to mature.

The cells destined to become oocytes are called *oogonia*. The oogonia divide several times by mitosis. After several mitotic divisions, some of the oogonia move apart and begin to be surrounded by an envelope of *follicle cells*. The *oogonium* surrounded by the follicle cells grows larger than the follicle cells and a fully grown oogonium called a **primary oocyte** is obtained. Under the influence of the pituitary hormones and stimulated by the *clasp of the male*, the primary oocytes are released from the ovary of the female into the body cavity. This process of the release of primary oocytes from the ovary is called *ovulation*.

The primary oocyte undergoes the first maturation division (meiosis—see Vol. I) during its release down the oviduct. The primary oocyte divides into a large **secondary oocyte** and a small **first**

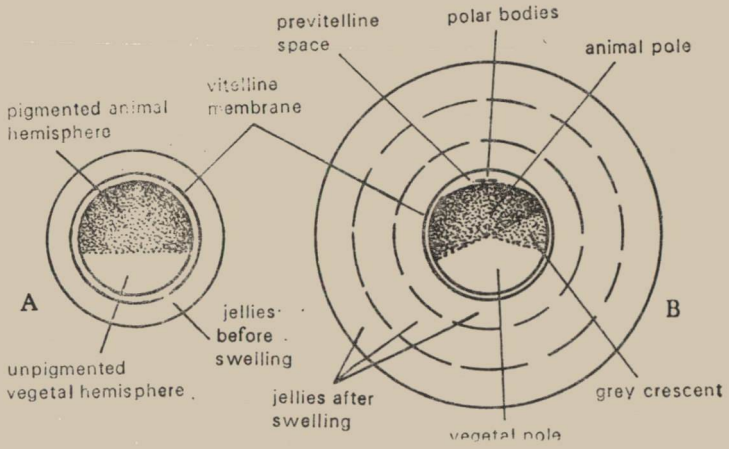


Fig. 13.1 An amphibian egg. (A) Before laying (B) After laying seen from the left side.

polar body, each one having a *haploid number* of chromosomes. Second maturation division occurs at the time of union of the male and female gametes. It divides the secondary oocyte unequally into a mature **ovum** or **egg** and a **second polar body.**

Each amphibian egg, as it comes from the cloaca of the female, is a single cell about 1·6 mm in diameter. It is surrounded by the *vitelline membrane* and by several layers of adhesive jelly which were added as it passed through the oviduct.

The eggs once laid adhere together in clusters and form the familiar **frog spawn.** On reaching water the jelly layers of the eggs swell and lose much of their stickiness.

Fertilization:

The eggs of amphibians are fertilized at the time they are laid. In frogs, the male clasps the female, holding her tightly with the front legs. This process is called **amplexus.** Laying of eggs in the surrounding water is a reflex act which is brought about in part by the clasping of the male (amplexus). During the clasping, the male sheds a suspension of sperms over the eggs as they leave the cloaca of the female.

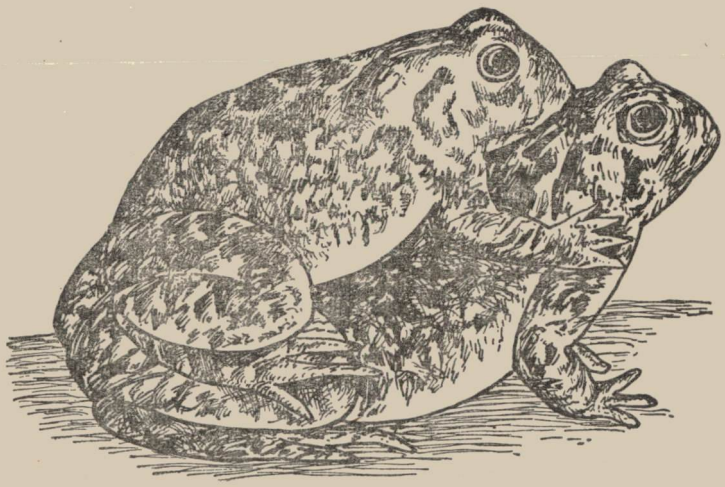


Fig. 13.2 Amplexus (Bufo fowleri).

A large number of sperms usually surround the egg mass in the water but only one of them is able to penetrate the egg membranes.

The entry of the sperm into the egg appears to induce the completion of the maturation of the secondary oocyte. The second polar body is extruded almost immediately.

At the point where the head of the sperm comes in contact with the vitelline membrane, the surface of the egg is raised into a small protuberance into which the sperm penetrates. The tail of the sperm detaches near the periphery of the egg. The head of the sperm after rotation moves towards the central region of the upper portion of the egg.

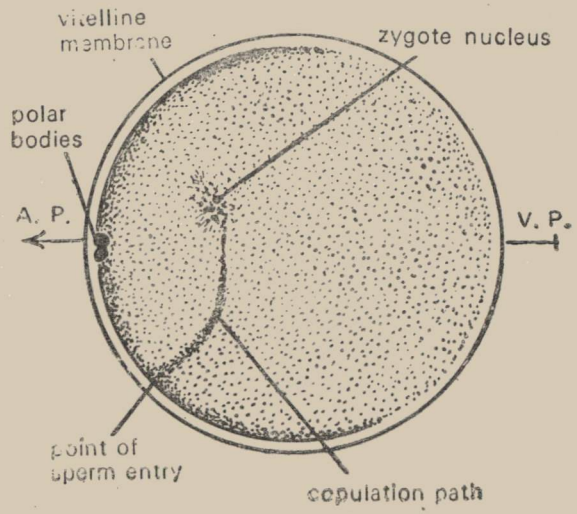


Fig. 13.3 Frog—Vertical section passing through a fertilized egg.

Within the mature egg, the sperm traverses a definite path called the **copulation path** in order to reach the **female pronucleus**. The fusion of the **male pronucleus** (i. e., sperm nucleus) with the female pronucleus (i.e., the nucleus of mature ovum) is called **fertilization** and yields a **zygote nucleus**. The fertilized egg is called the **zygote** or **oosperm**. The fertilized egg or zygote is about 1·6 mm in diameter, one half of the zygote is pigmented black and the remainder is almost white.

Polarity :

A polarity is seen in an amphibian egg in several ways.

(i) The egg is distinguished into a darkly pigmented *animal hemisphere* and a light *vegetal hemisphere.*

(ii) The yolk granules are fewer and smaller in the animal hemisphere and are larger and more packed together in the vegetal hemisphere.

(iii) The nucleus is located nearer to the animal pole, and it is there that the polar bodies are given off.

(iv) A thin cortical layer containing dark pigment granules covers the animal hemisphere and extends downward towards the vegetal pole.

(v) The vegetal hemisphere owing to the greater density of its yolk being heavier than the animal hemisphere, rotates downward and the darker hemisphere comes to lie upward. This *rotation of orientation* serves to indicate that fertilization has been accomplished.

Bilaterality :

The amphibian egg acquires bilateral symmetry soon after fertilization. The pigmented part of the cortex glides to one side like a cap, sliding sideways on a head (See fig. 13·1 B). Most commonly it glides to the side on which the sperm entered. By so doing it uncovers an area of yolk-rich cytoplasm on the opposite side of the egg. This area on account of its colour in the frog's egg is known as the **Gray Crescent**. The shift of the pigmented cortex has been referred to as the *rotation of symmetrization*, although the inner cytoplasm does not rotate at all. The gray crescent is the first visible indication of the side which will become the dorsal side of the embryo. The meridian of the egg, which passes through the animal and vegetal poles and the centre of the gray crescent, is destined to become the mid-dorsal line of the embryo. It is noted that after the *eighth cell stage*, the dorsal side of the embryo is stabilized.

At the eighth celled stage, the stabilized sides of the embryo can be recognized. The region of gray crescent is the dorsal side and

that opposite to this where the sperm entered is the ventral surface of the developing embryo. The animal pole forms the anterior end and the vegetal pole the posterior end of the embryo (See fig. 13.4).

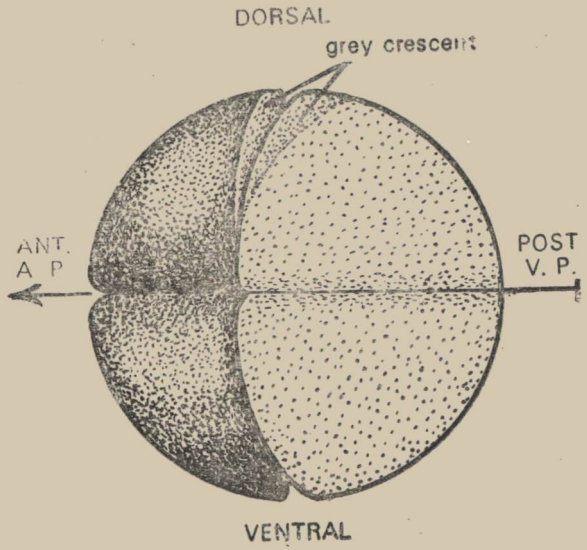


Fig. 13.4 Frog—8 celled stage from the side.

Cleavage :

The first plane of cleavage in frog's egg is *meridional*; usually it passes through the centre of the gray crescent.

The first cleavage begins as a shallow furrow at the animal pole and progresses gradually through and around the egg until it reaches the vegetal pole. It thus divides the egg into two **blastomeres** of approximately equal size.

The second cleavage also is meridional but is approximately at right angles to the first. It begins at the animal pole even before the first cleavage has completed itself at the vegetal pole. As a result of second cleavage, *four blastomeres* are formed.

The third cleavage plane is latitudinal typically at right angles to the first two cleavages. It passes well above the equator of the egg so that the eighth cell stage commonly consists of four

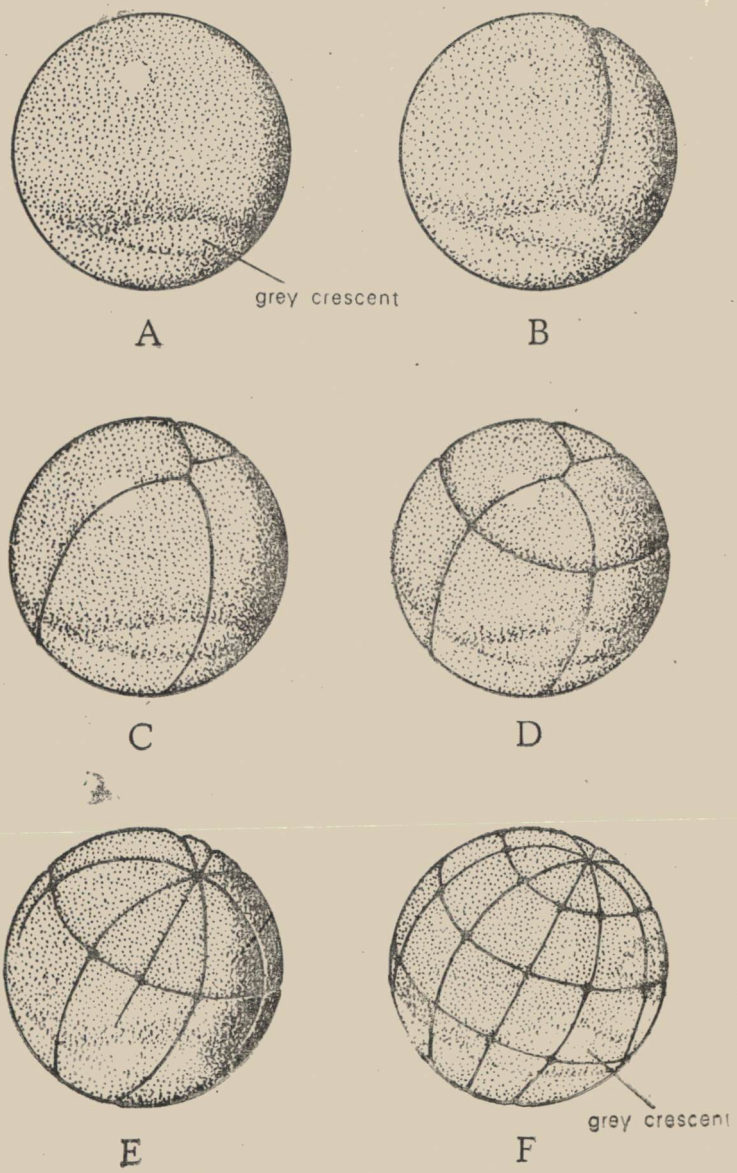


Fig. 13.5 Cleavages in frog's egg.

small animal blastomeres called **micromeres** above and four larger, yolk laden vegetal blastomeres called **macromeres** below.

During the early phases of cleavage the cell divisions are synchronous and rhythmic. However, from the third cleavage onward regularity of the cleavage tempo is lost and the blastomeres divide at differential rates. The micromeres divide faster than the macromeres. The macromeres divide slowly as the yolk hampers rapid cell division.

The Blastula: The repeated division of micromeres and macromeres ultimately produces a hollow ball of cells called the **blastula.** It's cavity is called the **blastocoel** which becomes apparent within the groups of blastomeres at the eighth cell stage only. The blastocoel is roughly hemispherical. It has a dome or roof of

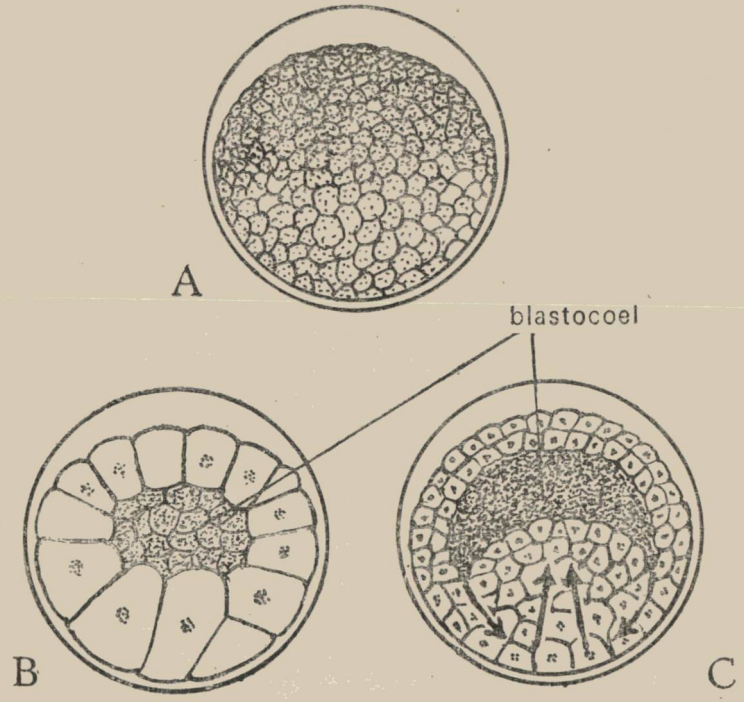


Fig. 13.6 The process of blastulation in Amphibia. The arrows in C, indicate the mass movements of the cells of the vegetal hemisphere.

smaller micromeres and a floor of larger yolk rich macromeres or vegetal cells.

As cleavage continues, the roof of the blastocoel expands and actually becomes thinner. The cells at the margins of the roof push downward on all sides while at the same time the floor of the yolk laden vegetal cells bulges upward from below. The cells from the centre of the vegetal pole area fountain upward internally until some of them reach the floor of the blastocoel. As a result of these shifts, the blastocoel takes the shape of an inverted bowl. These changes are preliminary to the mass movements of gastrulation which soon follow.

Fate Map of Blastula at the Beginning of Gastrulation :

Walther Vogt, a German investigator by the application of a stainning technique could mark out the regions on the surface of blastula and the movements of these regions during the process of gastrulation were traced. The regions so marked are referred to as the *fate maps* which show the prospective and presumptive fate of different regions of the blastula.

Vogt took small chips of agar, stained with a harmless vital dye e. g., Nile blue sulphate, Bismarck brown or neutral red. These stained chips of agar were placed for a few minutes in close contact with the surface of the egg. Brightly stained spots remained on the egg's surface. Vogt observed the changing positions of the marks and was able to draw the classic fate map of the surface of the blastula or beginning gastrula.

A fate map of an amphibian blastula at the beginning of gastrulation as drawn by Vogt showed the following three primary zones.

1. *The zone of prospective ectoderm* corresponds roughly to the animal hemisphere of the egg. It might be referred to as the *zone of expansion*, for during gastrulation it expands downwards and then converges to the vegetal pole.

During neurulation, the dorsal half of the prospective ectoderm folds inwards and becomes the brain and spinal cord. This area is called the *prospective neural plate*. The ventral half of the prospective ectoderm is the prospective epidermis.

2. *The zone of prospective notochord* and *mesoderm* also called *chorda mesoderm* is often referred to as the *marginal zone.* It is roughly a sub-equatorial belt around the blastula, although it is broader and extends above the equator on the dorsal side. It's dorsal part is approximately the gray crescent.

During neurulation, the cells of the prospective chorda mesoderm become distinguished into a central notochordal rod and several regions of mesoderm e. g., prechordal mesoderm, axial mesoderm (epimere) intermediate mesoderm (mesomere) and lateral mesoderm (hypomere).

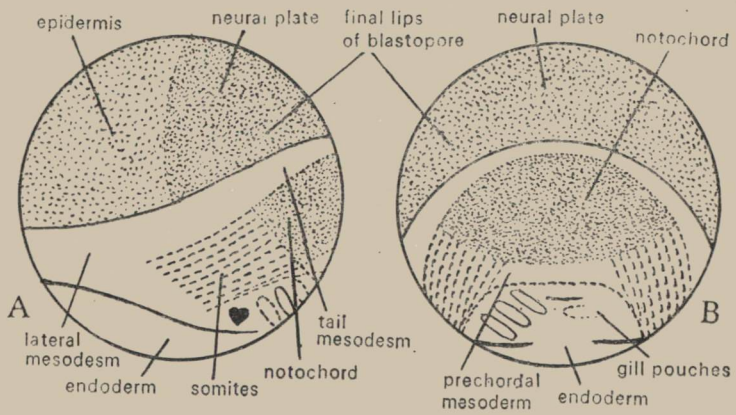


Fig 13.7 "Fate map" of an amphibian blastula
(A) Viewed from the left side. (B) Viewed from the dorsal side.

The prospective chorda mesoderm may be called the *zone of involution* also as its future fate is to roll around and beneath the lips of the blastopore. After having moved upward and dorsally on the inside of the blastula, it becomes the notochord and mesoderm (chorda mesoderm).

3. *The zone of prospective endoderm* consists of large yolk rich cells of the vegetal hemisphere but it includes also some smaller and more active cells which border the prospective chorda mesoderm.

This zone could be designated as the *zone of invagination,* because during gastrulation it sinks and glides into the interior of the egg and forms the endoderm. It is within this zone, a little below its dorsal margin, that the first slit-like *blastopore* appears.

The part of the prospective endoderm which first enters the egg during gastrulation gives rise to the lining of the fore-gut particularly the pharynx. The remaining part of the prospective endoderm becomes the yolk rich *mid-gut* from which the intestine is formed. Besides this, the large yolk filled cells of the vegetal pole come to lie on the floor of the intestine and contribute to the nutrition of the embryo.

Gastrulation :

Once the blastula is formed, or rather in the late blastula stage only, mass movement of cells actually begins. This process of mass *formative movements* of the cells of prospective areas of the late blastula is called **gastrulation** and the embryo is now said to reach the *gastrula stage*, (diminutive form of the Greek word *gaster* meaning stomach).

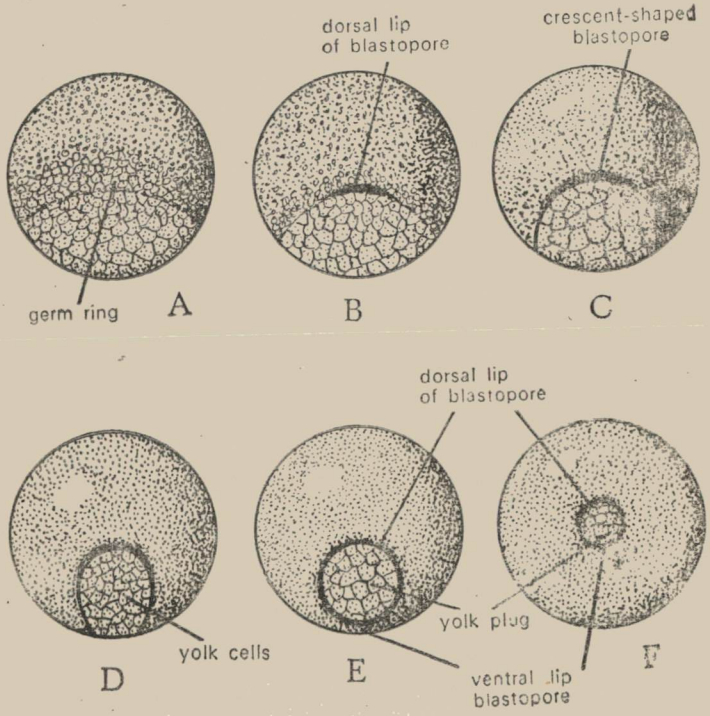


Fig. 13.8 The process of gastrulation in frog's embryo as seen from the posterior or blastoporal end.

Gastrulation is thus a dynamic process during which the major presumptive organ forming areas of the late blastula are rearranged in a way which permits their ready conversion into the body plan of the particular species.

The events occuring during gastrulation are described below.

Invagination of the Endoderm :

The beginning of the gastrulation is superficially marked by the appearance of a shallow, transverse and slightly pigmented groove on the dorsal surface of the egg. This groove is located in the region of the prospective endoderm, about half way from the equator to the vegetal pole. The groove narrows, deepens (invaginates), and then widens laterally into a crescent with its concavity towards the vegetal pole. This cresentic groove is the initial *endodermal blastopore* or **dorsal lip of the blastopore**. The crescent shaped blastopore soon widens to a semicircle, then to the shape of a horse-shoe, and finally closes to a complete circle. At the vegetal pole a mass of yolk cells called the **yolk plug** of endoderm is visible in the centre of the blastopore. Towards the close of gastrulation, the yolk plug is withdrawn into the interior of the egg.

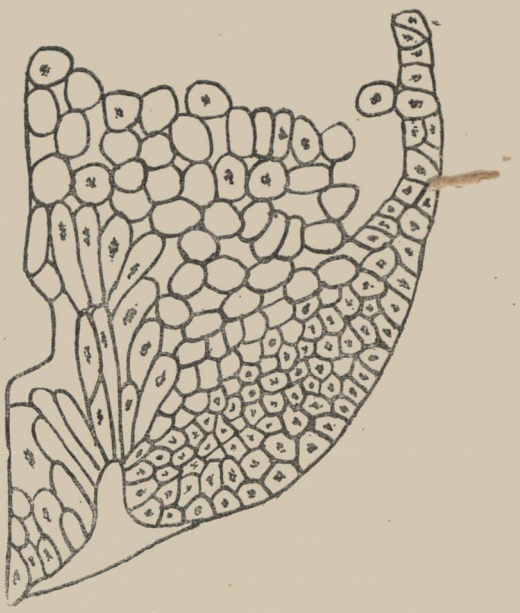


Fig. 13.9 Median section through the "beginning blastopore" of an amphibian egg.

The crescentic invagination at the blastopore is formed by the invagination of cells by changing their shapes. In order to invaginate, the cells become flask shaped by the contraction of the cortex

at their outer surface and the withdrawal of most of their substances inward. The initial furrow of invagination deepens as the flask shaped cells sink further inside the egg. At the same time, the prospective endoderm cells which border the blastopore move toward

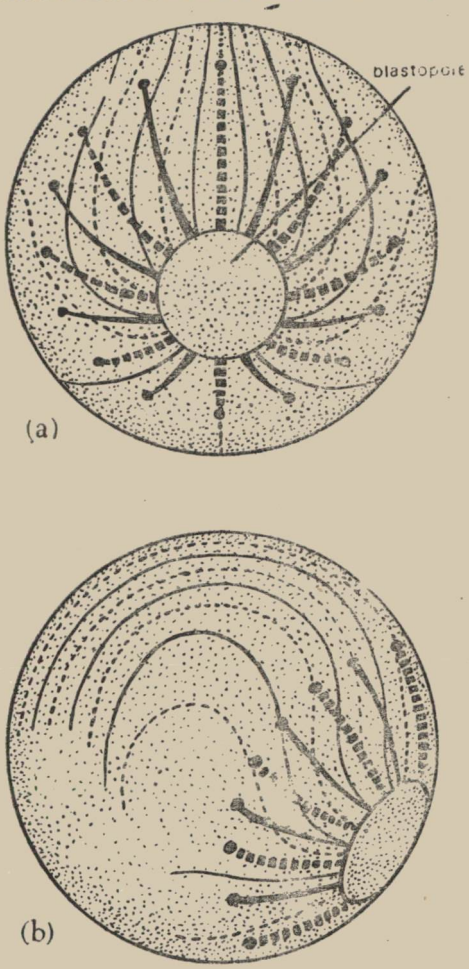


Fig. 13.10 Scheme of gastrulation in an amphibian egg (a) Gastrula seen from the blastopore and (b) viewed from the left side. Heavy lines indicate movement of materials in the outer layers of the gastrula and thin lines showing disposal of these materials inside after they have passed over the rim of the blastopore.

the furrow and follow the flask-shaped cells in. Once they get into the egg, the cells regain their cuboidal shape and expand upward toward the animal pole. The invagination of prospective endodermal cells, leads to the formation of a small groove beneath the dorsal lip

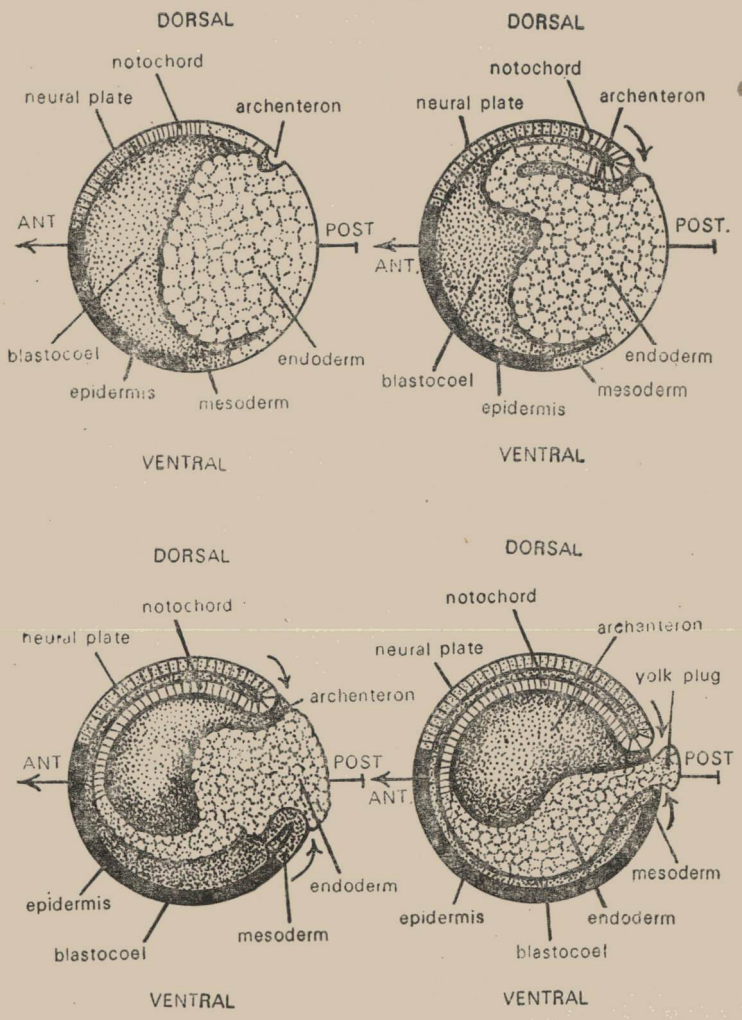


Fig. 13.11 Various stages (schemmatic sagittal sections) showing the process of gastrulation from the early stage of grastrula to a completed gastrula in frog.

of the blastopore. This small groove is the beginning of *archenteron*. Due to continuous invagination of the prospective endodermal cells the groove becomes large and turns into a distinct archenteron (primitive gut). With the enlargement of the archenteron, the blastocoel consequently becomes reduced to a mere crack.

For a brief time, the early gastrula consists of two layers. The inner layer lining the archenteron is definitely endoderm whereas the outer layer is prospective chorda mesoderm and endoderm, as well as ectoderm. We often use the terms *epiblast* (i e., outer layer; chorda mesoderm and endoderm) and *hypoblast* (endoderm) for these two transitional layers.

The invagination of the endoderm continues during the involution of the chorda mesoderm to be described later. The prospective endoderm of the vegetal zone glides beneath the descending lips of the blastopore and becomes the floor of the archenteron. The lateral margins of the endoderm split away from the mesoderm and glide upward toward the animal pole. They also move dorsally toward the mid-line. Thus, the endoderm, after invagination, forms a sort of trough which is open dorsally. The early splitting away of the endoderm from the mesoderm is not very obvious in frog for the cells of the two layers are difficult to distinguish. Later the endodermal and mesodermal cells separate apparently by *delamination*.

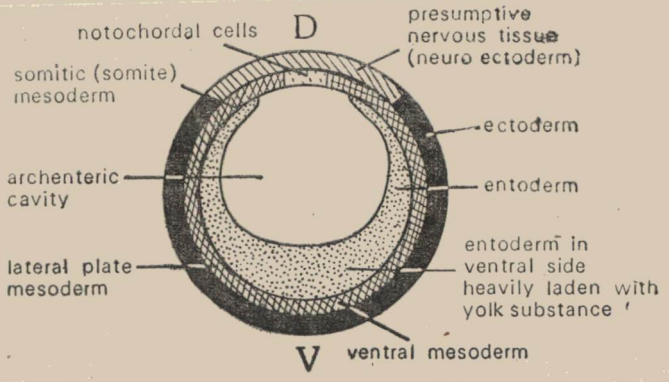


Fig. 13.12 Gastrulation in amphibia. Diagrammatic section indicating the arrangement of cellular layers during gastrulation.

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Involution of the Chorda-mesoderm :

After endodermal invagination, the chorda mesoderm cells move especially toward the dorsal and dorso-lateral lips of the blastopore, when they reach the lips, they roll around them and so disappear from sight. Once inside the egg, the chorda mesoderm cells migrate upward (toward the animal pole), keeping in close contact with the inner surface of the ectoderm. For a time, the chorda mesoderm forms the roof of the archenteron. Later, they become the notochord and the mesoderm. The chorda mesoderm cells enter the interior of the egg by *involution.* Instead of becoming flask-shaped with their broad ends inwards, as did the invaginating endoderm, they become temporarily wedge shaped with their broad ends directed outward.

Closure of the Blastopore :

The mass of yolk cells called the yolk plug which has been protruding between the lips of the small circular blastopore, finally withdraws into the gastrula. Consequent to this, the blastopore closes. It's lateral lips come together in the mid-line and the blastopore as such becomes a *vertical slit.*

The closure of the blastopore marks the end of the invagination of the endoderm, but the expansion of the ectoderm and the involution of chorda mesoderm continue for a time.

Due to the shift of the yolk laden endoderm toward the ventral side, the centre of gravity of the gastrula is changed. The ventral side now is the heaviest. As a result, the egg rotates until its dorsal side is uppermost. The animal pole area is now anterior and the region of the blastopore is posterior.

The Gastrula :

When the blastopore closes to a slit the amphibian gastrula consists of three layers of cells—ectoderm, chorda mesoderm and endoderm. The chorda mesoderm forms the roof of the archenteron. It's free lateral margins have pushed ventrally at the sides, between the ectoderm and the endoderm. The endoderm under-laps the lateral

chorda mesoderm internally and forms the side walls and floor of the cavity of the archenteron.

The anterior portion of the archenteron is broad and thin walled. It consists of the endodermal cells which are first invaginated. It becomes the *fore-gut.* The fore-gut, near its anterior end adheres closely to the ventral ectoderm. This is the site of the *oral plate* which later breaks through and becomes the opening of the mouth. The major portion of the endoderm, consists of the larger yolk laden cells of the mid-gut, that is of the intestine. Later, the cells of the ventral blastoporal lip give rise to the *hind-gut* from which the cloaca is formed.

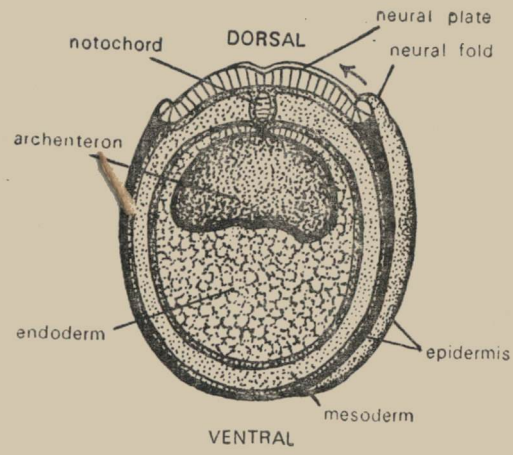


Fig. 13.13 Early neurula—anterior half.

It was mentioned that the endoderm after invagination is in the form of a trough open dorsally. During neurulation (to be described), the free lateral margins of the endoderm move upward to the mid-line beneath the notochord. Here they fuse and form a new or secondary roof over the gut. The gut is thus no longer an archenteron (primitive gut) but an enteron.

Neurulation :

Neurulation is the process by which a *neural plate* forms. This then folds or otherwise transforms into a *neural tube.*

During neurulation, also, the chorda mesoderm sub-divides nto the notochord and several regions of mesoderm. The mesoderm

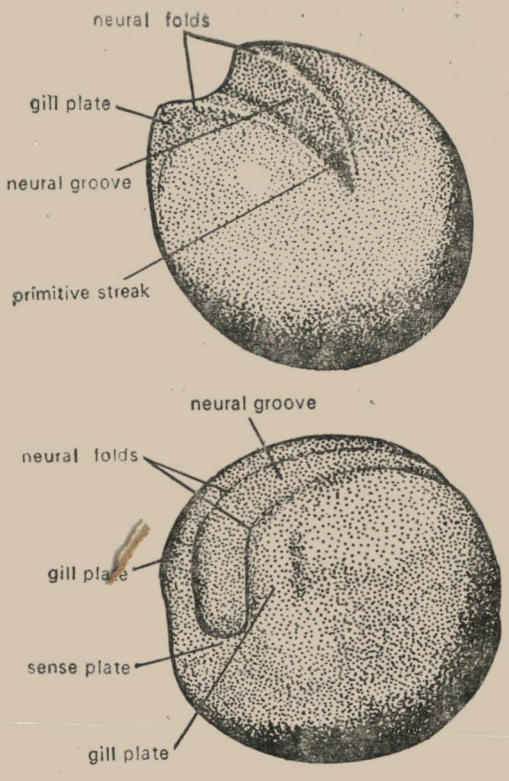


Fig. 13.14 External appearance of frog embryo in the neural stage

pushes anteriorly and laterally between the ectoderm and the endoderm until it almost completely surrounds the embryo. At the same time the free dorso-lateral margins of the endoderm move dorsally and close in, beneath the notochord.

The Neural Plate and the Neural Tube:

At about the time the blastopore closes to a slit, the **neural plate** becomes visible. The neural plate is a racket shaped area of dorsal

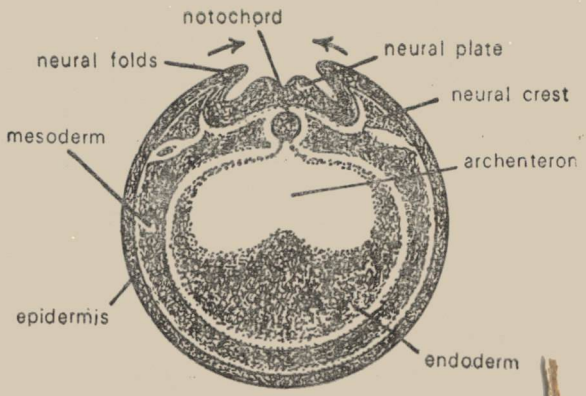


Fig. 13.15 Transverse section of the early neurula

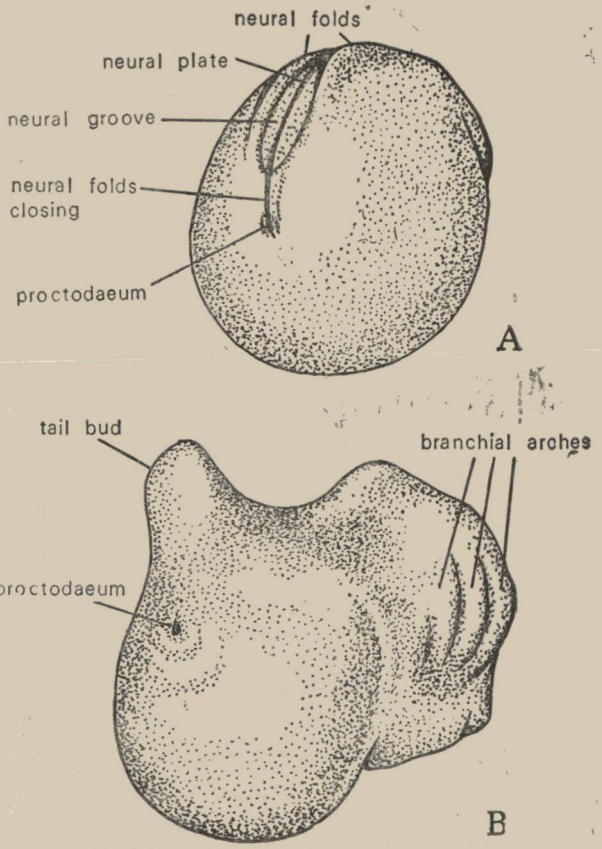


Fig. 13.16 (A) Early neurula with a neural groove
(B) Late neurula, tail bud forming.

ectoderm. It is broadest at its anterior end and is narrower posteriorly toward the blastopore. The neural plate is somewhat thicker than the surrounding epidermis and is usually pigmented. The neural plate shows a shallow, central longitudinal groove called the *neural groove*. This extends from the centre of the broad forward area of the neural plate back to the dorsal lip of the blastopore.

The margins of the neural plate soon rise up as the **neural folds.** The neural folds move toward the mid-dorsal line. The neural folds eventually come together and fuse at the mid-dorsal line to form the **neural tube.** The cavity of the neural tube is called the *neurocoel.*

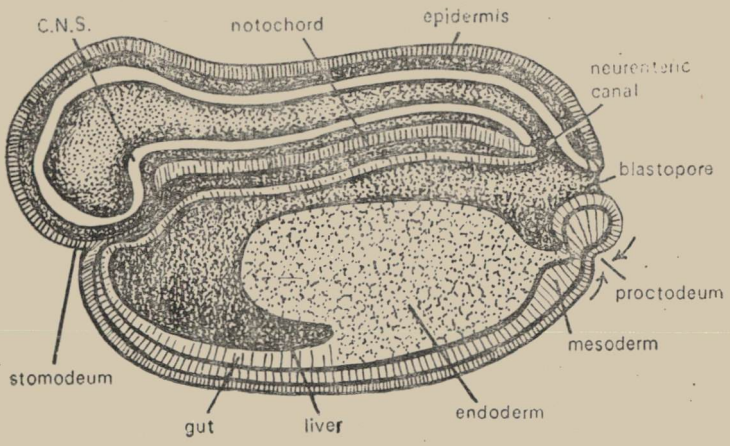


Fig. 13.17 Frog—Sagittal half of the late neurula.

At the anterior end of the neural folds an opening called the *anterior neuropore* remains for a brief time. Likewise, at the posterior end, the neural folds terminate at the lateral lips of the blastopore. When ultimately the neural folds at the posterior end come together, they enclose the dorsal opening of the slit-like blastopore. In this way for a brief time, there is potentially a passage way between the cavity of the neural tube (neurocoel) and the cavity of the gut (enteric cavity) which is known as the *neurentric canal.*

Neural Crest :

Along the margins of the neural plate are found certain cells known as the *mesectoderm*, separating from adjacent epidermis. They form what is known as the *neural crest*. The cells of the neural crest, unlike the cells of the neural plate proper, lose their epithelial character early, become loose and migrate individually. The cells of the neural crest give rise to various tissues, notably the *nerve ganglia*, *pigment cells* and certain *cartilages of the head*. Some of the neural

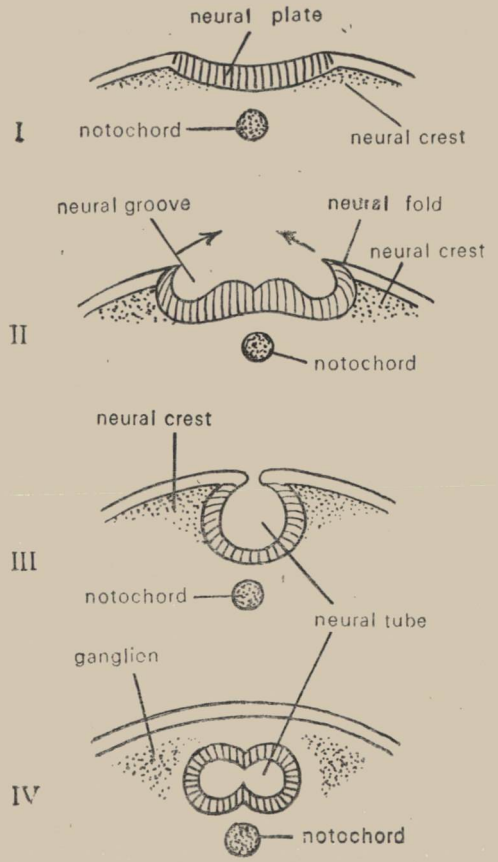


Fig. 13.18 Diagrammatic representation of the various stages in the formation of the neural tube.

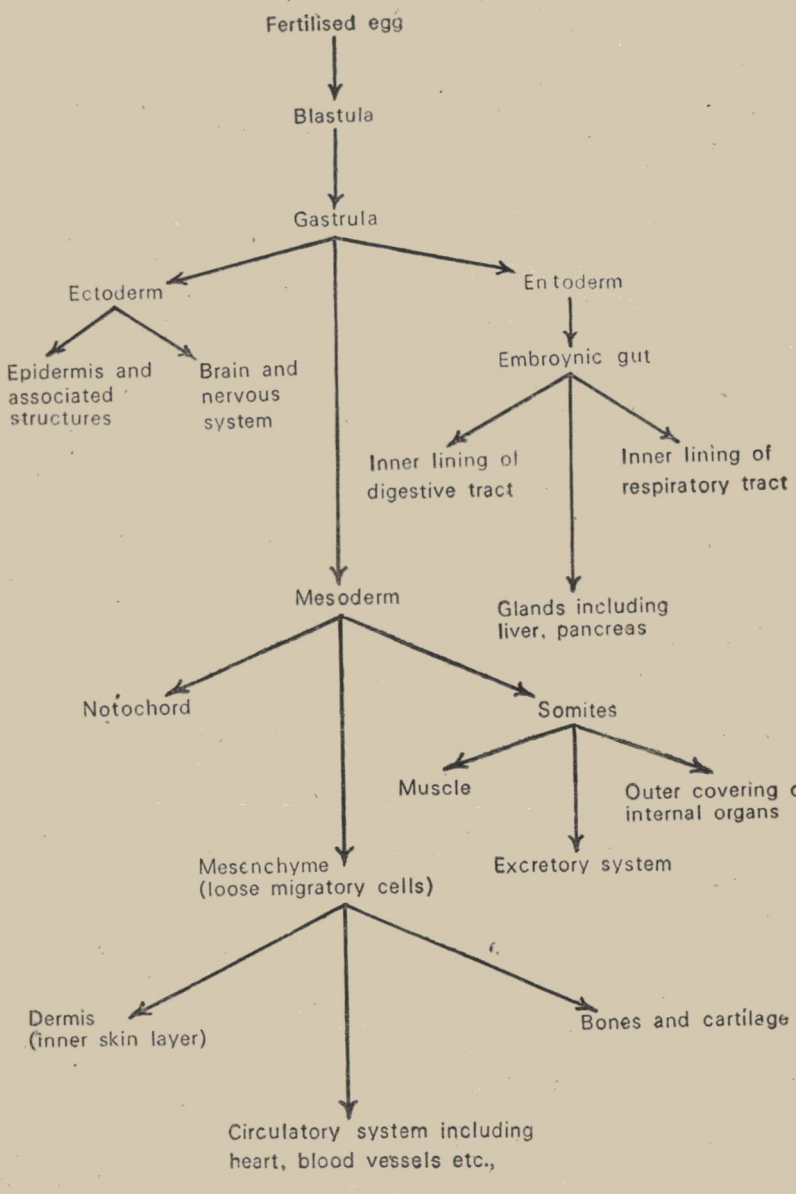


Fig 13.19 Chart showing the names of certain structures derived from the three layers in the gastrula. i.e., ectoderm, endoderm and mesoderm

crest cells also give rise to mesenchyme. An important product of this mesenchyme it the visceral arch skeleton.

Organogeny : In the later stages of development from the three germ layers, the main embryonic organs are elaborated. This phenomenon of the formation of organs is referred to as **orgonogeny** Certain important organs and structures elaborated from the three layers of the gastrula are summarised in the chart (Fig. 13·19).

Once the three germ layers reach their final positions with respect to one another, their fates begin to be determined. It should however be remembered the development of unified organs depends upon the normal interaction between germ layer and germ layer. (cf. Embryonic induction and inductive reactions).

Development of the Brain :

As regards the development of the nervous system, the wider end of the neural tube develops internal ridges and soon three primary cerebral vesicles, the *fore-brain*, the *mid-brain* and the *hind-brain* are distinguished. The *spinal cord* develops from the remainder of the neural tube.

The Development of the Notochord :

As already stated, the chorda cells in the completed gastrula lie as a narrow sheet of cells in the mid-dorsal region of the roof of the archenteron. These chorda cells at first are not very clearly distinguishable from the mesoderm lying on either side of the chorda cells. The mesodermal cells soon get separated from the chorda cells by a narrow cleft. The chorda cells later arrange themselves in the form of a cylindrical rod which also assumes the chacteristic vacuolated appearance. Around this cylindrical notochord, the **notochordal sheath** develops.

Further Development of the Mesoderm :

At the completion of the process of gastrulation, the bulk of the mesodermal cells lie closely applied, almost like a mantle, to the

endoderm cells. They are, however, clearly demarcated from the ectoderm. Very soon the differentiation between the endoderm and mesoderm becomes apparent. The mesodermal sheets on each side of the notochord, first get separated. Later the mesodermal sheet, several cells thick, from each side of the notochord, extends almost down to the mid-ventral line, even in the region where the large yolk containing cells lie piled up in the floor of the archenteron. Each mesodermal sheet thus extending downwards towards the mid-ventral line forms the **lateral plate mesoderm** also referred to as the **lateral plate.** As extension of lateral sheets of mesoderm towards the mid-ventral line proceeds, a split appears in the mesoderm. The cavity thus formed in the mesoderm by this split is called the **coelome.** On account of the appearance of coelomic cavity, the lateral plate mesoderm is thus separated into two layers. At outer one of **somatic mesoderm** and an inner one of the **splanchnic mesoderm.** The two halves of the lateral plate mesoderm by the breaking of their intervening walls, meet in the mid-ventral line. Due to this, the coelom extends mid-ventrally as well. When fully formed, the coelome extends, except near the mid-dorsal line, around the developing gut. The coelomic cavity contained by the somatic and splanchnic layers of lateral plate mesoderm forms the **general body cavity,** also referred to as the **Peri visceral cavity** or the **Splanchnocoel.**

The mesoderm lying on each side of the notochord, divides into segments or **somites** and is called **dorsal mesoderm** or **segmental plate.** It can be distinguished from the lateral plate mesoderm by becoming metamerically segmented. Between the segmental mesoderm (somites) and the lateral plate mesoderm, lies an intermediate region which forms the **nephrotome.**

From each somite, three embryonic structures are derived. (1) The **myotomes** which give rise to the voluntary muscles of the body. (2) The **dermatomes** from which mesodermal parts of the skin (e.g., the deeper layer of the skin and the connective tissue) are obtained. (3) The **sclerotome** from which the skeleton is developed. Portions of the coelom are present within the **somite** and **nephrotome.** The coelomic cavities are referred to as **myocoel** and **nephrocoel** respectively. Anteriorly, in the region of the pharynx where the development of the somites is interfered, by the development of the

sense capsules (particularly auditory capsules) and the viscerals clefts, the coelome is restricted to a ventral portion. This ventral portion of the coelom later modifies and separates from the splanchnocoel to form the **pericardial cavity.** In this region, only the rudiments of the **heart** are laid down.

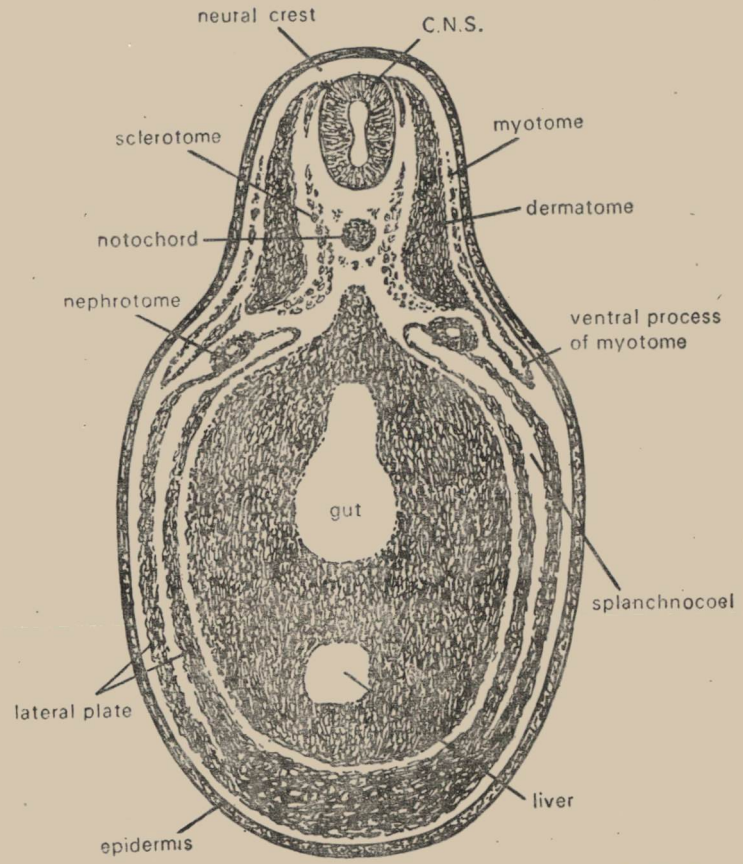


Fig. 13.20 A transverse section passing through a young tadpole through the region of trunk.

The Archenteron and the Gut :

As stated earlier, the small cavity appearing beneath the crescent shaped notch of the blastopore is the beginning of the **archenteron.**

The slit-like archenteric cavity in the course of development expands dorsally and laterally with continued involution of cells at the blastopore. The archenteric cavity thus expands gradually obliterating thereby the blastocoel, which is ultimately eliminated totally. The roof of the archenteron is composed of the involuted layers of cells, endoderm, mesoderm and beyond this the outer layer ectoderm. The floor of the archenteron is filled up with yolk containing cells, several layers in thickness. Eventually the invaginated prospective endodermal area forms the walls of the archenteron with the exception of a narrow cleft immediately beneath the notochordal cells.

The anterior and the dorso-lateral endodermal walls of the archenteron are thin but the floor as stated, for sometime, is filled

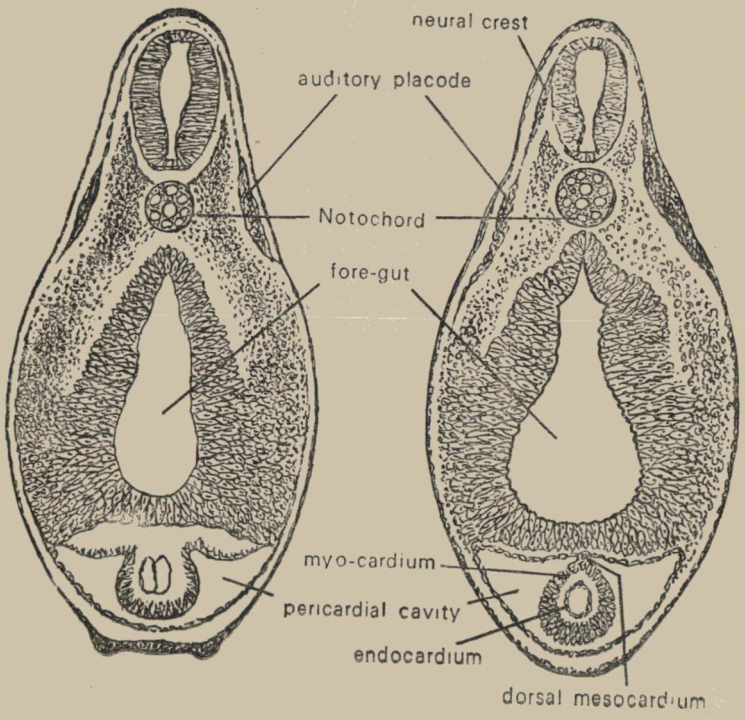


Fig 13.21 Stages in the development of pericardial cavity
Section passing through the region of the fore-gut

up with yolk laden cells. When the notochord differentiates, the upper edges of the endoderm meet and fuse in the mid-dorsal line and thus the roof of the archenteron is also completed. At the posterior end for sometime, the blastopore is occluded by the yolk plug which is later withdrawn into the floor of the archenteron. In the meanwhile the blastopore loses its circular shape and by the meeting of the central portions of the lateral lips it becomes elongated dorso-ventrally and this part is now referred to as the '**primitive streak**' (Fig. 13·14). The neural folds above the blastopore as stated, meet to form the neurenteric canal. The lower part of the primitive streak marks the position of the future invagination of the ectoderm to form the proctodeal invagination. The proctodael invagination or **proctodaeum** (Fig. 13·16A & B) eventually establishes connections with the posterior part of the archenteric cavity.

At the anterior end, ventral to the neural tube, in the middle of an elevated area of ectoderm, a similar invagination of the ectoderm appears giving rise to **stomodeum.** The buccal cavity develops from the stomodeum. Further, from the stomodeal invagination, below the fore-brain, the hypophysis arises which contributes to the formation of the pituitary body. The archenteron as mentioned, lined by the endoderm, forms the **mesenteron** (mid-gut) and its derivatives.

Soon after the completion of gastrulation, the mesenteron differentiates. The anterior region of the mesenteron forms the pharynx, the oesophagus and the stomach. The posterior part becomes the lining of the intestine.

The anterior region of the mesenteron is a wider and more spacious cavity with relatively thin walls. Immediately behind the anterior region is a depression in the floor of the gut. This depression is called the **liver diverticulum**. The cells of the wall of this diverticulum later proliferate to form the **liver.** The lumen of this diverticulum persists as the lumen of the bile duct.

Visceral Pouches :

At about the time of hatching, five pairs of **visceral pouches** push from the lateral walls of the pharynx towards the ectoderm.

The most anterior is the *hyoid pouch*, which never opens to the exterior but ultimately gives rise to the *tympanic cavity* of the *middle ear* and the *eustachian tube*. The remaining four pouches meet

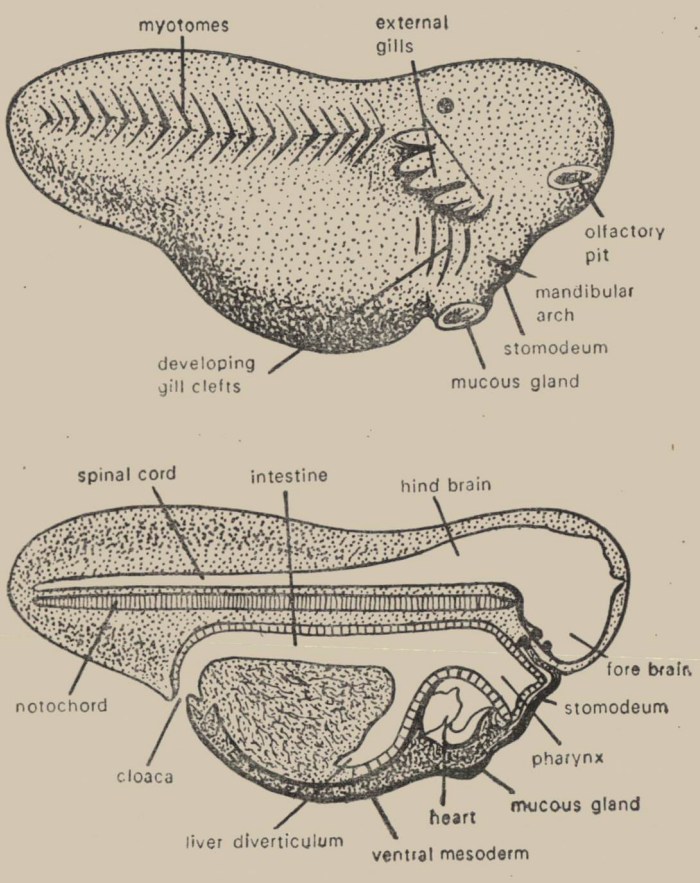


Fig. 13.22 Above : Tadpole soon after hatching.
Below : Longitudinal section passing through the same.

groove-like depressions of the surface and open through them to the exterior as the *four branchial clefts*. The hyoid and branchial arches of the visceral skeleton develop later in the mesodermal tissue behind the hyoid and branchial pouches respectively.

External Gills :

The three pairs of external gills grow out from the inter-branchial septa behind the first three branchial pouches. The three pairs of external gills grow rapidly into plume-like structures. These external gills begin to function at hatching but they have however only a transitory existence as they wither away soon after the formation of the operculum or gill cover.

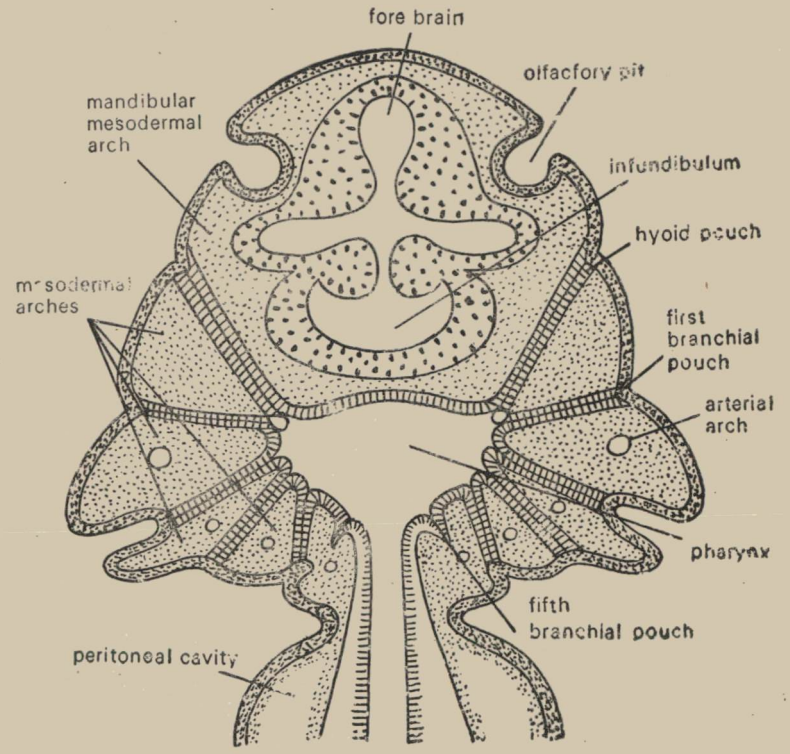


Fig. 13.23 A horizontal section passing through the anterior end of a tadpole at the time of hatching. The five visceral pouches have formed but none has yet opened.

The Development of an Operculum :

Very soon after the formation of the branchial clefts, a fold of skin begins to grow backwards on each side from the hyoid arch.

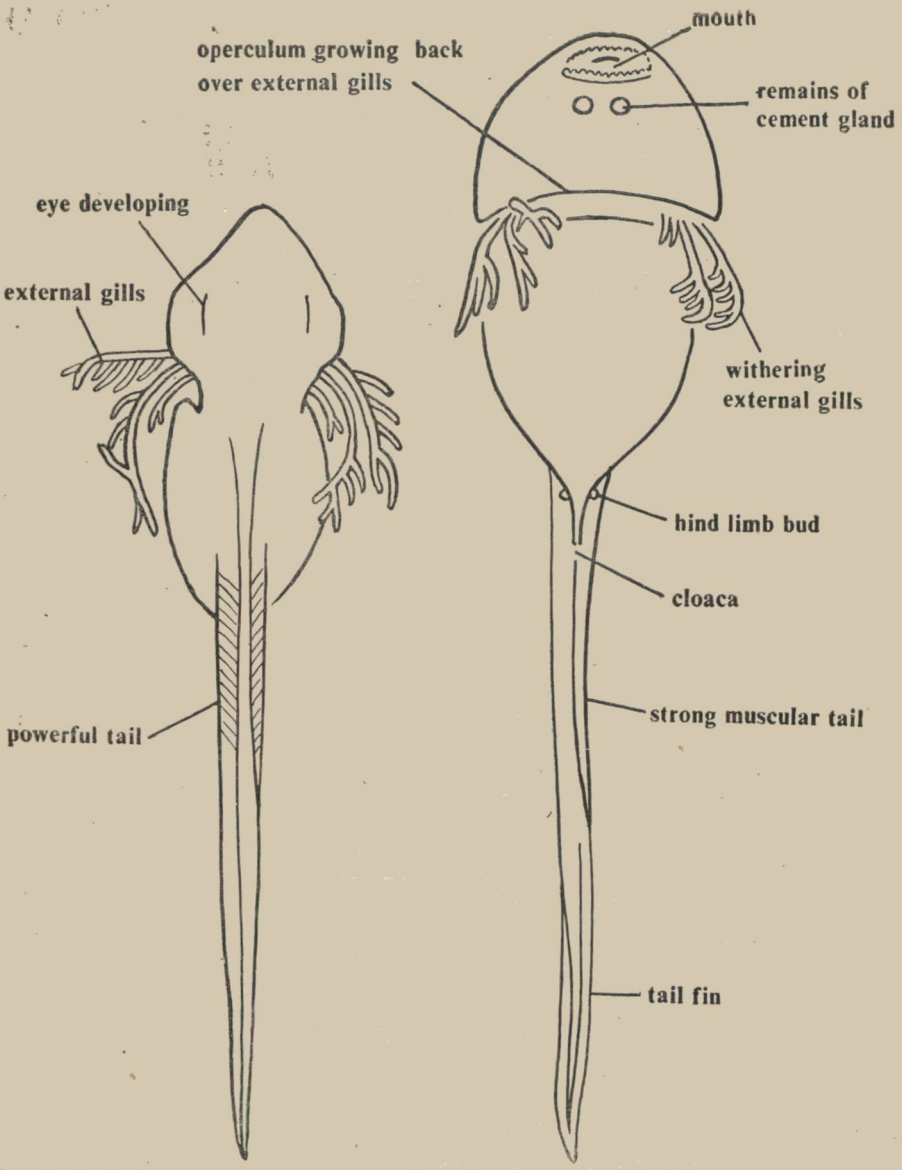


Fig. 13 24 Left : Tadpole with three pairs of external gills. Body and gill surfaces are ciliated to create stream of water over gills. Right : Tadpole two weeks after hatching showing the operculum growing over the external gills.

The two folds fuse with one another ventrally, while, dorsally they pass into the body wall. Thus, they form a sort of outer coat covering over the branchial clefts and external gills. The fold enclosing the branchial clefts and the external gills is called the **operculum** and the cavity beneath it is the *opercular chamber* or *peribranchial chamber*. The thin posterior border of the operculum finally fuses with the skin behind the branchial clefts, but at one point *on the left side*, a small *spout-like funnel* opens to the exterior through the *spiracle*.

In breathing, water passes from the mouth and the pharynx through the branchial clefts into the opercular cavity and thence out again through the spiracle.

The Second set of Gills or Internal Gills:

As the operculum develops, the three pairs of external gills gradually diminish in size and eventually undergo total atrophy. The first set of gills or the external gills are however replaced by four pairs of internal gills more ventrally on the inter-branchial septa of the first, second, third and fourth branchial pouches.

The internal set of gills differ from the external set in being invisible externally as they are covered by the operculum. Further, the second set of gills comprises four pairs of gills as against three pairs of external gills. The fourth pair of internal gills arise on the fourth pair of internal septa. The fourth internal gill however consists of a single gill filament.

The term internal gills is not suitable for the second set of gills because they are no more internal than are the former gills. It it rather more appropriate to call the first set as *primary gills* and the second set, the *secondary gills*.

In the process of respiration, the water is taken in from the mouth and from the pharynx through the branchial clefts and is passed over the internal gills where the exchange of gases takes place. The water eventually enters the gill chamber from where it is expelled to the outside through the spiracle situated on the left side of the body of

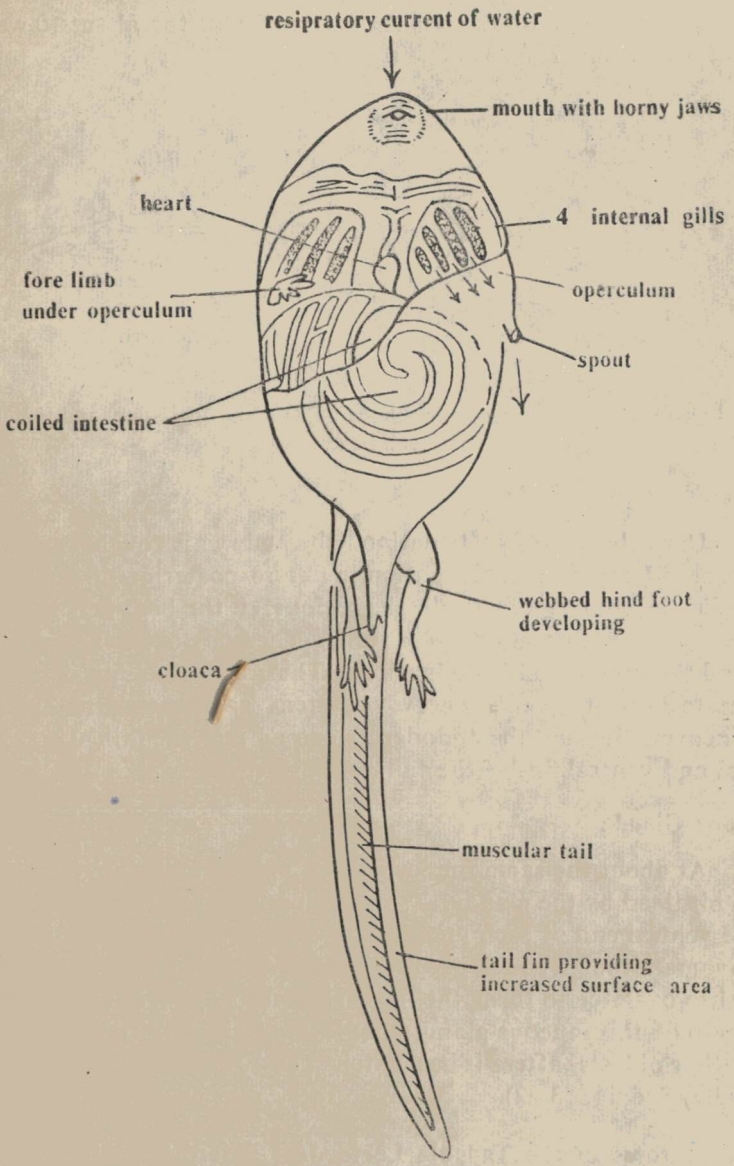


Fig. 13.25 Ventral view of a dissected tadpole. The spirally coiled intestine and the internal gills can be seen.

the tadpole. The tadpole uses the internal gills for about 10 weeks during which time it feeds actively and grows.

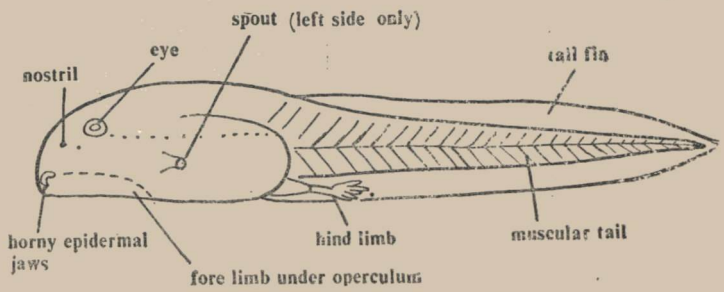


Fig. 13.26 Tadpole seen from the left side. The operculum and the spout can be noticed.

Formation of the Tail:

Upto the end of gastrulation, the embryo is roughly spherical in shape. Later on, an elongation in antero-posterior direction sets in. This of course, affects all the regions of the body but is accensuated by the formation of a tail. The body extends backwards beyond the proctodeal invagination. Thus, a distinct tail is formed. The notochord, the central nervous system, the mesoderm and the mesenchyme (but not the endoderm) extend into the tail. Later, the dorsal and ventral fins of the tail are formed.

Mucous Gland:

At about the same time when the external gills are forming, a deep pit lined by the glandular epithelium develops in the ectoderm at the ventral end of each mandibular arch (i. e., the tissue between the hyomandibular pouch and the stomodeal invagination). These pits then coalesce to form the **mucous gland** or *cement gland.* With the help of this mucous gland, the larva attaches itself to weeds and other objects, after it has hatched and wriggled out free from the jelly (See fig. 13·22).

Chief Features of the Tadpole Larva Just Before Hatching:

The larva which hatches from the egg is called the **tadpole larva.** Under normal conditions, the tadpole hatches from the egg membranes about fourteen days after fertilization.

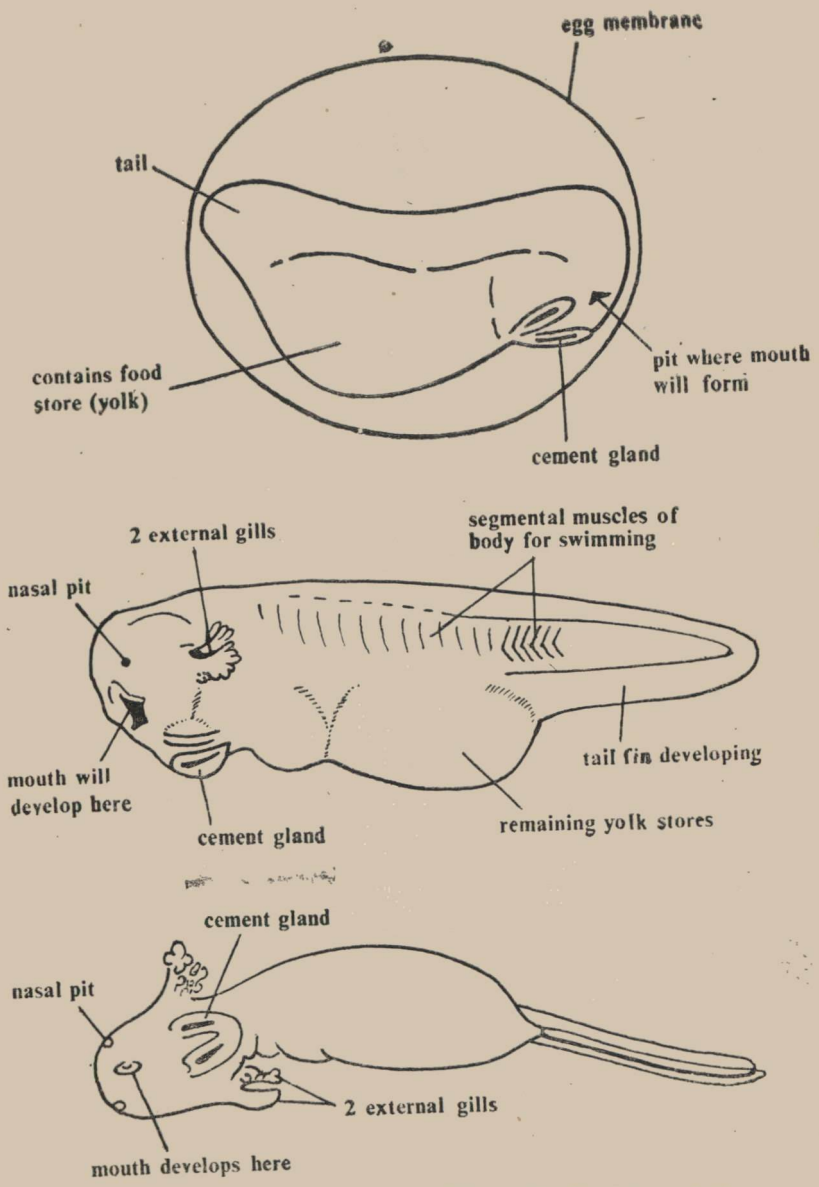


Fig. 13.27 Above : The embryo of frog with albuminous jelly.
Middle : Tadpole just hatched seen from the left side.
Below : Just hatched tadpole seen from below.

The tadpole that hatches is about 7 mm. in length and is a small, blackish, fish-like creature.

The neural tube is completed, the neurenteric canal closes; and further the rudiments of the related structures including the organs of special sense are already laid down. The gut is in the form of a straight tube. In the pharyngeal region, four pairs of visceral pouches are present but they do not as yet open to the exterior. The gut at this stage has one opening, the *anus*. The heart is in the form of a simple S-shaped tube but begins to show divisions into chambers. The blood vessels start developing in the mesoderm. Three tubules of the pronephros are as yet present, but the longitudinal duct reaches back to the cloacal (proctodeal) region (Fig. 13·28).

The ectoderm of the tadpole is ciliated. It has a tail but the tail fins have not developed. In this condition, the fish-like creature called the tadpole larva is ready to hatch.

Hatching of Larva :

At the time of oviposition, it was mentioned that the egg mass swells up by the absorption of water. The egg mass has the consistency of firm compact jelly. This state persists from cleavage to the completion of gastrulation. In the post gastrula phase, the compact jelly becomes progressively softer and when the young larva is ready to hatch it becomes very loose and watery.

As the jelly of the egg mass becomes soft, the embryo begins to move within the perivitelline space. The ectoderm cells of the gastrula develop cilia which persist until several days after hatching. By means of ciliary movement, the young embryos are always in a rotary motion within the perivitelline space. When the myotomes are differentiated, the embryos now and then contract, curving the body to the right or left side. As the tail bud is formed, these movements become more frequent and vigorous. This type of movement finally enables the young larva to make its way through the softened jelly mass.

Upon emerging, the young tadpole larva swims for a few seconds and then drops resting on its sides. This movement is

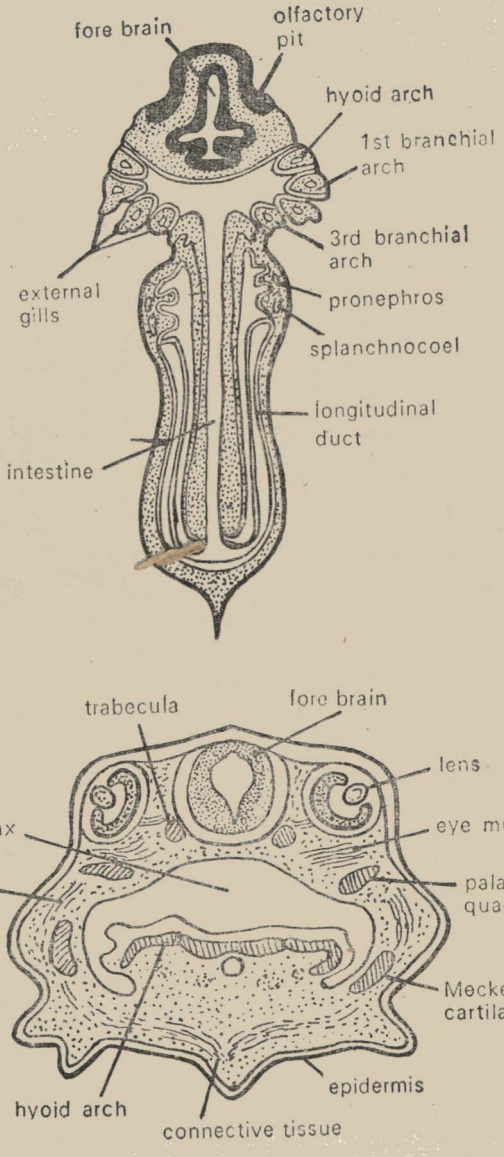


Fig. 13.28 Above : Horizontal section through a newly hatched tadpole. Below : Transverse section through the head region of a 12 mm. larva.

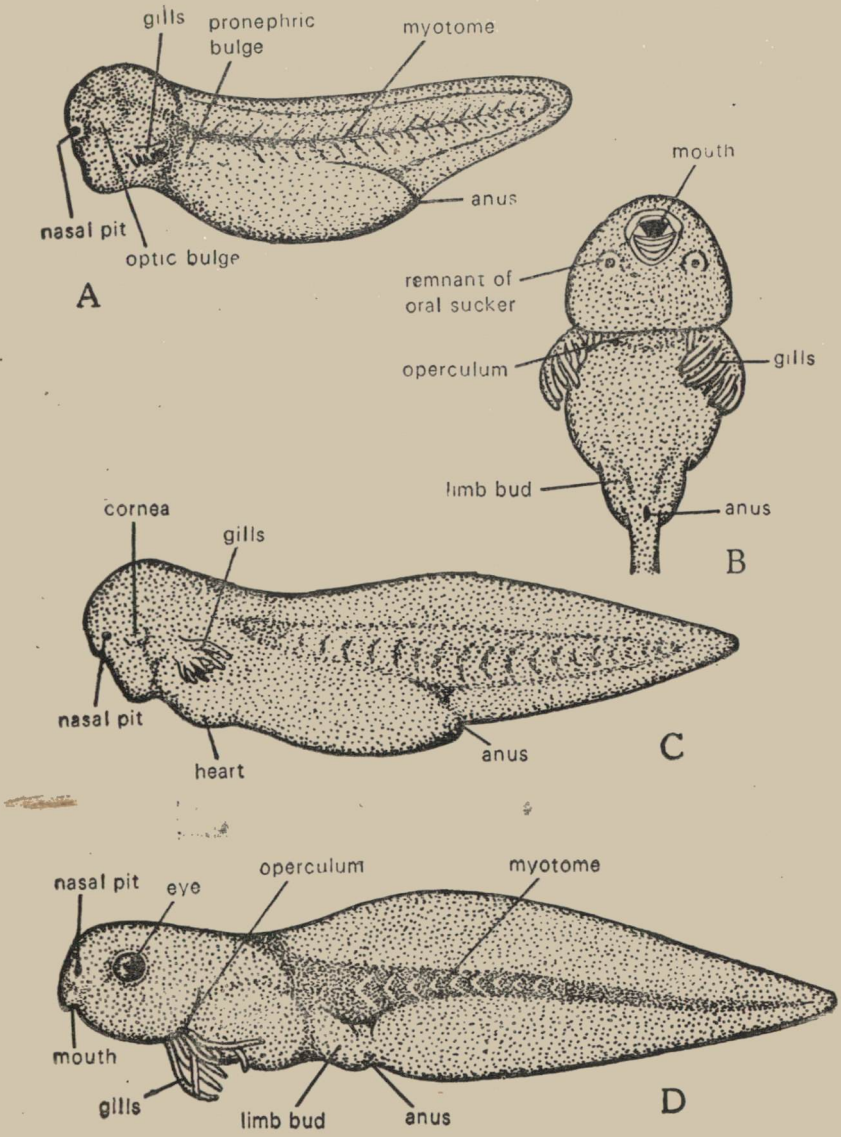


Fig. 13.29 The external appearance of the tadpole larva of frog with reference to the gills and the formation of the operculum. (A) Larva at the time of hatching. (B) Tadpole seen from the oral surface. (C) Larva of 8 mm. in length. (D) Larva of 12.5 mm. in length.

repeated until the tadpole locates a place, where it will attach itself to the surrounding object by means of its mucous glands which produce a very sticky secretion. The larva may stay attached for several hours and then swims again for a few seconds in search of a new location.

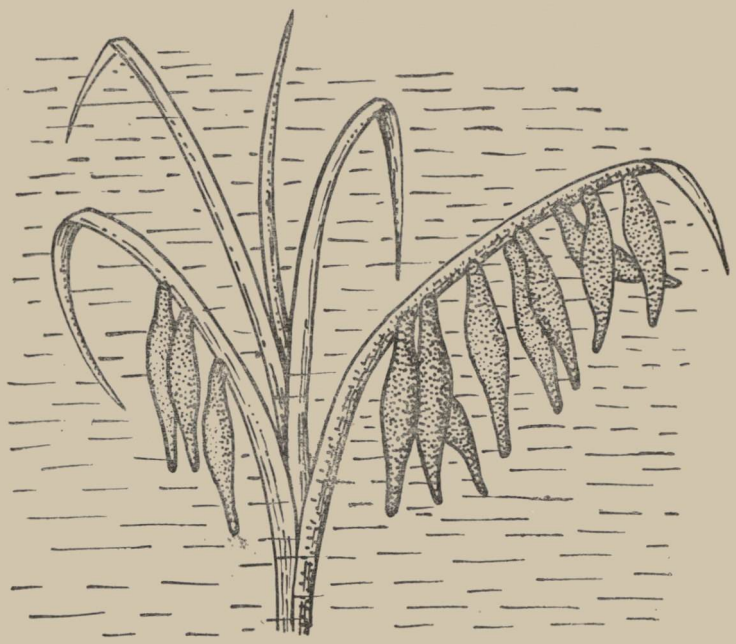


Fig. 13.30 The young tadpoles attached to the waterweeds.

During the early larval period, no food is taken in, from the environment. As a matter of fact, the stomodeal depression is present and the mouth has not been formed as yet. The larva lives for sometime at the expense of the yolk contained in the yolk cells.

The Gut:

When the tadpole is approximately 8 mm long, the **stomodeum** or **oral plate** breaks through and establishes connection with the pharynx. The **mouth** is thus formed which is oval in outline. With the formation of the mouth, at the same time, the visceral clefts are also completed connecting the exterior with the pharynx. The mouth

becomes surrounded by a pair of **horny jaws.** The upper horny jaw consists of three rows of very small **horny cones** also referred to as **'teeth.'** The lower jaw has four such rows of horny cones. These horny cones are formed by ectodermal epithelial cells, and when mutilated or lost, are immediately replaced by others. These teeth are composed of merely a cornified epithelium and are not homologous to the true teeth found in the adult frog. The teeth of the adult frog are partly ectodermal and partly mesodermal in origin.

The mouth leads into a spacious **oral** or **buccal cavity** lined by ectoderm. The remainder of the alimentary canal is lined by endoderm excepting the anal region which is formed by the ectodermal proctodaeum. The oral cavity is followed by the **pharynx.** It is a very highly specialised region in the frog's larva as well as in all other vertebrates. It is chiefly characterised by the presence of visceral arches and clefts as already mentioned. With the utilisation of the yolk cells, the **mid-gut** region of the larva begins to elongate and twist upon itself in the formation of the **intestine.** *As the tadpole is herbivorous, it needs a long intestine. The intestine of the larva when fully formed is nine times the length of the tadpole and is arranged in a double coil resembling the spiral of a watch spring.* (Fig. 13·25). At the time of metamorphosis when the frog assumes a carnivorous feeding habit, the intestine shortens considerably as a shorter intestine is sufficient for this type of feeding.

The Tail:

Other internal changes are also to be noted in the tadpole larva. The elongation of the tail takes place. With the formation of a dorsal and a ventral tail fin, the tail assumes the function of a powerful locomotory organ. The other striking features of the young larva are the paired chevron-like myotomes. The trunk from the head to anus contains twelve or thirteen of them and the remainder totalling well over forty are added by growth in the tail region. The strong tail musculature enables the young tadpole to swim about rapidly by undulating movements of the tail (See figs. 13·26 and 13·29).

Sense Organs:

The nasal pits appear as two small pores on the anterior aspects of the head. The eyes which are still in formation, can be

identified laterally by their circular outline on a slightly higher level and just behind the nasal pit. Still further back in the region of the hind brain, beneath the ectoderm can be identified the auditory capsules. In addition to these sense organs, the *lateral line sense* organs which are characteristic of fishes also develop by the time, the larva assumes a length of fifteen millimetres. The oral sucker or the mucus gland begins to degenerate. The vascular system is fish-like and remains as such till the lungs develop.

The Lungs:

Soon after hatching, the lungs were apparent as small buds from the posterior end of the pharynx. The lungs make their appearance as the median laryngotracheal diverticulum in the posterior region of the pharynx in the 10 mm. larva. The lungs proper branch out as two separate sacs from the posterior region of the diverticulum. In the later life of the larva, the lung sacs branch out into smaller units and still smaller units called the *branchioles*. The lungs become functional after about three months of larval life, when the tadpoles come to the surface of the pond and gulp bubbles of air. The internal gills begin to degenerate and at metamorphosis the gill slits become obliterated by the over growth of epithelial cells. The right operculum fuses with the skin followed by the fusion of the left operculum also with the skin.

The Kidneys:

The pronephros is the larval excretory organ. It begins to function at the time of hatching of the larva. The pronephros is gradually replaced by the mesonephros. The mesonephros develops tubules when the larva attains a length of 12 mm. Thus, the kidney (mesonephros) of adult frog begins to form.

The Limbs:

The limbs appear as buds from the body wall. At first only the hind-limbs are visible from the outside. The fore-limbs lie hidden beneath the operculum, wherein a prominent bulge can be

noticed. The fore-limbs emerge however shortly before metamorphosis. During this process, the operculum on the right hand side becomes thin and weak and then perforates to form a hole through which the fore-limb on the right side pushes out. The left fore-limb emerges through the spiracle.

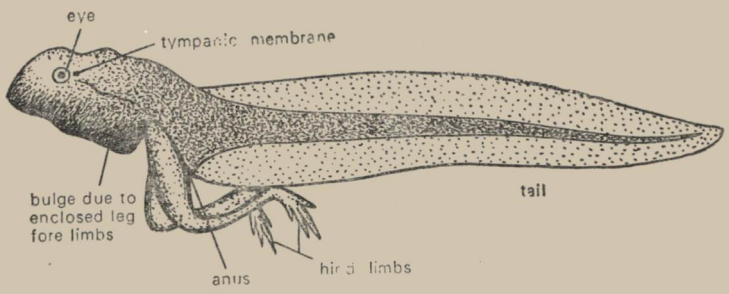


Fig 13.31 A tadpole larva in which a bulge due to the enclosed fore-limbs can be seen. The hind-limbs are visible.

Skeletal Structures :

In the embryo and the early larva, the notochord is the only skeletal structure. With the appearance of the limb buds, a cartilaginous skeleton is laid down. The cartilaginous skeleton persists throughout most of the larval life of the tadpole. The cartilaginous skeleton of the larva however during and after metamorphosis is largely replaced by bone.

Metamorphosis :

The tadpole larva as we have studied is quite a different creature — *morphologically*, *physiologically* and *ecologically*, from an adult frog.

The transformation from the larval to the adult condition is called **metamorphosis.** In some animals, metamorphosis involves gradual changes, but for many others it is characterised by sudden and dramatic alterations in their appearance, life habits, biosynthetic patterns and physiology. The term **metamorphic climax** is applied to the period when radical changes occur most rapidly in metamorphosis.

In amphibians as in insects, secretion of a kind of brain (hypothalamus—neurosecretory area) hormone is involved in the initiation of metamorphosis, and a hormone triggers the catacylsmic destruction of larval organs and the growth of hitherto quiscent structures (cf p. 317– 319). In the case of amphibians, however the processes of destruction and of growth are so nicely co-ordinated that the organism retains its functional integrity throughout metamorphosis instead of lying dormant and otherwise helpless as in the case of *pupating* insect.

The tadpole larva of frog, as we have studied, has an oval outline and long finned tail. The 'horny teeth' and jaw coverings surround the mouth. The folds of the operculum, shield the gills which grow from the lower ends of the visceral arches. The larva feeds exclusively on vegetation rasping away the plant tissues, and digesting them in a long coiled intestine.

The duration of the larval period in anurans is variable. In many species, the tadpole produced in the spring undergoes metamorphosis during the early summer. In certain forms, the tadpole stage may last for a year or more before the *premetamorphic transformation* commences.

As stated, under the influence of hormones, usually at the end of three months of larval life, the tadpole larva of frog undergoes a rapid series of changes which transform it into a *young frog*.

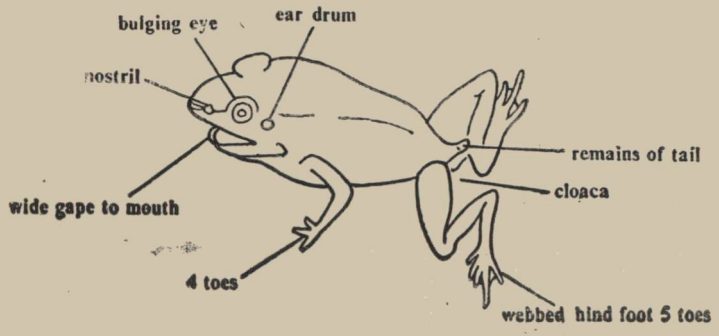


Fig 13.32 A young frog just emerged from water on to land.

The first sign that metamorphosis is about to take place, is that, the tadpoles come to the surface most frequently to gulp air into the lungs via the mouth. The hind-limbs which grow slowly during the premetamorphric period, now are, about the length of the body. Thus, a series of swift changes, called the metamorphic climax, commences. The fore-limbs grow and erupt through the gill covers. The skeleton of the head is completely remodelled, nostrils appear, powerful jaws and tongue are formed and muscles for pumping air arise.

The larval skin is cast off and the skin later becomes thick and glandular. The tail is resorbed. The gills are resorbed and the lungs take over their respiratory function. The eyes protrude

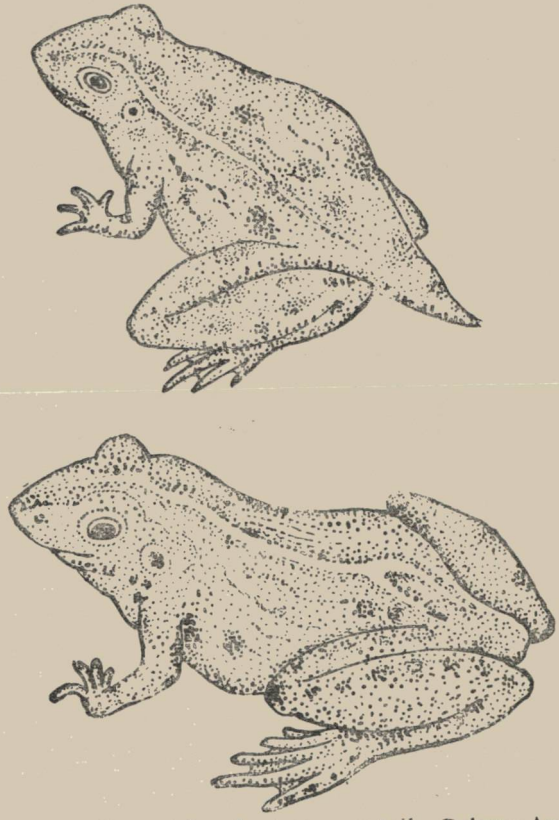


Fig. 13.33 Above : Frog with a short, stumpy tail. Below : An adult frog.

and acquire lids. The lining of the intestine is sloughed and replaced by a new one, as the intestine itself shortens in adapting to the carnivorous mode of feeding of the adult frog.

A short and stumpy tail still persists in the young frogs when they leave the water for the land. This stumpy tail also however disappears within a week. The young frogs at first prefer damp pastures in which they may sometimes be found in vast numbers. They continue to grow and feed chiefly on insects. They gradually assume the adult form and colour. The little frogs not more than three quarters of an inch long, take 3 years to grow to their full size ready for breeding.

After metamorphosis, some anurans take up a land dwelling existence, returning to water only to breed. Others spend a good deal of time out of water but generally remain in a moist environment.

Hormonal Control of Metamorphosis in Amphibians:

The hormones of the thyroid and pituitary play an important part during the metamorphosis of a tadpole into an adult frog.

The working of the **pituitary-thyroid axis** during metamorphosis is summarised below.

In the first instance, under the influence of secretions from the embryonic pituitary, the thyroid gland begins to produce its hormone at a low level. This production stimulates the growth of the hind-limbs and more gradually the appearance of the fore-limbs.

At the stage when fore-limbs appear, the thyroid in response to the enhanced production of **thyroid stimulating hormone (TSH)** by the pituitary, begins to secrete its hormone, now, more actively. The larva as such enters the *metamorphic climax*, swiftly transforming into a frog. Thereafter the thyroid function declines to a lower level.

The increased production of **TSH** by the pituitary is thought to be triggered by a kind of brain hormone called **thyrotropin releasing**

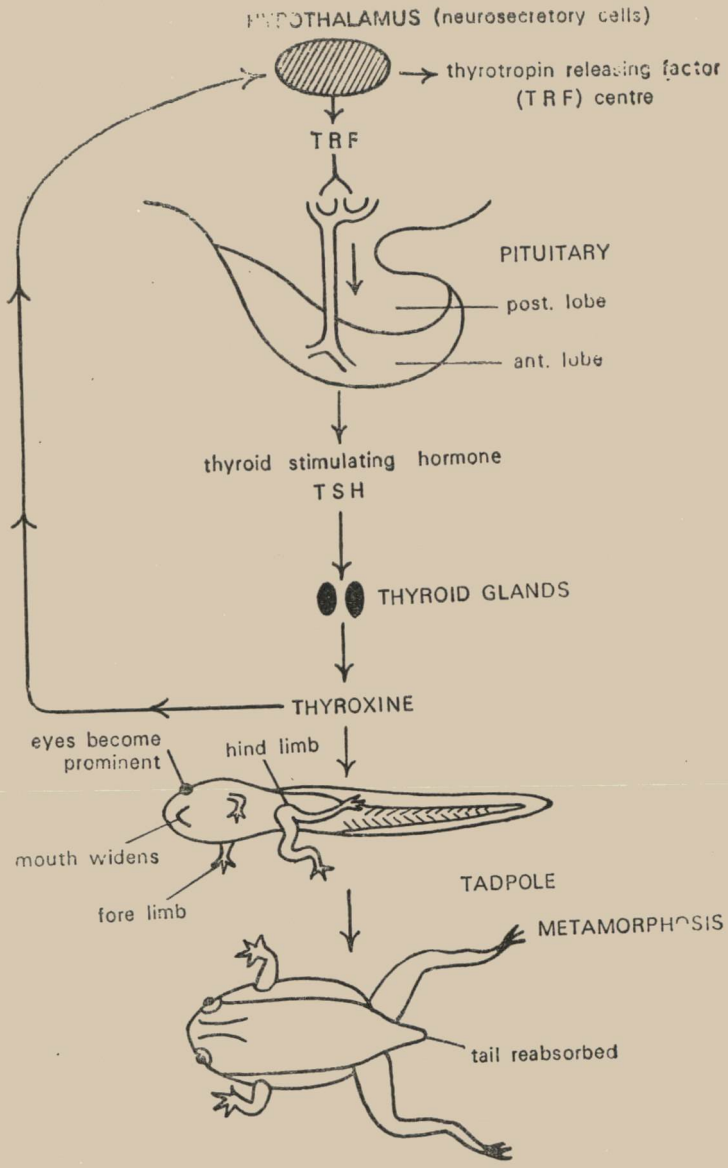


Fig. 13.34 At the critical period of metamorphic climax in the tadpolel arva of frog the role of **hypothalamus, anterior lobe of pituitary** and the **thyroid glands** are illustrated diagrammatically.

factor (TRF) which is produced by *neuro-secretory cells* whose cell bodies are situated in the *hypothalamus* on the ventral side of the brain. It is probably the thyroid hormone (thyroxine) itself, that is responsible for this activity of the hypothalamus. At the critical period for metamorphic climax, the hypothalamus responds to the premetamorphic thyroid hormone and releases *thyrotropin releasing factor TRF.* This TRF neurohormone is carried by a direct vascular connection to the anterior lobe of the pituitary, causing it to release TSH into the circulation. The TSH in turn, causes the thyroid gland to produce more of its own hormone, which brings about the swift and orderly transformation of the tadpole into the frog (Fig. 13.34).

EMBRYONIC INDUCTION AND INDUCTIVE REACTIONS

During the process of embryonic development, many experiments were performed to find out the secrets as to how the adult is latent in the ovum and further, how the *ovum* which seems nearly structureless can produce a complex structure.

Hans Spemann and his associates, at the University of Freiburg, performed several experiments on the developmental mechanics. Most of the experimental work was done on the development of amphibians.

In 1918, Spemann began an important series of experiments, in which he transplanted small discs of cells from one region of an **early gastrula** to another gastrula. These transplantation experiments were done chiefly on the embryos of newts.

In Spemann's original work, he found that a disc transplanted from one part of the prospective ectoderm to another part of the same zone developed according to its new location. Thus, a disc of prospective epidermis which was transplanted into the area of future neural plate, developed as an integral part of the neural plate. Conversely, a disc of prospective neural plate when planted into the region of prospective epidermis, became the epidermis. Likewise, a disc of prospective ectoderm, transplanted to the region of prospective chordamesoderm may become notochord and mesoderm.

On the basis of these experiments, we can thus conclude, that at the beginning of gastrulation the cells of the animal hemisphere

(prospective ectoderm) are either undifferentiated and undetermined as to their fate (uncommitted) or else they are labile and capable of reversing their differentiations when transplanted to changed surroundings.

The problem now was, what determines, whether prospective ectoderm will become epidermis or neural tissue? On the basis of their experiments, **Hans Spemann** and **Hidla Mangold** (1924), reported that the fate of the prospective ectoderm is decided by the relation of the ectoderm to the adjacent chordamesoderm cells from the dorsal lip of the blastopore.

To confirm that the dorsal lip cells of the blastopore called prospective chordamesoderm are the inducers of embryonic organisation, Hans Spemann and Hilda Mangold selected a disc of chordamesoderm. This was implanted to the ventral side of an egg or was placed in the blastocoel so that it came in contact with a prospective ventral ectoderm. This implant brought about the differentiation of the secondary axial structures of the embryo. It was noted that the disc itself becomes notochord and axial mesoderm and further it induces the adjacent ectoderm to become a neural tube. The lines are however not sharp between the host tissues. Some cells of the implant may become neural tissue and some cells of the host may form mesoderm and even notochord. *The important point to be remembered here is that the host and implant tissues together constitute one self-regulating* **embryonic field** *and they differentiate as an organized whole.*

The material of the dorsal chordamesoderm is so important in organizing the structures of an embryo that Spemann tentatively called it '**The Organizer**'. It is, roughly speaking, the substance which was the grey crescent (cf. p. 278). It's action in stimulating the adjacent ectoderm and mesoderm to become the dorsal structures of an embryo, is a classic example of **embryonic induction.** Besides the embryonic induction brought about by the chordamesoderm cells of the dorsal lip, many more examples of embryonic inductions and interactions are now known to us. On account of this knowledge, we now prefer to use the terms embryonic inductions and inductive reactions instead of the terms *organiser* or *the organisation centre of the embryo.*

During embryonic induction, an active tissue referred to as the **inductor** has to come in contact or near contact with a receptive tissue which is referred to as the **competent tissue.** This contact or a near contact of an inductor with a competent tissue affects the fate of the receptive tissue to become determined or start its development in a causal pathway, which directs the receptive tissue to achieve specifically a differential state.

In the example quoted, the *chordamesoderm* is an *inductor which comes in contact or near contact with the overlying ectoderm,*

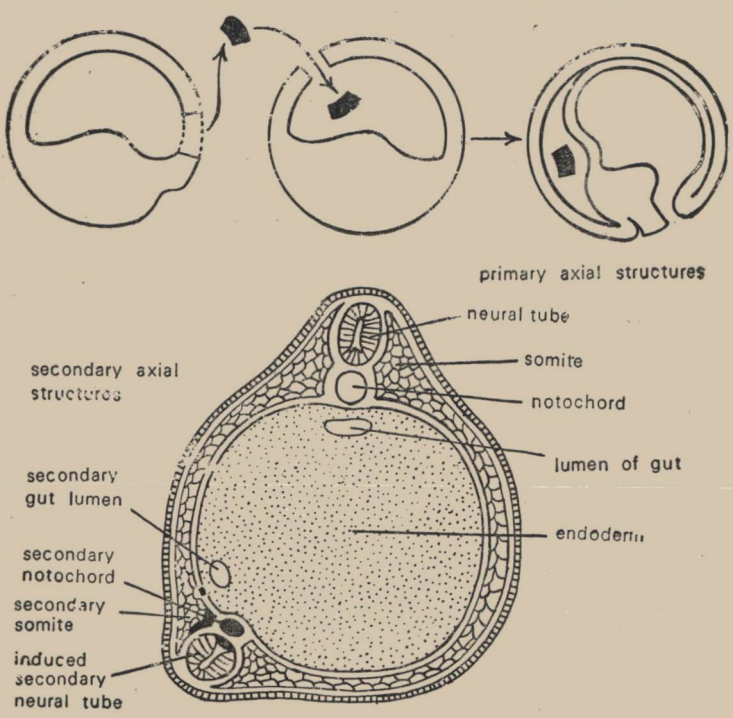


Fig. 13.35 Induction of a secondary set of axial organs by the implantation of a disc of chordamesoderm. Gastrulation movements of the host relegate the graft to a position subjacent to prospective ventral ectoderm. The graft thus induces the formation of secondary axial structures like the induced neural tube, secondary somite, notochord and the gut lumen. The primary axial structures of the host however develop normally in the mid-dorsal region.

which is, in this case, the receptive or competent tissue. The inductor (chordamesoderm) thus determines the fate of this competent tissue (ectoderm) to become the neural plate. The process of induction however, is limited, in both space and time. Only the prospective ectoderm is competent to respond to the inducing stimulus of the chordamesoderm and gives rise to the neural tissue. Further the prospective ectoderm will so respond, only for a definite period, during gastrulation. As gastrulation proceeds further, the competence wanes. Then soon after neurulation has begun, it ceases entirely. The neural ectoderm has now, new competencies; for example it's epidermis will respond to the stimulus of an optic vesicle by forming a lens.

Spemann, Yamada and others have also discovered that different agents have different inductive effects. They have, at least in part, classified the following type of *inductors* or *organizers.*

1. **Archencephalic inductor:** The **dorsal lip*** of the blastopore at the beginning of gastrulation induces the ectoderm to form fore-brain, eyes and nose. It has, therefore, been called the **archencephalic inductor.**

2. At a somewhat later stage, the dorsal lip (the cells of the initial dorsal lip having entered the gastrula) induces the production of mid-brain, hind-brain, and the inner ears. At this stage the dorsal lip is termed as **deuterencephalic inductor.**

3. Still later, when gastrulation is nearing completion, the new dorsal lip stimulates the ectoderm to form the spinal cord and even notochord and somites of the tail. The dorsal lip at this stage is spoken of as a **Spinocaudal inductor.**

4. In addition to the above, some inducing agents have also been found which cause early gastrula ectoderm to become mesodermal and endodermal tissues.

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*It should be remembered that the dorsal lip of the blastopore is not a growing point spinning out the tissues behind it, but is a region over which the cells are rolled, There is, therefore, no constant mass of tissue that can be called, the 'dorsal lip material', as the material of the lip constantly changes.

It will be noted that in each of the above mentioned examples, the inductor determines some region of the embryo, not particular organs. Thus, the same agent will cause a variety of organs to be produced—ectodermal, mesodermal, and even endodermal; but they all belong to the same region of the embryo.

As the process of gastrulation progresses the various organ systems of the embryo are laid down under the influence of inductor (organizer) and these structures so laid down, themselves then acquire the power of inducing later formed structures to develop. These, in turn, develop inducing properties (organizing properties) and such type of process goes on as embryological development continues. **In this way we can recognise a series of inductors (organizers) of the second, third and even fourth degree (secondary and tertiary inductors) which can be arranged in a sort of hierarchy at whose apex is the primary inductor (Primary organizer) i.e., the chordamesoderm cells of the dorsal lip of the blastopore.**

A classic example of such chain inductive action and relationship between the different parts of the developing embryo is the tissue of the optic cup. The **optic cup** is laid down under the influence of the primary inductor. The optic cup in turn now causes overlying ectoderm to differentiate into a lens. If the optic cup is removed, a lens fails to develop. The lens as such is said to be a **dependent differentiating structure.** Once the lens is formed, the **eye cup lens complex,** then induces the overlying tissue to differentiate the transparent cornea and the surrounding mesoderm, to form the sclerotic coat of the eye-ball. These chain inductions have been examined experimentally; if a step in the sequence is omitted, the next steps fail to occur. Thus, it was observed experimentally that if the optic vesicle of the chick embryo is excised, prior to its contact with head ectoderm, the lens fails to form, without the lens and optic vesicle, the other inductions associated with the development of the eye do not follow.

We have now a knowledge about similar examples of inductive relationships between the different parts of the developing embryo. A few of such examples are given below.

1. The development of nasal placodes depends on the presence of fore-brain.

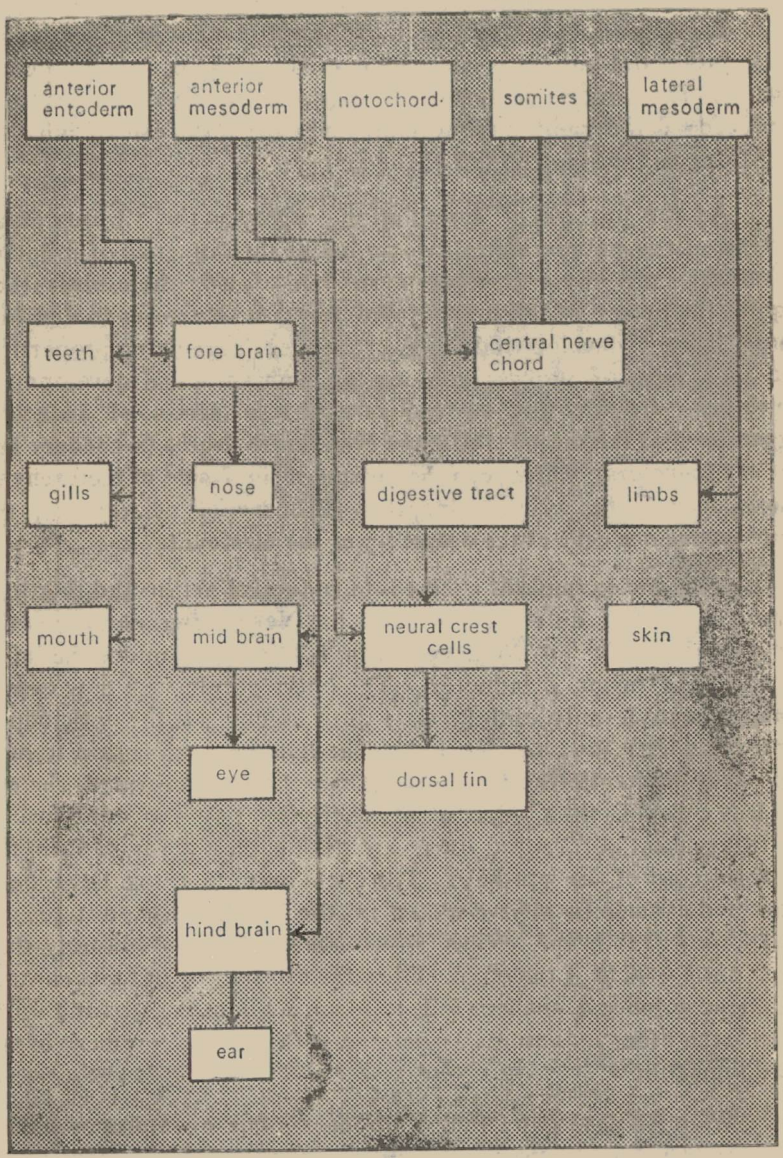


Fig. 13.36 Inductive relationships between different parts of the developing embryo. The arrows point from the inducing tissues to the induced organ which ultimately appears. This array of induction however is far from complete.

2. The development of the posterior lobe of the pituitary is dependent on the presence of the tip of the notochord.

3. The teeth develop, in the presence of pharyngeal endoderm.

4. The development of the dorsal fin depends on the mesenchyme, derived from the trunk neural crests.

A few of the inductive relationships as noted between the different parts of the developing embryo are also shown in the form of a chart (See Fig. 13·36).

Chemical nature of inducers: We have as yet no clear idea about the way in which the inductors make their effect felt. It is however, fairly certain, that the stimulus is due to the diffusion of some chemical substance or substances from the inducing tissues. Pieces of prospective ectoderm or even pieces of agar were placed in contact with the dorsal lip of the blastopore for a short time. They acquired the ability to induce the formation of a neural plate from prospective ectoderm. Confusion arises due to the fact that the properties of primary inductor can be imitated by a great variety of chemical substances like methylene blue, steroids, fatty acids, and practically any animal tissue in which the proteins have been denatured by heat, precipitation by alcohol or other means. Despite this confusion, two classes of substances i. e., ribonucleic acids and proteins—have been repeatedly implicated as specific inducers, and it is likely that both may play a part.

There is also a strong experimental evidence that proteins are specific inducers in certain systems. For instance, cartilage formation from presumptive cartilage cells can be induced in tissue culture on the application of extracts from the notochord. The notochordal extracts on analysis showed to contain pure protein fraction. Likewise, substances, that induce the development of mesodermal structures have also been isolated and shown to be proteins.

Experiments on chick embryos have also revealed that a fat soluble vitamin *A*, also acts as an inducer. Vitamin *A* when added to a medium in which chick embryonic ectoderm is grown, stimulates the formation of ciliated, mucus secreting epithelium. In its absence

keratinised epithelium forms. Hormones are also known to act as inducers.

The above experimental data reveals that embryonic induction is not a property of a restricted class of substances. They suggest that differentiation may be the result of complex mechanisms which can be influenced at different points.

Revision questions

1. Give an account of the development of frog from the fertilization of an egg to the formation of the germinal layers.

2. What are the structures derived from the three layers i.e., ectoderm, endoderm and mesoderm formed in the process of gastrulation in frog?

3. Mention in brief the process of neurulation in frog's embryo.

4. Discuss in brief the development of mesoderm and its derivatives in frog.

5. What are the chief features of the tadpole larva just before hatching?

6. Describe in detail the general features and the internal structure of the tadpole larva of frog.

7. Define the terms *metamorphosis* and *metamorphic climax* and also give details pertaining to the metamorphosis of the tadpole larva into an adult frog.

8. Discuss in brief the role of thyroid, anterior lobe of pituitary and the hypothalamus at the critical period of metamorphic climax in the tadpole larva of frog.

9. Write what you know about **embryonic induction** and **inductive reactions**.

10. What is the role of '**organizers**' or '**inductors**' in development? Explain the terms archencephalic, deuterencephalic and spinocaudal inductors.

11. Discuss in brief a classic example of a "**Chain inductive action**" as revealed by the tissue of the optic cup. Give also some examples of inductive relationships between the different parts of the developing embryo of frog.

12. Write notes on the following :
    (a) Grey crescent.
    (b) Fate maps of blastula of frog.
    (c) Organogeny.
    (d) Neural crest.
    (e) Nuerenteric canal.
    (f) The organizer.

PART II

General Survey of Vertebrates

CHAPTER XIV

FISHES

(The True Aquatic Vertebrates)

Fishes have been defined primarily as *aquatic* and *gill breathing* vertebrates equipped with *fins*. The branch of zoology which deals with the study of the fishes is called *ichthyology*.

Inspite of diversity in the shapes, sizes, varieties and distribution of fishes, we can however establish *three major categories of fishes* belonging to

(1) Class Cyclostomata

(2) Class Chondrichthyes

(3) Class Osteichthyes

The general term *Pisces* is applied to all the above three categories of fishes. The general characters of fishes belonging to the above mentioned three classes will now be discussed.

1. *Class Cyclostomata* includes the lampreys and hag fishes. The anterior end of the body in lamprey is modified into a round funnel shaped sucker in the centre of which is the aperture of the '*mouth*'. The lampreys and hag fishes are thus referred to as the *Cyclostomes* or round mouthed fishes. The cyclostomes *lack jaws*; hence they are called *agnathans* as well.

The cyclostomes differ from other vertebrates in the following features. They have no differentiated head, jaws, paired fins, limb girdles or reproductive ducts. They possess a single nasal sac and gonad. The internal ear has only one or two semi-circular canals.

The class cyclostomata is divided into two orders.

1. Order *Petromyzontia* (Gr. *Petra*: rock, *myzon*: sucker) and
2. Order *Myxinoidea*.

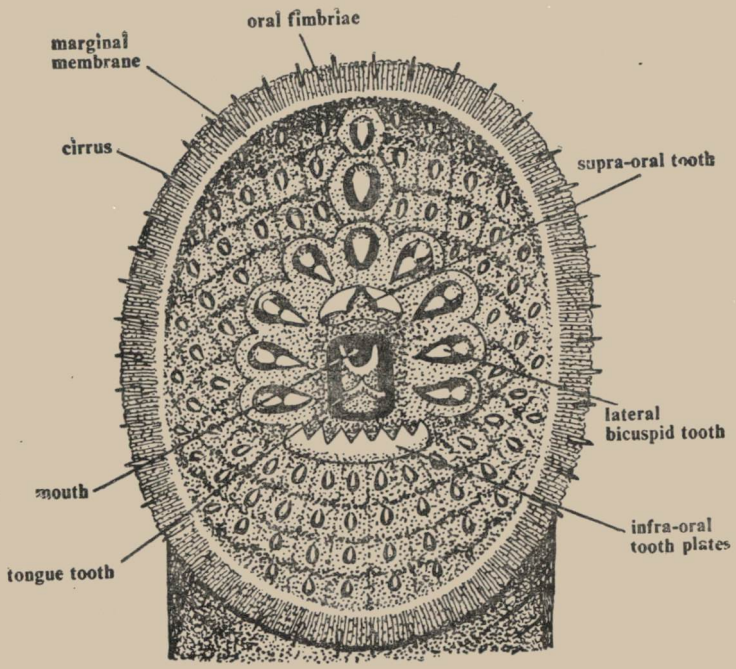


Fig. 14.1 The suctorial 'Mouth' i. e., 'Buccal Funnel' of a lamprey.

Order Petromyzontia is represented by lampreys. Three species of lampreys are common in the Northern hemisphere. Sea lamprey (P. marinus) attains a length of one metre. The *lampern* or common fresh water lamprey (Lampetra fluviatilis), reaches a length of about 90 cm and the *sand pride* or lesser fresh water lamprey *(Lampetra planeri)* does not exceed 45 cm in length.

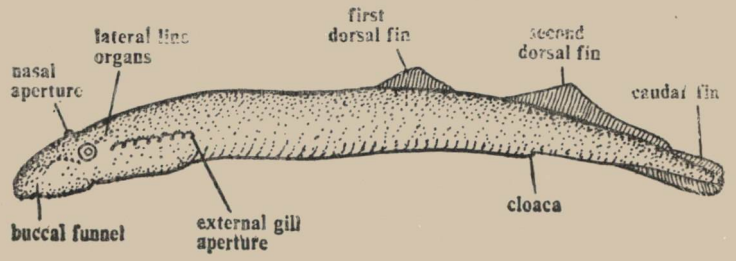


Fig. 14.2 An adult lamprey – Petromyzon marinus.

The members of this order possess suctorial mouth with horny jaws, dorsal single nasal sac not connected to the mouth, 7 pairs of gill pouches which open separately. Eggs are small and prolonged larval stage is to be seen. The larva is called **Ammocoete larva.**

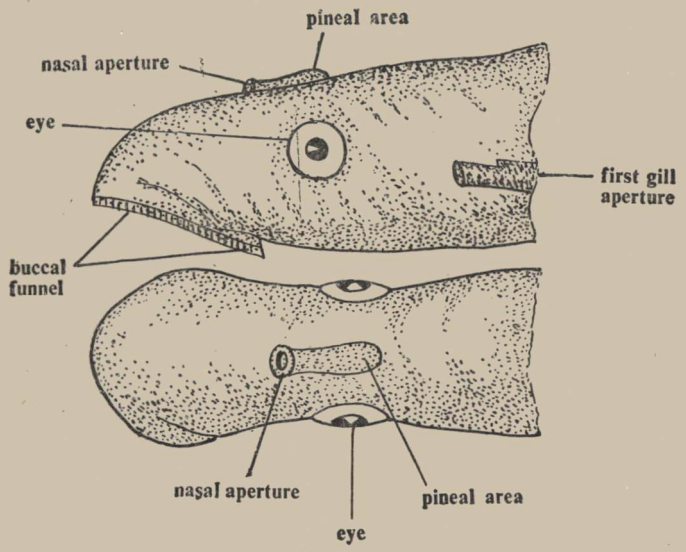


Fig. 14.3 Petromyzon fluviatilis—Lateral and dorsal views of the head.

Order Myxinoidea (Gr. *Myxa* : slime) is represented by hag fishes. **Myxine** is some 45 cm long. *Eptatretus (= Bdellostoma)* is fully one metre in length. Both are remarkable in secreting an immense amount of slime when disturbed. They are called as such **slime eels.** It is said that two specimens of Myxine kept into a bucket of water are capable of gelatinising the whole with their secretion. The mouth of hag fishes is not expanded into a funnel. The mouth is nearly terminal and surrounded by **short tentacles.** The nasal sac is found near the end of the head and it opens through a duct into the pharynx. Eyes are found beneath the skin. 10 to 14 pairs of gill openings are found. Only a narrow caudal fin is found surrounding the end of the tail. Eggs are large, development is direct. All are marine.

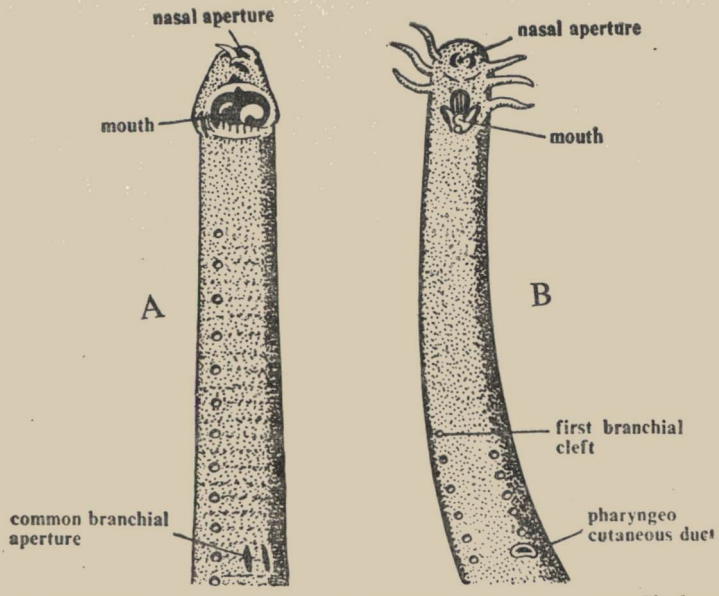


Fig. 14.4 (A) Myxine glutinosa, (B) Bdellostoma—Eptatretus Cirrhatum,

Class Chonrichthyes (Gr. *Chondros*: cartilage+*ichthys*: fish) (Elasmobranchs). In this class are included, the **sharks, skates and rays.** The skeleton consists of cartilage only—hence the name chondrichthyes or cartilaginous fishes. They are called *elasmobranchs* as they have "plate" gills i. e., gills borne on wall-like partitions between gill chambers. The gills are not covered by an *operculum* or gill cover. The elasmobranchs form a very compact group of fishes. They are nearly always marine with predacious habits. The body is more or less completely covered with **placoid scales** (denticles) which are modified in the mouth to form rows of teeth. The intestine is short and provided with a spiral valve. These fishes have true jaws (Gnathostomes).

The best known member of this class is the **shark.** Its body shows a number of distinct advances over the lamprey. It has a mouth with movable jaws lined with several rows of teeth. It has at the front end of the head a pair of nostrils.

External Characters of Dogfish–Scoliodon sorrakowah :

The shape of the body of a dogfish is streamlined. The anterior end is smoothly rounded and reaches its maximum girth about one-third of the way from the front end and later tapers gradually to the end of the tail.

The body is divisible into head, trunk and tail. There are however no distinct boundaries between these three regions.

The head is bluntly pointed and is produced in front into a wedge shaped **snout.** The large circular **eyes** are situated at the sides of the head. The upper and lower eye-lids are merely out growths of the skin of the head and are immovable. Each eye is further provided with a **nictitating membrane** which lies along the antero-ventral border and can be drawn over the eye in time of danger. The pupil is narrow and vertical.

The **nostrils** are in the form of two obliquely placed crescentic apertures one on each side of the snout. Each nostril is partially covered by a small fold of skin. Nostrils are only concerned with smell. They do not serve as passage for respiration as they do not open into the mouth through the internal nostrils.

Behind the eyes are situated a series of vertical slits, five on each side called the **gill slits.** Gill slits open internally into gill pouches which lead into the pharynx. In the allied genera *Loxodon, Goleocerdo*, etc., there is a minute opening, the spiracle, in front of the gill slits. The spiracle is absent in *Scoliodon.*

Owing to the forward prolongation of the snout, the **mouth** is situated on the ventral side of the head. It is in the form of a wide crescentic opening. It is bounded by the upper and the lower jaws, each of which is armed with one or two rows of backwardly directed teeth with smooth non-serrated edges. The teeth are the specialisations of the placoid scales. In catching the prey the shark brings its jaws into play by raising the snout and thrusting the mouth forward.

The dogfish is provided with two sets of fins unpaired and paired. Each fin is a flattened expansion of the skin supported by cartilaginous rods and horny fin rays.

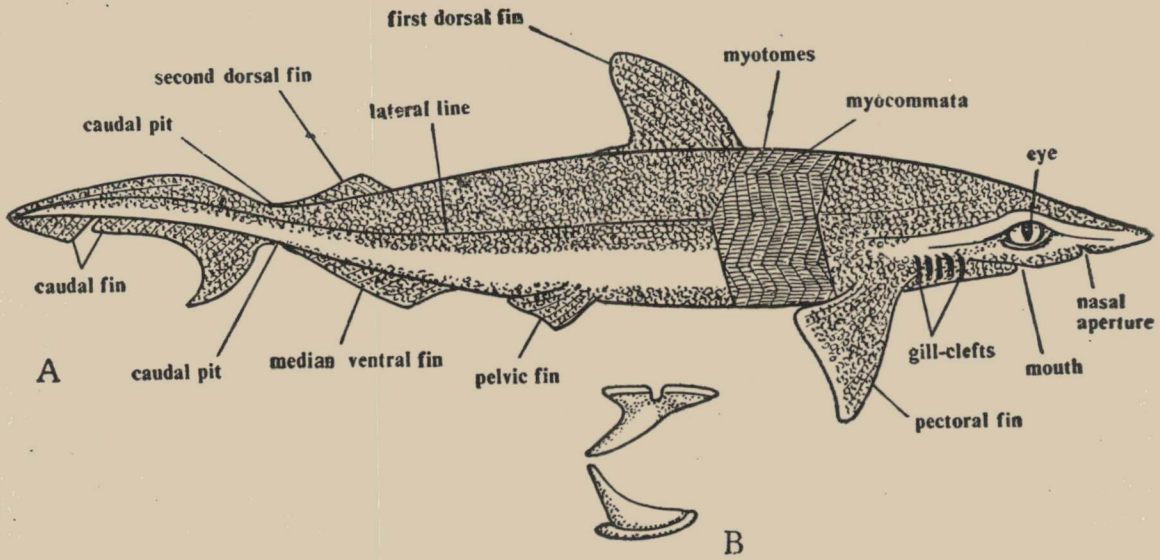


Fig. 14.5 (A) Lateral view of the shark Scoliodon sorrakwah with a part of the skin removed to show the muscles (B) Teeth of the upper and lower jaws.

The median unpaired fins comprise the two dorsals (anterior and posterior) and a ventral. The **first** or **anterior dorsal** is triangular in shape and is situated a little in front of the middle of the body. **The second** or **posterior dorsal** is also triangular in outline but is very small. It is situated midway between the first dorsal and the tip of the tail. The **caudal fin** extends along the dorsal and ventral surfaces of the tail in the median line and forms a dorsal and a ventral lobe. The dorsal lobe is very much reduced and forms only a low ridge along the greater part of the upper surface. The ventral lobe of the fin is well developed and is divided into two parts. The anterior part is much larger and more extensive than the posterior. At the root of the tail there is a shallow pit both on the dorsal and ventral surfaces. These are called the **caudal pits** and form a characteristic

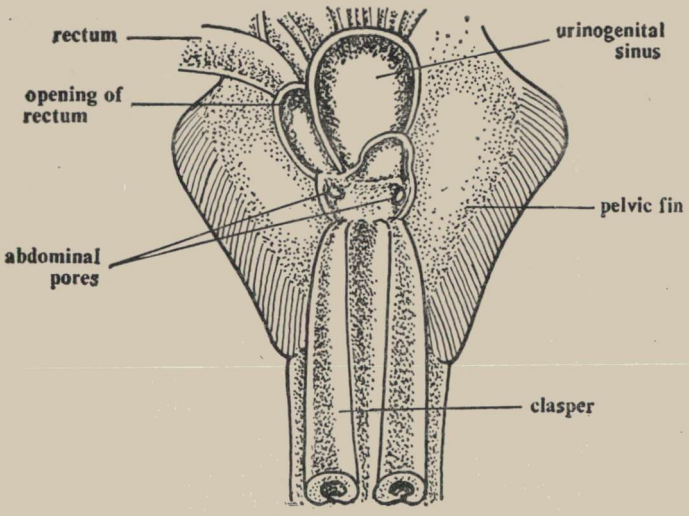


Fig. 14.6 Pelvic fins and the claspers in a male dogfish.

feature of this genus. The **ventral median fin** is situated in the mid-ventral line about two inches in front of the caudal fin more or less opposite the second dorsal. The basal edges of each of the two dorsal and of the ventral fins are produced behind into long narrow fleshy processes called the basal lobes. As regards the paired ones, there are two pairs of fins. An anterior pair of fins is called the **pectoral fins**. The large **pectoral fins** originate from the ventro-lateral margins of the body immediately behind the gill clefts and spread

out more or less horizontally as triangular expansions. The **pelvic fins** are much smaller than the pectorals and arise close together from the ventral surface at the junction of the trunk and tail. In the female, these fins are simple sub-triangular appendages but in the

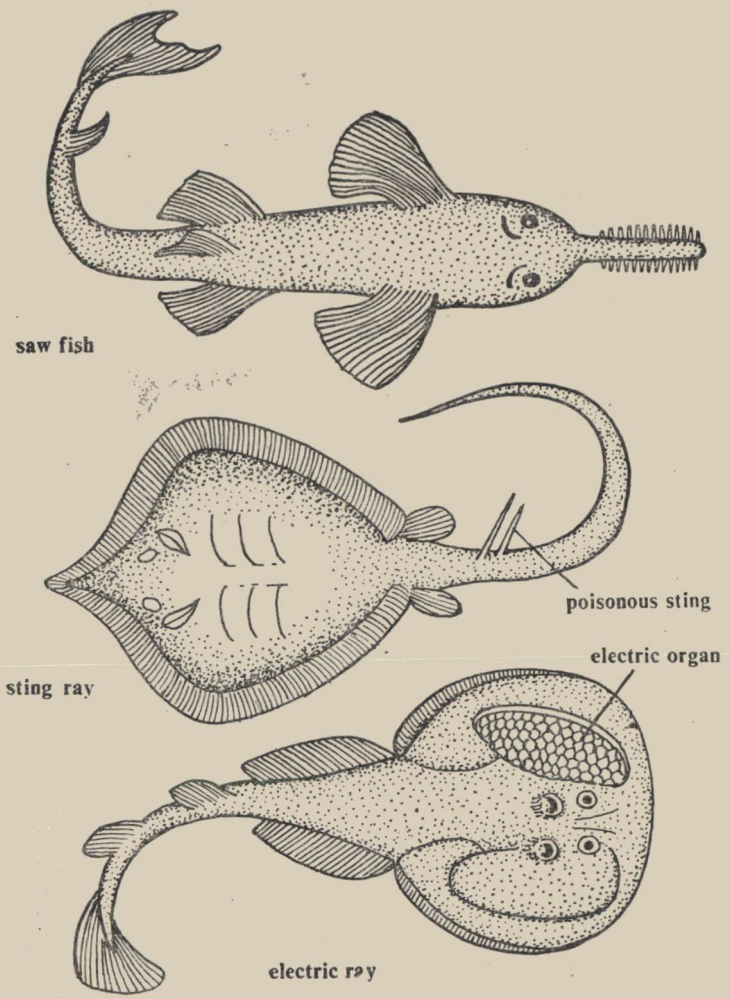


Fig. 14.7 Some elasmobranch fishes.

male, connected to the inner edge of each pelvic fin there is a copulatory organ called the **clasper** or **myxipterygium.** There are as such

two claspers in males. All the fins are directed backward which is of advantage in forward progression.

Trunk and tail: The trunk extends from the head to the region of the cloacal aperture. The **cloacal aperture** is an elongated opening at the root of the tail between the two pelvic fins. There is a pair of openings situated on elevated papillae on either side of the cloaca. These are the **abdominal pores** through which the coelom communicates with the exterior.

The region of the tail extends from the cloacal aperture. As mentioned, the tail is surrounded by the caudal fin.

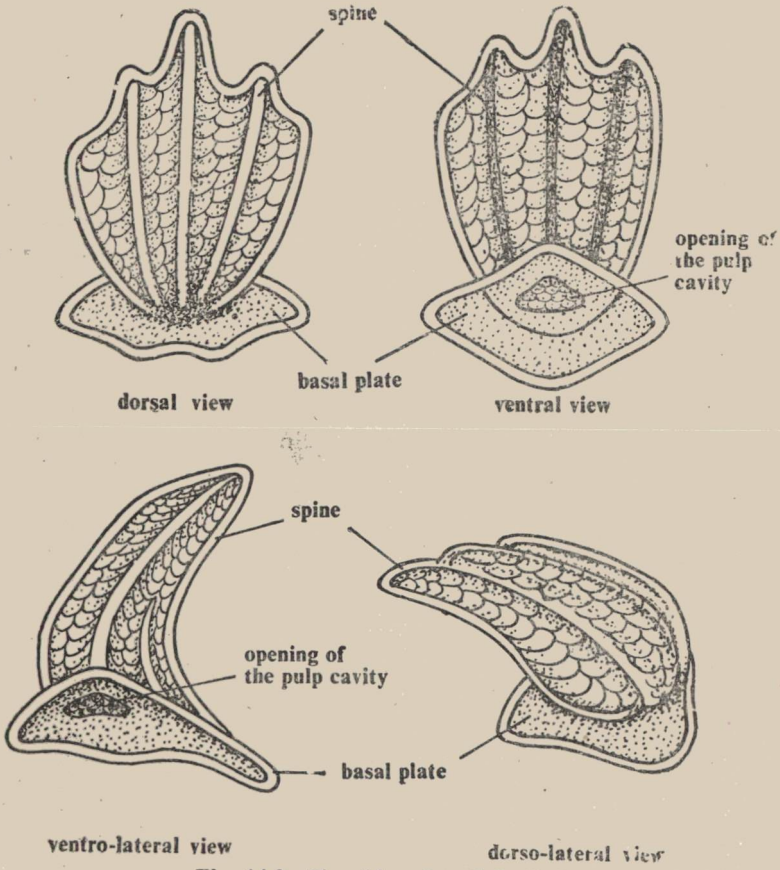


Fig. 14.8 Placoid scales of Scoliodon.

A faint line runs on either side of the body extending from the head to the posterior end of the body. This is called the **lateral line.**

Placoid scales : The skin of dogfish is covered by minute **placoid scales** arranged in regular oblique rows. They form the exoskeleton of the shark and cover the entire surface of the body and even parts of the fins. As the spines of the scales are directed backwards, the skin feels rougher when a finger is passed over it forward than backward. The structure of a typical placoid scale is shown in figure 14·8.

Rays and skates are cartilaginous fishes that have become specialised for life on the bottom of the ocean in shallow waters. They feed mainly on invertebrates.

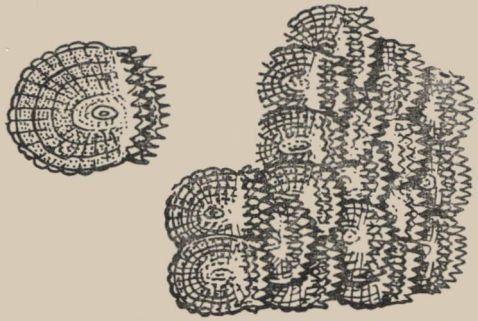
Class Osteichthyes includes the fishes with chiefly bony skeleton (cartilage in sturgeons and some others). They also possess true jaws. Paired fins are present and are supported by fin rays of cartilage or bone. On the basis of this, class osteichthyes is divided into two sub-classes.

(1) Sub-class **Actinopterygii** includes **ray-finned fishes.** In modern actinopterygians the cartilaginous or bony basal supports of the fins (projecting outside the body wall) are very much reduced. They are so reduced that the fin fold or fin web lying outside the body wall is supported by the dermal fin rays alone—hence the name **Ray-finned bony fishes.**

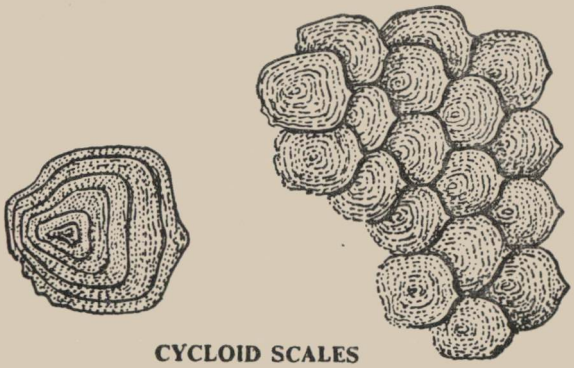
(2) Sub-class **Crossopterygii :** In the pectoral and pelvic fins, the basal skeletal supports projecting beyond the body wall consists of lobes—hence the name **lobe finned fishes.** They are covered with scales, around which the fin rays radiate. These lobes contained skeleton, which is supported to bear a relationship with the limb bones of higher vertebrates.

In bony fishes, the skin is often delicate, with many mucus glands. The dorsal scales are usually embedded in the skin. Some fishes are scaleless.

All the recent bony fishes are covered usually by two types of scales – the **ctenoid** and the **cycloid** scales. These are found in the form of thin semi-transparent plates lying above a fibrous material covered by a layer somewhat resembling bone. These scales are embedded in pockets of dermis. In *ctenoid scales* (comb-like), the



CTENOID SCALES



CYCLOID SCALES

Fig. 14.9 The types of scales in Osteichthyes (bony fishes).

exposed hind part of each scale or the free edge has many tiny spines or a serrated border e.g., *Perch, Bass Flounder*. The cycloid scales on the other hand lack the spiny or serrated border i. e., the free border of these scales, presents and even curve. Some bony fishes are devoid of scales e. g., Cat fishes.

Bony fishes have a terminal mouth with teeth. Jaws are well developed and are articulated to the skull. There are two olfactory

sacs which are usually not connected to the mouth cavity. Eyes are large and without eye-lids.

Heart is two chambered (1 auricle and 1 ventricle) with a sinus venosus and conus arteriosus. It contains only venous blood. The red blood cells are nucleated and oval.

The chief respiratory organs are the gills. The gills are found in gill chambers at each side of the pharynx. The gill chamber is covered by a bony shield called the **operculum** or **gill-cover.**

In most of the modern fishes, a thin walled sac, the **air bladder, swim bladder** or **gas bladder** is found above the gut and below the vertebral column. It may be connected to the pharynx through a duct or may not be connected to it. The bladder is filled up with gases (O, N, CO_2) and acts as a **hydrostatic organ.** It is concerned in some way with **floatation.** It adjusts the specific gravity of the fish to that of the water at different depths. It gives the fish just the amount of buoyancy it requires to remain at whatever level of water it may dwell, whether near the surface or deeper down to about 200 fathoms. The fishes that live in the deeper regions of the sea, as well as most sea-bed dwelling fishes, have no use at all for a gas bladder, and hence do not develop one. The original function of gas bladder in primitive fishes was probably a respiratory one. In these fishes it serves the purpose of a lung.

The body temperature of fishes is variable, depending upon the environment.

The gonads are typically paired. They are mostly oviparous i.e., breed by laying eggs. The fertilisation is external. No embryonic membranes develop.

The External Characters of a Bony fish e.g., a Carp:

The general characters of an actinopterygian fish can well be followed by the study of a bony fish, *Labeo rohita* or *Labeo calbasu*. It belongs to the family of fishes commonly known as *Carps*.

Carps are abundant in fresh waters and the estuaries of India, Sri Lanka and Burma.

Labeo calbasu may grow to about three feet in length. The body is divisible into **head**, **trunk** and **tail**. There is a single **median dorsal fin** and the **caudal fin** surrounding the tail is deeply forked. Just posterior to the anus lies a single **median anal fin.** In the paired fins are included, the two lateral pectoral fins and two lateral **pelvic fins.** There runs a **lateral line** on each side of the body from the head to the region of the tail. The head bears a mouth with well developed jaws without teeth. A pair of eyes are found. Anterior to each eye are a pair of nostrils. The gills are covered on each side of the body by a gill cover or an **operculum.** The **snout** is obtuse and somewhat depressed. It projects beyond the mouth and

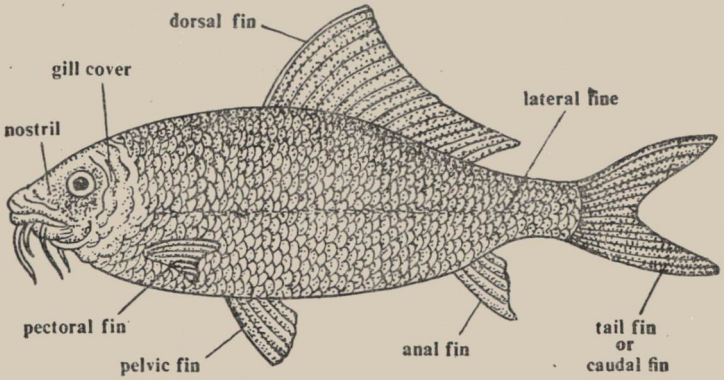


Fig. 14.10 A common Indian carp-Labeo calbasu.

is covered with tubercles. Arising from the snout and the upper jaw are to be seen two pairs of **barbels.** In the pharynx are found three rows of hooked teeth. The head is devoid of scales but the skin of the trunk is provided with rows of dermal **scales.** The scales are arranged in an imbricating manner and protect the fish from any mechanical injury. The scales together with the fin rays supporting the fins, form the **exo-skeleton** of the fish.

Crossopterygian fishes or lobe-finned fishes : They are characterised by the presence of a nostril which opens inside the mouth cavity. The group as such also receives the name **Choanichthyes (Choanae=internal nostrils).**

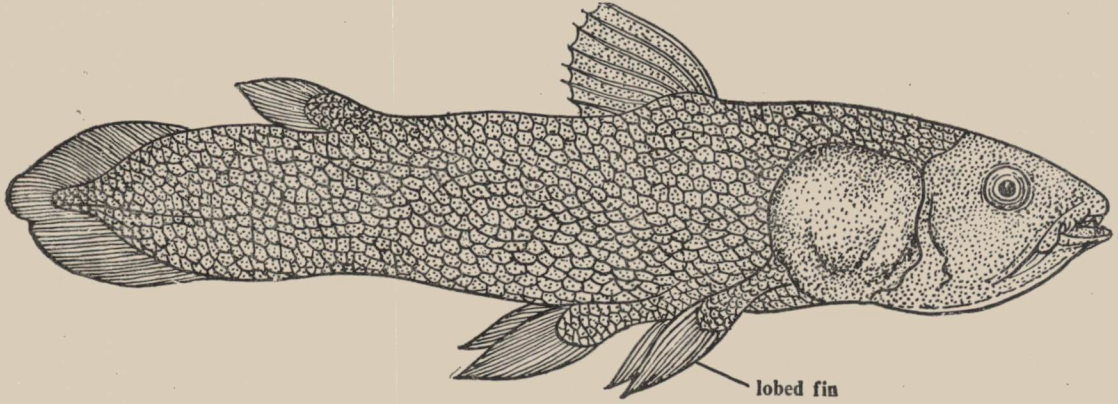


Fig. 14.11 Latimaria chalumnae—A ccelacanth fish.

The crossopterygians have a bony endo-skeleton. The body is covered with over lapping cycloid scales. The appendages are in the form of lobe fins. The lobe fins contain skeletal structures that correspond with similar bony structures in the appendages of the true land vertebrates. The most important characteristic feature is the presence of a highly developed **respiratory lung** or **lungs** for respiration in addition to the gills. The gills are however covered with an **operculum**. The intestine contains a **spiral valve**. The auricle of the heart is imperfectly divided into a right and left part. There exists a contractile conus arteriosus. The lung receives blood from a pulmonary artery which is given off from the fourth afferent branchial vessel. Likewise, a pulmonary vein opens into the left division of the auricle. There exists a distinct cloaca.

The group of crossopterygian fishes today is probably reduced to one recently discovered group of **coelacanth fishes** and to a few species of lung fishes belonging to the order **Dipnoi**. The order Dipnoi includes the aberrant members of an ancient side line arising from the Crossopterygian stock.

Coelacanth fishes: In this group are now included certain fishes which until 1939 were supposed to have died out fifty five million years ago. A live specimen of this group in 1939 was trawled up off the east coast of South Africa. It was named as *Latimeria chalumnae*. It is a 'living fossil' estimated to have lived in the Devonian period. The length of the fish is some 5 feet having a steel blue colour. Few more specimens were however collected subsequently and described. A characteristic feature to be noted is the presence of thick lobe shaped fins. Much attention has been focused on these fins in the hope to know how the fins became limbs of higher land vertebrates.

The lung fishes included in order Dipnoi are represented today by three living forms. 1. **Neoceratodus**, 2. **Protopterus** and 3. **Lepidosiren.**

1. **Neoceratodus** is an Australian lung fish found in the fresh waters of South Eastern Queensland. It lives in the deep, still places of the river's bed. It occasionally rises to the surface to gulp in air. The lung is single. The body is stout and cylindrical and

compressed posteriorly from side to side. The tail is straight. Large round scales cover the body surface. It may grow to a length of 6 ft. The paired fins are thick and trowel-like. With the help of such fins, it can even 'walk' across the mud of river and lake bottoms. There are five gill clefts covered by an operculum. **Neoceratodus** cannot survive entirely out of water. It can however live in pools laden with rotting vegetable matter by taking mouthfuls of air at the surface.

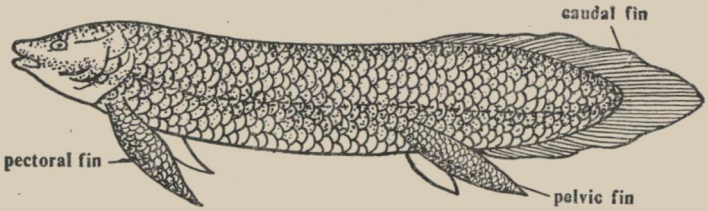


Fig 14.12 Neoceratodus forsteri—Australian lung fish

2. **Protopterus** is an African lung fish confined to the fresh water of tropical and sub-tropical Africa. *Protopterus aethiopicus* may attain a length of about 7 feet but a fish larger than 5 feet is exceptional. The lungs are paired. There are five gill clefts covered by an operculum. The fish from time to time rises to the surface of the

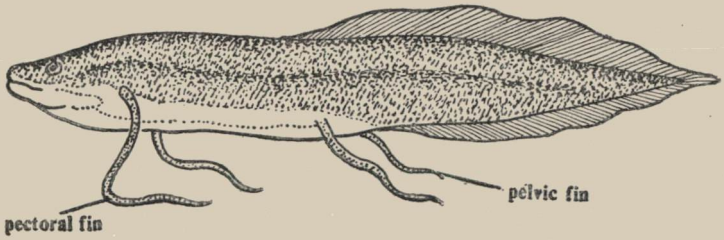


Fig 14.13 Protopterus—African lung fish.

marsh to take mouthfuls of air. The paired fins are slender and tapering. It can swim rapidly with powerful tail strokes. In addition, it is able to 'walk' along the bottom and through weeds by using its slender and filamentous paired pectoral and pelvic fins as 'legs'. The body is elongate and cylindrical. The eyes are small. Thin imbricating cycloid scales cover the surface of the body.

With the approach of dry season and the drying up of marshes, *protopterus* burrows into the earth. It then coils itself up and due to the secretion of mucus from its skin gland a cocoon or capsule around the body is formed. It can remain dormant in this capsule for months together. With the beginning of rainy season, the *protopterus* emerges from its capsule. The eggs are then deposited in a 'nest'. The male guards the nest. Young larvae hatch out of the eggs in about eight days time. The larvae are provided with external gills.

3. **Lepidosiren:** *Lepidosiren paradoxa* is the lung fish of South America.

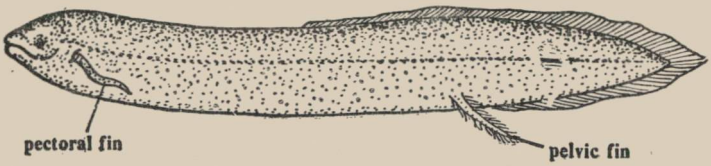


Fig 14.14 Lepdosiren paradoxa—South American lung fish.

The scales are small and deeply buried in the skin. The fins (limbs) are reduced in the form of short styles. There are four gill clefts having much reduced gills. The lungs are paired. It may reach a length of about 4 feet. Its food is partly vegetarian and partly carnivorous. *Lepidosiren* spends the dry season at the bottom of a deep tubular burrow. Later in the rainy season, the eggs are laid in L-shaped burrows excavated in the bottom of the swamp. The larvae, like those of *Protopterus*, possess external gills and glandular cement organs.

Revision questions

1. Describe in detail the salient features of Agnathous vertebrates or jawless vertebrates as represented by the existing members of the Class Cyclostomata.
2. Describe in brief the general characters of Chondrichthyes and Osteichthyes.
3. Give an account of the general characters of *Scoliodon* i.e., Indian dogfish.

4. Describe the main differences between the Actinopterygian i.e., ray finned and Crossopterygian i. e., lobe finned fishes.

5. Describe in brief the various types of scales met with in fishes.

6. What is an 'Air-bladder'? Discuss its importance in a bony fish.

7. Mention in brief the external characters of a bony fish as represented by a Carp e.g., *Labeo calbasu*.

8. Write a brief note on Coelacanth fishes.

9. Give an account of lung fishes mentioning in brief the general characters of *Neoceratodus; Protopterus* and *Lepidosiren*.

CHAPTER XV

CLASS REPTILIA – REPTILES

The Scaly Creeping Vertebrates:

The class reptilia, includes the lizards, snakes, turtles, tortoises, crocodi'es, alligators and the New Zealand tuatara lizard (*Sphenodon punctatum*). The class name Reptilia refers to the mode of locomotion (*L. reptare*: to creep) since the reptiles move about by their body, creeping or crawling on the ground. The study of reptiles is called "**herpetology**" (Gr. *ereptos*: reptile).

Reptiles are most abundant in the warmer regions of the world. Very few live in the colder parts of the temperate zone and none are present in the Arctic or Antarctic regions.

An outline classification of existing reptiles is given below.

Class Reptilia:

Sub-class Anapsida.

Order 1. *Chelonia* (e.g., Turtles, Terrapins and Tortoises).

Sub-class Lepidosauria.

Order 2. *Rhynchocephalia* (e. g., *Sphenodon*).

Order 3. *Squamata* (Lizards and Snakes).

Sub-order Lacertilia (=Sauria)

(e.g , *Gecko; Lacerta; Anguis; Heloderma*).

Sub-order Ophidia (Serpentes)

(e. g., Boas; Pythons; Vipers; Cobras; Krait; Sea Snake).

Sub-class Archosauria.

Order 4. Crocodilia (Loricata).

(e.g., Crocodiles; Alligators and Gavials).

The general characters of snakes and the distinguishing features of poisonous and non-poisonous snakes are now discussed.

THE SNAKES

The snakes are reptiles which are included in the sub-order ophidia (serpentes).

The skin of snakes is covered with scales, and the outermost epidermal layer is periodically shed in the form of a continuous *slough.*

The snakes are limbless creatures with elongate bodies. They have completely lost their limbs. There are never any hints of anterior appendages, girdles, sternum or episternum. *Pythons*, *boas* and a few others however possess rudiments of a pelvis and even small clawed structures which represent hind legs as vestiges. The snakes crawl or creep by winding their body from side to side, usually pushing against the irregular surfaces. The movements by such horizontal undulations have been referred to as *serpentine movements.* The words serpent and the snake mean the same. The word serpent is derived from the Latin 'serpens' (=creeping), while the word snake is from the Anglo-Saxon 'snaca'.

The snake has a distinct head, body and tail. There is in the rear under part of the body an opening called the '*vent.*' This is a common opening, into which the hinder part of the alimentary canal and the urinogenital ducts open. The part behind the 'vent' is called the *tail.*

The snakes have no eyelids, hence its steady unwinking stare. In place of the eyelids, each eye is covered by a single watch-glass shaped transparent scale.

Snakes have no external sound receiving tympanic membranes. They also lack eustachian tubes. The actual auditory apparatus consists as in a cobra of a small semi-cartilaginous columella auris, which lies in the skull. Due to the lack of tympanic membranes the snakes cannot hear sounds carried through the air but they do perceive certain vibrations from the ground carried to the 'ear' through the bones of the skull. The *snake charmer's* music on the pipe as such is more to please the spectators rather than to please the cobra. The cobra is deaf. The cobra as a matter of fact sways its hood largely in response to the movement of the snake charmer's pipe. The snakes perceive sound as *substratum vibrations.* The mouth of the snake is usually very flexible and widely distensible.

The tongue of a snake is slender, deeply notched or forked at its outer end. It is a protrusible structure. It is retracted into a tubular sheath when at rest. The tongue can be thrust out even when the mouth is closed because of the presence of grooves in the jaws. When the tongue is protruded it makes a quivering movement, sweeping in a vertical direction with the tips expanded. It serves as an important olfactory organ, carrying the smell-bearing particles in the air or on the ground to the special sense organs (*organ of Jacobson*) in the roof of the mouth. The tongue thus helps the animal to smell its surroundings. The prevalent idea that the tongue can inflict an injury is erroneous.

The nostrils lie on the sides of the head. The snakes which live in water have their nostrils on the top of the snout. The 'hiss' of a snake is due to the forcible expulsion of air through its nostrils after it has inhaled a large quantity of air into the lungs. The Puff-adder, *Bitis arietans* can produce the loudest hiss among all African snakes, and Russel's Viper among the Indian snakes.

The snakes are essentially carnivorous. They eat insects, eggs, amphibians, other reptiles, birds or small mammals. They are thus helpful in keeping down the number of small reptiles and rodents in jungles and swamps and even in houses. Millions of frogs, rats, mice and insects are swallowed annually by snakes. Further, all snakes are cannibals as well. They eat other snakes and even those of their kind. Except in the burrowing forms, the mouth and gullet of snakes are extremely distensible due to which the snakes are able to catch and swallow the living prey, often much thicker than themselves.

Pythons and Boas live almost exclusively upon birds and mammals, which they squeeze to death in their coils. They are non-poisonous and only a few are large enough to be dangerous to man.

The sexes are distinct in snakes. Each kind or species is considered to breed true. Hybrids are not known and some snakes

bring forth their young alive. As a rule, the female lays eggs in the sun or at places where there is sufficient heat to hatch. Snakes breed quickly, producing 10 to 100 eggs a year.

Snakes have a world-wide distribution. They predominate in the warm climate and lush regions of the tropics. Snakes have not been reported from the Arctic region and New Zealand. In Ireland and Madagascar no poisonous snakes have been reported. About 216 species of snakes are found in India, of which only 52 species are really poisonous.

Snakes can live in different habitats. Some snakes live under ground, some on land while there are also snakes which live on trees, in bushes, in marshes, in fresh water and also in sea water. Except earth snakes and blind snakes very few burrow, though some live in ant holes, tree holes and burrows of other animals.

Teeth of Snakes:

The snakes have four rows of curved and pointed teeth in the upper jaw (maxillae) and two in the lower jaw (mandibles).

The two rows of the teeth in the upper jaw are situated in the middle of the roof of the mouth on the palate and are called '**Palate teeth**' and the other two upper rows of teeth are situated all along the margins of the upper jaw and are hence called **Maxillary** or **marginal** teeth. On either side of the lower jaw along its margin, there is only a single row of teeth. As mentioned earlier, the recurved teeth of snakes help them to hold the prey firmly from escaping and assist in the propulsion of food into the mouth. Non-venomous snakes possess teeth only of this character.

Faags:

In venomous snakes some of the maxillary teeth are modified as **poison fangs**. They are not found on the mandibles. Fangs may be grooved or tubular curved teeth and act like a hypodermic syringe needle. They are perfectly adapted for injection of the poison under the skin. The ducts from the poison glands open at the base of the fangs and the poison is ejected through their pointed ends.

At the bases of the poison fangs there are buds of newer fangs. When a fang breaks, it's place is taken by a new fang developed by the fang bud. The new fangs may emerge in three to six weeks. It should, as such, always be remembered that a poisonous snake removed of it's fangs may soon develop it and inject the venom.

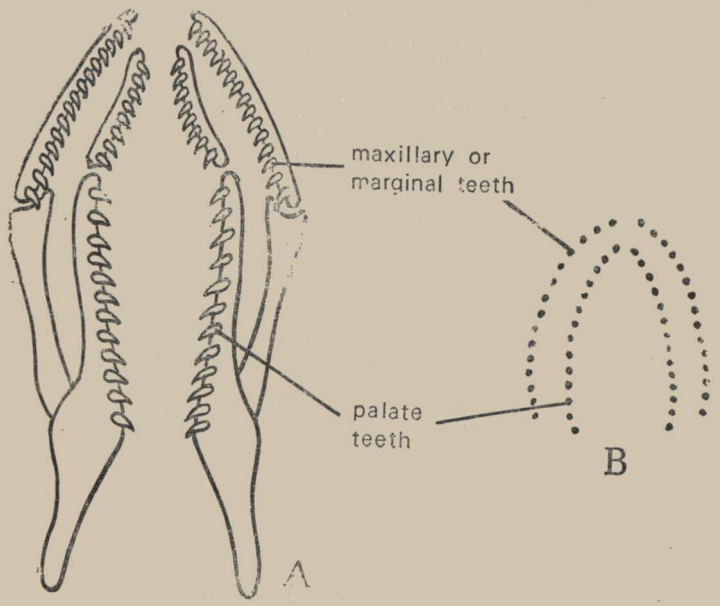


Fig. 15.1 (A) Teeth in the upper jaw of a typical non-poisonous snake.
(B) The section of the same.

The fangs may be found either at the posterior region or at the anterior region of the maxilla. The bites of snakes having fangs at the hinder end of maxilla are usually not fatal to man, whereas the bites of snakes possessing fangs at the anterior region of maxilla are lethal to man. All coral snakes, King Cobras, Cobras and Kraits belong to this category.

The Poison Glands:

The poisonous snakes possess a pair of **poison glands** somewhat almond-shaped, situated one on each side behind the eye and stretch backward in length according to the size of the gland. From each gland a duct arises called the **poison duct** which carries the poison to the base of the fang. The anatomical position of the

poison gland corresponds to that of the *parotid gland* of mammals. It's similarity with the parotid gland is also strengthened by serous character of the secretion. Further, the poison gland like the parotid gland, has only one excretory duct. The venom gland in poisonous

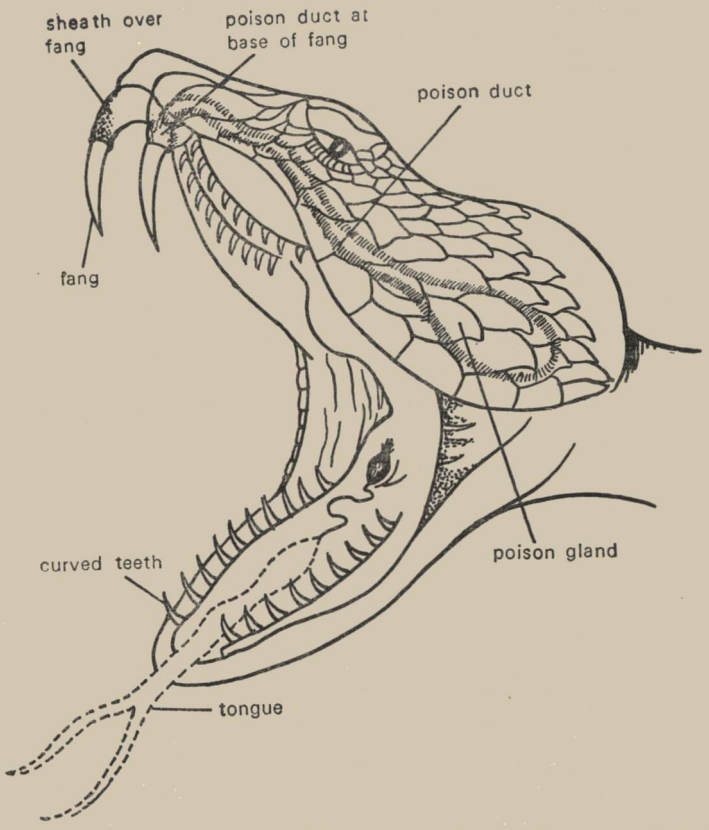


Fig. 15.2 The head of a viper widely open showing the fangs and the poison glands as well as teeth and tongue.

snakes is thus a modification of the parotid salivary gland highly evolved to produce the '**Venom.**' The **venom** of a snake is a complex toxin which is a '*protein* and *enzyme*' combination. The venom secreted by the poison gland paralyses the prey and also probably assists in digestion.

Scales on the Body of Snakes :

In all snakes, the scales covering their head, dorsal and ventral surfaces of the body retain their characteristics, throughout their life. The scales present on the body of snakes as such, form a good distinguishing feature to identify them.

The scales as already mentioned form a superficial covering on the body of reptiles. A brief description of the scales found on the head, dorsal part (back) ventral part (belly) and the tail region of the snakes is given below. This would be much helpful in the identification of the type of snake and on the basis of these characters only, one can tell whether a snake is harmless (non-poisonous) or harmful (poisonous).

The most primitive type of scales called the **imbricate scales** (semi-circular) are found all over the body of blind snakes (*Typhlops braminus*). There is no distinction between the dorsal and the ventral scales (See fig. 15·8 Top).

The scales in the highly evolved snakes are well defined and are arranged in particular patterns on the dorsal and the ventral surface of the body.

Scales on the Head :

The scales on the head of a snake may be small and do not show any differentiation in scalation. In primitive snakes, such type of scales are found. Likewise, in *Sand boa* and *Vipers*, the scales found on the head are very small and not differentiated.

In a majority of snakes, the scales found on the head are such that their length is greatar than the breadth. Such scales are called '**shields.**' The **head shields** are arranged usually in a characteristic pattern. The head shields as such receive different names according to their position on the region of the head. The terms used for the head shields are no doubt technical but the meanings are clear and they are as such self explanatory. The names and description of the head shields on the dorsal, ventral and lateral surfaces are given below.

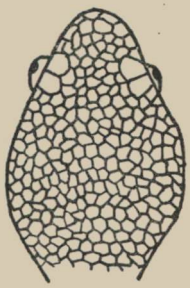


Fig. 15.3
Head of a snake covered with small scales.

Head Shields:

The big shield found on the head between the eyes but not touching them is called the **frontal.** Behind the frontals are two shields known as the **parietals**. On the side of the parietals are the **temporals.** The two shields immediately infront of the frontals are called '**prefrontals.**' The paired shields infront of the prefrontals are known as the **internasals.** The head shields in which the nostrils are situated are referred to as '**nasals**' or '**nose shields**'. The shields which cover the margins of the upper lip are called '**supra-labials**' or **upper lip shields.** These shields extend to the gape of the mouth. The central shield forming a covering in the middle of the upper lip is referred to as the **rostral** or '**beak shield.**' The shields lying along the margin of the lower lip are known as '**infralabials**' or **lower lip shields.** The centrally placed lower lip shield is called the **mental** or '**chin shield.**' The number of upper

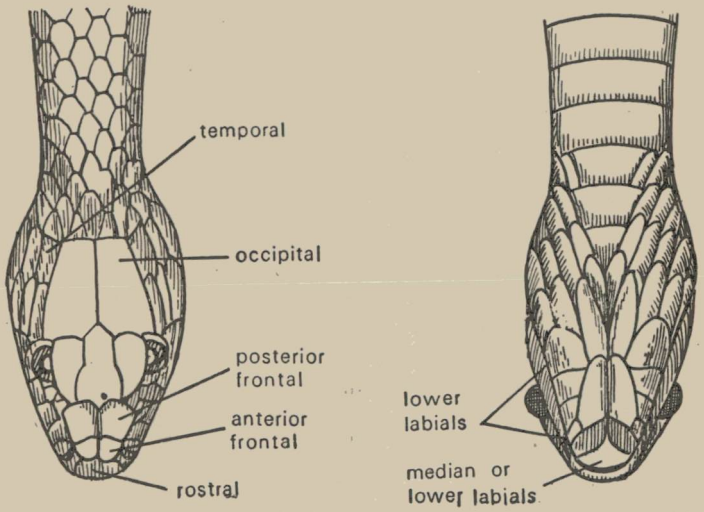


Fig. 15.4 Diagrams of the shields on the head of a snake. Left : Shields on dorsal surface. Right : Shields on the ventral surface in Ptyas mucosus.

and lower lip shields may be 4 to 7 or more. Behind the 'mental' or 'chin shield' in the middle, are found usually the two pairs of shields. As these shields according to their position are under the tongue they are called the **sublinguals.** The anterior pair is referred to as the **anterior sublinguals** and the posterior pair is called the

posterior sublinguals. The central groove separating the sublinguals on either side is called the '*mental groove*.' The last shield along the margin of the lower lip, touching the posterior sublingual, may be considered as the last infralabial shield.

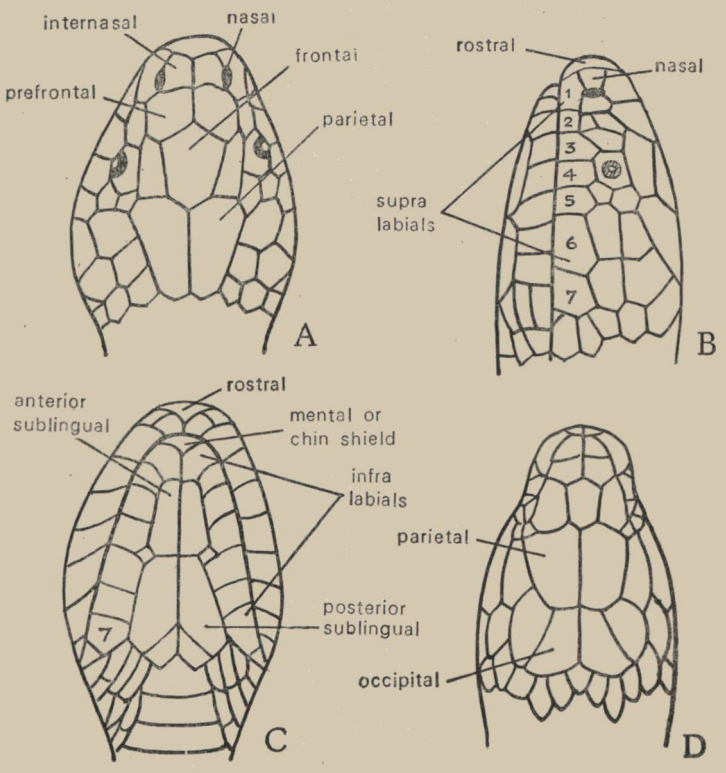


Fig. 15.5 (A) Head shields of a snake on the dorsal surface. (B) Lateral view of the head of a snake. (C) Under surface of the head of a snake. (D) Top of the head of a King Cobra.

The scales or shields surrounding the eye are also named by the position they occupy.

The shield above the eye is **supraocular**, and that which is below it is **subocular**. The scale found infront of the eye is called **preocular** and that which is found behind the eye is referred to as the **postocular**.

In the King Cobra, there are found two large shields called the occipitals lying behind the parietals.

The region between the nostril and the eye is referred to as the *Loreum*. The shields or the scales covering this region are called the '*Loreals*.'

Body Scales—'Back' :

The scales covering the dorsal surface of the body or 'back' are called **'dorsals'** or **'costals'** when they cover the dorso-lateral surface of the back. The costals may be contiguous or overlapping. They may be smooth, polished or dull and stiff. There may be a central ridge in each scale. Such scales are called **'Keeled.'** If a slight prominence is found on the scale it is called **tuberculated** as in sea snakes. The scales that lie along the centre of the back on the spine are referred to as *vertebrals* or *spinals*.

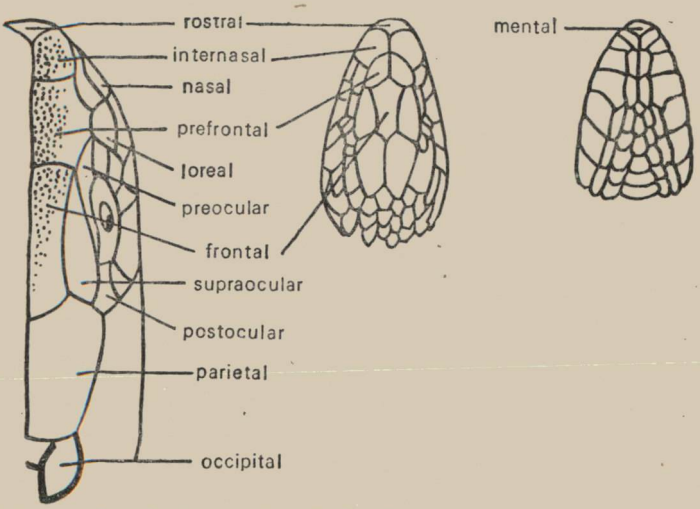


Fig. 15.6 Head scales in a snake. Left : Enlarged drawing of head shields. Middle : Dorsal head shields (full view). Right : Ventral head shields.

The scales on the back may also show variations in shape. The scales may be oblong with a line e g., scales of rat snake. In some, the scales may be rhomboid with spaces in between as are seen in a cobra. The scales may be semi-elliptical having a thin line in the centre e.g., Russel's Viper. In some snakes, the over-lapping elliptical scales with serrated lines are found. Such type of scales are seen behind the head in *Echis carinatus*.

The number of longitudinal rows of the scales on the back are counted in a serial row from side to side. This is always uniform in each species of snakes (See fig. 15·7 Top).

Belly :

The lower side or the ventral surface of the body of a snake is called the belly. It is that part of the body which touches the

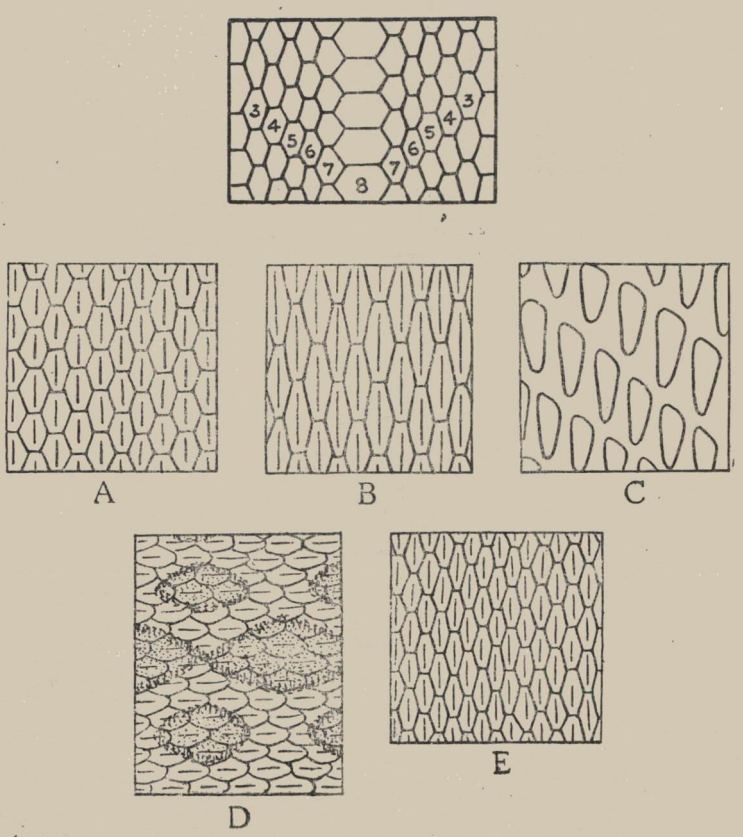


Fig. 15.7 Scales on the dorsal surface of the body of a snake. Top : Central row of big dorsal, hexagonal scales as seen in a Krait. (A) Oblong scales with a line as seen in a rat snake. (B) Semi elliptical scales with a thin line in the centre. (C) Rhomboid scales with a space in between as seen in a Cobra. (D) Scales of a Russel's Viper—semi-elliptical with a thin line in the centre and prominent elliptical patches. (E) Overlapping elliptical scales with serrated lines like a 'saw' seen behind the head in *Echis carinatus*.

ground as the snake crawls along. The scales on the belly are usually very broad. When the width of a scale is much in excess of it's length, it is referred to as a 'plate.' The belly plates or the scales on the belly are called the 'ventrals.'

Sometimes the belly is covered with small semi-circular or imbricated scales as on the back.

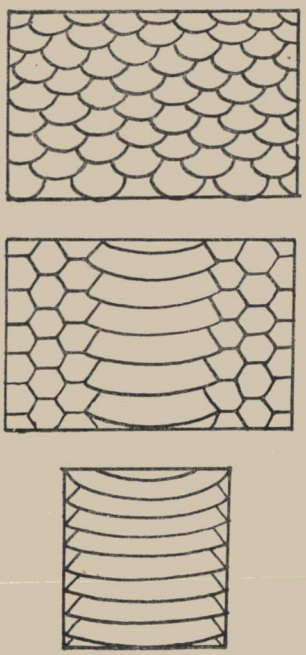


Fig. 15.8 Belly plates of snakes. Top : Belly covered with small scales Middle : Broad ventral plates limited to the middle of the belly. The last rows of small scales which cover the back are visible on the under surface of the snake. Below : Belly covered with large transverse belly plates No small scales are visible on the under surface of the snake.

In some, the ventral plates are somewhat broad but are limited to the middle part of the belly. They are not broad enough to cover the entire width of the belly. The remaining portions of the belly on each side of the broad but narrow ventral plates are covered by small scales. Such type of belly is seen in a Python. In some snakes the belly is covered by complete transverse plates extending over the

entire width of the belly. Such type of belly shields are seen in a Rat snake and the Cobra.

The scale in which the 'vent' is located is called the *'anal scale.'* The anal scale may be single, bifid or very rarely trifid. The scales behind the 'anal scale' on the undersurface of the tail are called **'sub-caudals'** or **tail shields**. The sub-caudals may be entire, extending over the whole breadth of the tail such as are seen in Krait. In others, the sub-caudals may be divided into two rows. Such type of sub-caudals are seen in the Cobra.

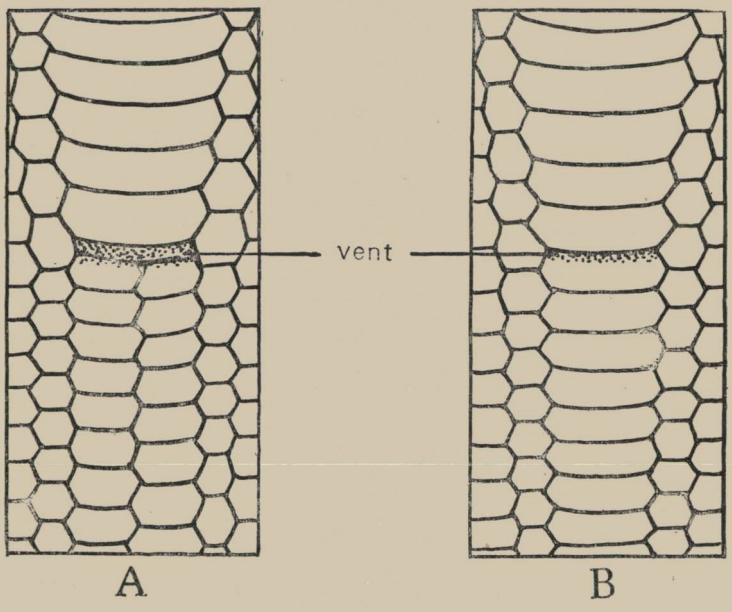
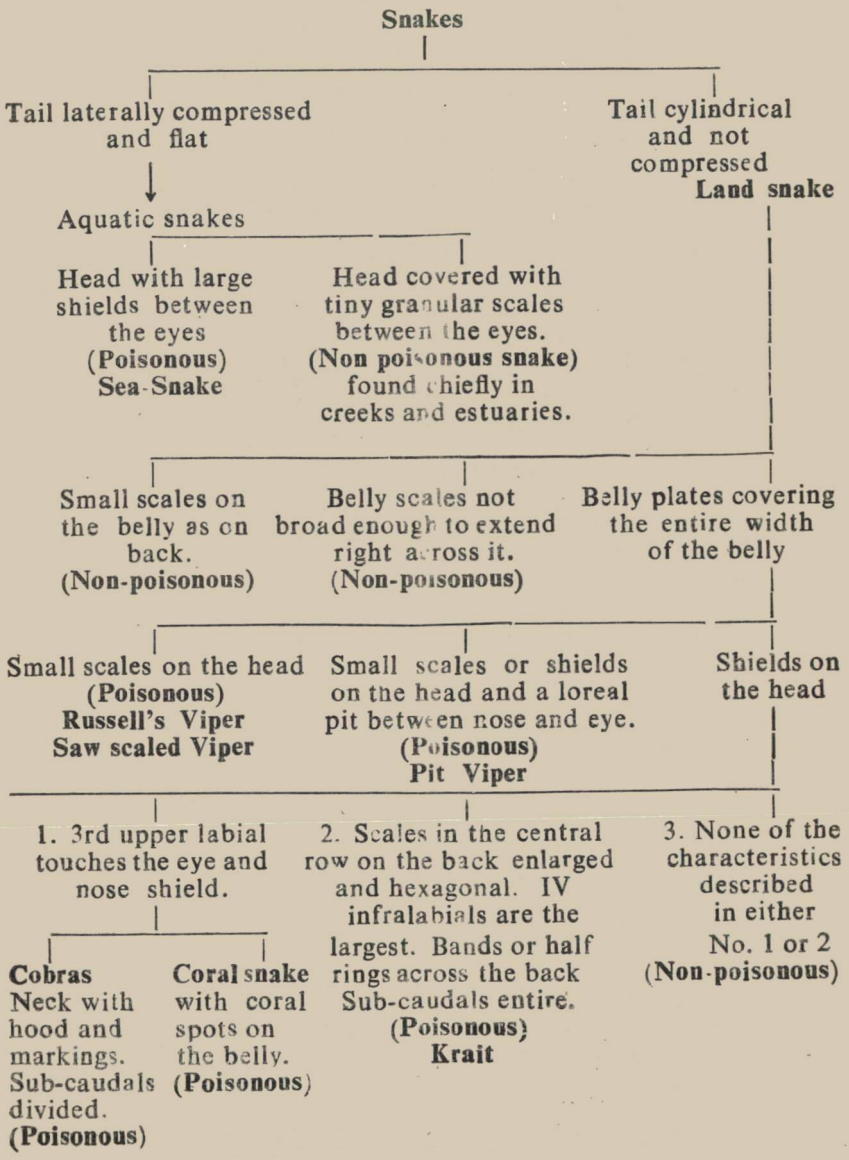


Fig. 15.9 (A) Ventral scales near the region of the 'vent.' Behind the vent the sub-caudals are divided into two rows. e. g., Cobra (B) Ventral scales in a single row. The sub-caudals are entire even beyond the vent e.g., Krait.

The salient features to distinguish a poisonous snake from a non-poisonous snake are given in the form of a table.


Snakes
Tail laterally compressed and flat
Tail cylindrical and not compressed
Land snake
Aquatic snakes
Head with large shields between the eyes (Poisonous) Sea-Snake
Head covered with tiny granular scales between the eyes. (Non poisonous snake) found chiefly in creeks and estuaries.
Small scales on the belly as on back. (Non-poisonous)
Belly scales not broad enough to extend right across it. (Non-poisonous)
Belly plates covering the entire width of the belly
Small scales on the head (Poisonous) Russell's Viper Saw scaled Viper
Small scales or shields on the head and a loreal pit between nose and eye. (Poisonous) Pit Viper
Shields on the head
1. 3rd upper labial touches the eye and nose shield.
2. Scales in the central row on the back enlarged and hexagonal. IV infralabials are the largest. Bands or half rings across the back Sub-caudals entire. (Poisonous) Krait
3. None of the characteristics described in either No. 1 or 2 (Non-poisonous)
Cobras Neck with hood and markings. Sub-caudals divided. (Poisonous)
Coral snake with coral spots on the belly. (Poisonous)

CERTAIN NON-POISONOUS AND POISONOUS SNAKES OF INDIA

Some details with reference to the distribution, chief characters, habits and other relevant aspects about certain non-poisonous and poisonous snakes of India will now be given.

Non-poisonous Snakes

Ptyas mucosus *(Zamenis mucosus)*

Rat Snake—Dhaman

Ptyas mucosus is called the Rat snake owing to its fondness for rats as it's food. This snake is also familiarly known as '*Dhaman*' — a word which is Sanskrit in origin means a 'rope.'

The Rat snake is found all over India in plains and also at some altitudes. They are also found all over the world, in Europe, Asia, North and West Africa (Senegambia) and North and Central

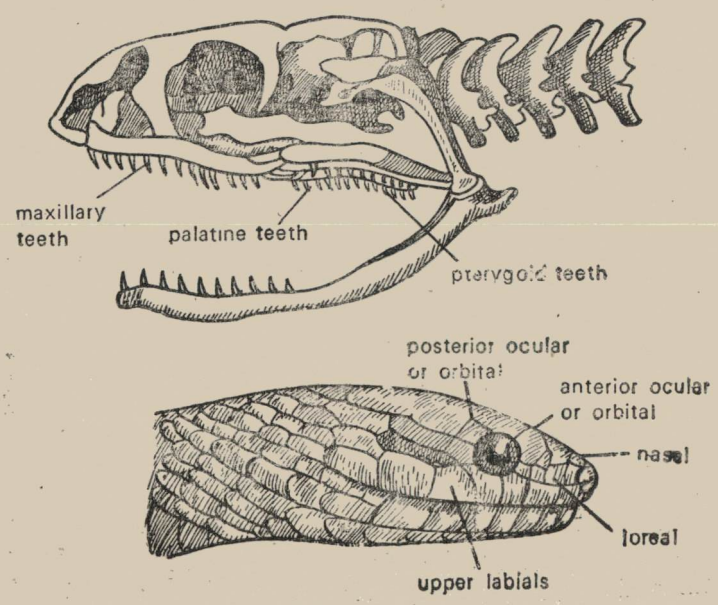


Fig. 15.10 Above : The skull with lower jaw of **Ptyas mucosus**. Below : The shields on the head of **Ptyas mucosus**. (See also fig. 15.4.)

America The males attain a length of 2,250 mm and the females are 1,800 mm in length.

The Rat snake has large eyes and a round pupil. The pupil has golden yellow specks all round it. In some of the snakes, the tail is fairly long being one-third of the whole length of the snake. In *Ptyas mucosus* the tail is about one-quarter of the total length of the snake.

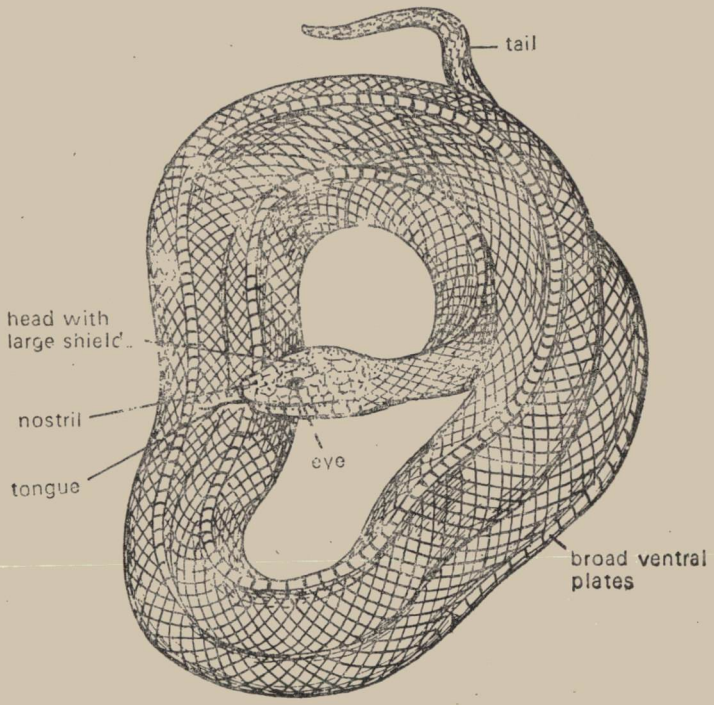


Fig 15.11 Ptyas mucosus (Dhaman).

Ptyas mucosus is a robust snake. It's generic name *Zamenis sp.* is a Greek word which means '*very strong*.'

The head is distinct from neck. The loreal region is concave with two or three shields. The nostrils are large. A subocular scale is found between the two nasals. There are two post-oculars. Fourth and fifth supralabials touch the eye. The supraocular forms a ridge on the eye.

Scales on the body are in 16 to 17 rows. Some of the rows are slightly keeled. The sub-caudals are paired.

The snake is dirty yellow in colour. The tips of the scales are black. The anterior and ventro-lateral scales have very prominent black borders. The scales on the posterior part of the body towards the tail are bordered in an irregular manner so as to form a reticulate pattern of cross bars. The belly is whitish or yellowish. The yellow colour is prominent near the throat. The young snakes are olivaceous yellow and have distinct markings. The irregular cross bars in the posterior region of the body are similar to the adult.

The snake is timid. It can climb a tree. It lives mainly on mammals, rats, frogs, toads, lizards and even snakes. If cornered, it inflates the lower part of the head and can bite viciously. The tail being long and pre-hensile, the snake uses it to tie a knot and exert a pull on the victim.

The snake can emit a foul odour on touch and also secretes a black substance from the anal glands. The snake, when squeezed, gives a guttural noise like that of a kite. Although ferocious in look, it can be domesticated and handled without being bitten.

There is no truth in the belief that Dhaman is the male cobra. Cobras and Dhamans are snakes of totally different kinds and no hybrids are known. Dhamans and Cobras are however found in similar surroundings. Another belief that it's bite causes blindness in persons over 40 is also erroneous.

Dhaman is oviparous. The eggs are blunt at both the ends. The young ones emerge from the eggs during the rainy season. It is a non-poisonous snake. In some rural areas this snake is reported to be eaten by the people.

Natrix piscator (Tropidonotus piscator)

Checkered Keel Back or Checkered Water Snake or Common Pond Snake

Natrix piscator is called '*Pani Ka Samp*' in Hindi. It is distributed all over India. The males are about 900 mm and females 1,200 mm in length.

Natrix piscator is commonly found in the vicinity of water, near ponds, tanks, paddy fields and rivers.

The scales on the back are keeled due to which the back is somewhat rough. In colour, it varies from yellow to very dark olive brown. There are dorsal black spots arranged in a pattern, one series on vertebral, two at sides and two laterally. This

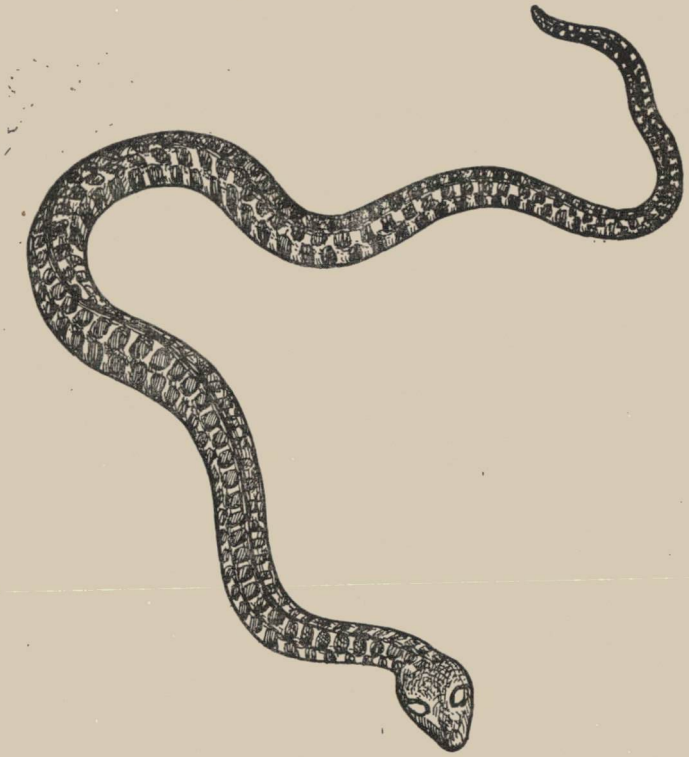


Fig. 15.12 Natrix piscator — checkered keel-back

arrangement of coloured spots gives the appearance of a chequer and as the scales are keeled on the back, the snake is also referred to as *checkered keel back snake*. A narrow, oblique, black streak runs from behind each eye. The ventral surface is white with black borders more prominent in the posterior region.

Natrix piscator is a very vicious snake. It usually bites quickly and tenaciously. When this snake strikes, it erects its body

somewhat like a Cobra. It is however not poisonous. It is usually observed during day time. It can jump clear off the ground. It can swim as well. It chiefly eats frogs and fishes. This snake retires in the hot weather and comes out when the monsoons set in.

The female is very prolific, and lays about 50 to 75 eggs usually in March and April. The young ones hatch out in May — June of the same year.

Natrix piscator is essentially a snake of the plains, but also occurs in hills upto an elevation of 6,300 feet.

Natrix stolata (Tropidonotus stolatus)

Buff striped Keel-back

Natrix stolata is called '*See'a-ki-lat*' in Hindi and *Vanacogli* in Telugu. It is found all over India The males attain a length of about 720 mm and the females have a length of about 620 mm. The circumference is about 30 mm.

The snake is found in the plains, usually in rice fields, grassy cultivated islands, gardens, and grass farms. It also occurs sometimes around bungalows near plants grown in pots. It usually takes shelter in holes in the ground or in the masonary of walls, in drains etc. It is very fond of lying in water. Although a dweller of plains, this snake has also been reported at an elevation of over 5,000 feet.

Natrix stolata is an olive green snake. On the dorsal surface are found reticulated black spots with irregular cross bars. There are also two buff coloured longitudinal stripes which run all along the sides of the body. These stripes are more prominent posteriorly. The scales on the back are keeled, hence the common name *Buff striped keel-back snake.* The belly is white with black spots on the sides. The eyes are large with round pupils and the iris has yellow flecks

Natrix stolata feeds mainly on frogs, toads and insects. It is an in-offensive and harmless snake.

The head of the snake has black bordered shields. The mouth has a cream coloured region extending upto the eyes. This snake is seen in large numbers during the rainy season. It appears during day as well as at night. During the winter months, it hibernates.

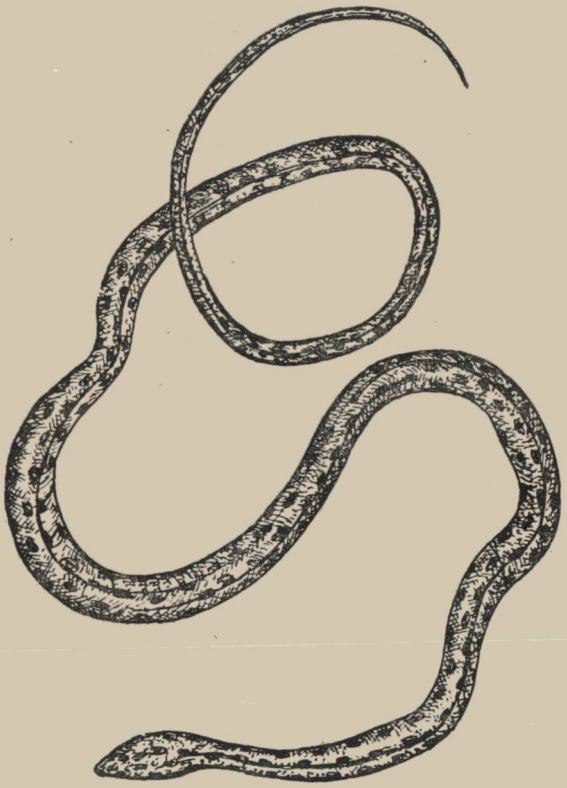


Fig. 15.13 *Natrix stolata (Tropidonotus.) Buff striped keel-back.*

The female usually lays about 5–10 eggs. Eggs are laid in soil heaps sometime in April–May and the young ones hatch from the eggs during the rainy season.

POISONOUS SNAKES

The **Tiger snake** (*Notechis scutatus*), a relative of Cobra is the most poisonous snake in the world. It is found in Australia. It's

venom is 40 times more toxic than that of Cobra. As regards the Asian snakes, the **Krait** has the most toxic venom.

In India, some 50 species of poisonous snakes are found. **Cobra, Russel's viper**, the **Saw scaled viper** and the **Krait** are the chief poisonous snakes of India as they inflict the most serious fatal bites. The **coral snakes** are also poisonous. They are, however, not very commonly found in India. **Sea snakes** belonging to the *family Hydrophiidae* are also found in India within a few kilometres from the sea shore, especially in river mouths. Some 21 species of sea snakes are reported from Indian waters. The sea snakes are also important poisonous snakes of India but no correct figure is available regarding the number of persons bitten by them.

A few of the above mentioned venomous snakes of India will now be discussed.

Family Elapidae includes **Cobras, Coral snakes** and **Kraits** which are all poisonous.

Cobra—Naja naja; "Nag" :

The people living in tropics must have seen the Cobra. In Portuguese language the word Cobra is used for any snake. In that language '*Cobra-de-Capello*' is the term used for Indian Cobra. It means a *hooded snake*.

The most prominent characteristic of Cobra is its well marked *hood*. It has long ribs on the neck just behind the head with muscles attached. The ribs behind the neck however are shorter and smaller. When the neck muscles contact, the ribs stand out side ways, due to which the neck expands laterally forming as such the hood. The hood of a Cobra is well marked, widely expanded and slopes down gently from just behind the head towards the back. The Indian Cobra is black or of wheat colour. In the lower Rajasthan, an *albino* variety of Cobra is occasionally seen. This Cobra has a faint marking on the hood and light bands on its underside. The local people in Rajasthan call this Cobra as *Basuki Nag*.

The hood of Cobra sometimes bears what is called a spectacle mark something like V. Such Cobras are of two varieties. The two ringed or spectacled Cobra is called the **binocellate Cobra.** In others, there is found on the hood an oval spot surrounded by an ellipse. This is called the **monocellate Cobra.** Binocellate Cobras are common in

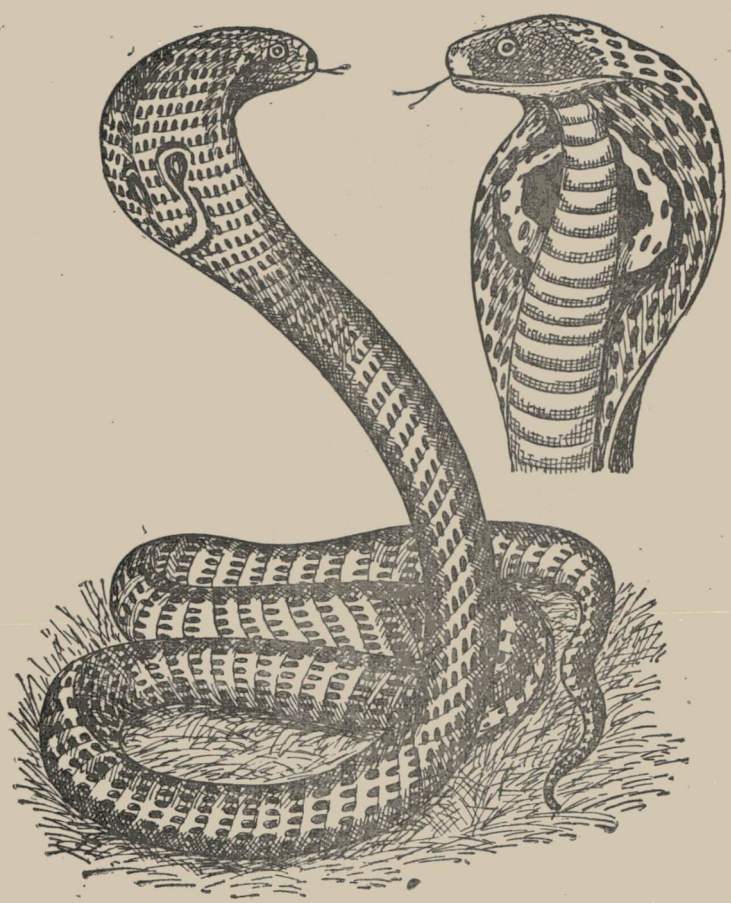


Fig 15.14 The Cobra, *Naja naja;* 'Nag'

Maharashtra, while monocellate varieties are common in Bengal. The spectacle marks on the hood consist of black spots surrounded by white ones. These marks if present can only be seen when the neck is expanded. The hood cannot be distinguished when a Cobra dies

or is killed, as in these cases the neck becomes stiff. There are also certain Cobras where no mark is found on their hood. Such Cobras are commonly found in Kutch, Rajasthan, Kathiawar and Central India.

The other important diagnostic characters of Cobra are as follows.

1. The third shield of the upper lip in Cobra is big and extends from the eye to the shield containing the nostril. This is a characteristic only of the Cobras and the Coral snakes (See fig. 15·15).

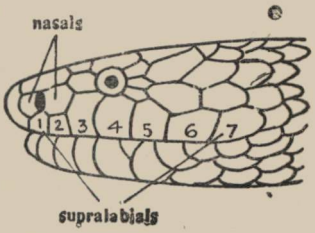


Fig. 15.15 Later view of the head of Cobra showing third upper labial shield

2. There is also found in the Indian Cobra a tiny shield, wedged in between the fourth and fifth infralabial shields. This tiny shield is called the *Cuneate* or *Wedge shield* (See fig. 15·15). This shield is however absent only in rare cases.

3. The sub-caudal shields i.e., the shields under the tail are double (See fig. 15·9 A).

4. There are three black stripes on the underside of the hood extending from the 10 to 17 ventrals.

5. There are two black spots extending from the fourth to sixth scale size, between 15 to 30 ventral scales on the underside of the hood.

6. The frontal shield of the head is larger than broad and it's anterior margin is truncated.

7. There are smooth oblique scales on the body, which are 25–35 on neck, 21–25 in the mid-body and 15–17 at the vent. The ventral scales range from 176–200.

The maxillary bone extends beyond the palatine. Behind the poison fangs are 1–3 small teeth. The loreal is absent. The nostrils are large, elliptical and vertical.

The common belief that a Cobra has a jewel on its head is not true. Likewise, there is no evidence to show that a Cobra takes revenge after a lapse of time. The belief that the Cobra is attracted by music is also erroneous. There is no evidence as well, that an old Cobra has white hairs or moustaches. There is also an erroneous belief that many old and palatial buildings are inhabited by a Cobra which is said to *'Guard the Wealth.'* Cobra has an important place in mythology. It is worshipped by a certain section of the society on the *'Nag Panchmi'* day. The images resembling the hood of a Cobra are placed under *pipal* trees where many a lady circumambulates such trees for fecundity. There is also no evidence to prove that by 'mantras' the effects of Cobra's, Krait's, Russel's viper's bites can be neutralized.

There are six different sub-species of Cobra in Asia, belonging to the genus *Naja* (also spelled *Naia*). In Africa, there are nine sub-species of genus Naja. The common sub-species of Cobra is the binocellate variety *Nai naia naia* inhabiting most parts of India. The other two types of Cobras found in India are the Black Cobra, *Naia naia axiana* found in North Western India and the monocellate Cobra (*Naia naia kaouthia*) of North Eastern India.

The Cobra's main defensive tactics is to raise its impressive hood in an attempt to frighten the attacker. It usually raises the front part of it's body with expanded hood about 2½ feet from the ground and thus gets an effective striking range of the same length. If one keeps beyond this range, then the snake is likely to retreat. If one moves or runs, the snake is said to give a chase for some distance. Under such circumstances the speed of the runner due to fright is reduced and eventually may fall a victim to the snake. The speed of Cobra in fact is far less than that of man. Further, the Cobras are timid creatures. The raising of their hood is in self-defence rather than for aggression. Cobra's hiss is a respiratory act and when erect, it can hiss in a fierce and explosive manner. They may attain a length of about 1,800 mm. The male Cobras are longer.

The Cobra feeds chiefly on rats, mice, frogs and toads and less frequently on birds and their eggs. Is does not eat another Cobra.

The Cobras are seen in the early morning or evening. In old houses with thatched roof, it has been seen under the roof where it may have gone in search of the prey. The presence of this snake near human habitations is in search for it's food. Cobras are very often found in the thick growth of trees, the jungle and in open country with or without vegetation. It is also found in gardens, in cultivated fields or in plains. It can swim well in water. It climbs trees in search of birds.

The Cobra sheds it's skin more frequently in summer. The younger Cobras shed the skin quicky.

Mating takes place during the rainy season. Nine to ten months after mating, the egg laying takes place in the month of April. 56 eggs are laid in three days. The eggs are deposited in an old termite mound or a rat hole. The eggs are mixed with the soil and dry vegetation. The females stay coiled around the eggs for about 60 days of incubation. The eggs hatch after 60 days. The young ones have a well formed hood. The young Cobra is very alert and irritable. They have a miniature pair of poison fangs and venom in their poison glands. The bite of a young Cobra may be lethal. The skin of the young Cobra is shed first on the 2nd day followed by a shedding on 7th, 21st and 30th days. After this, the shedding becomes less frequent. After about a month, the young Cobras, like the adults go in for frogs, mice and lizards. The length of the snake on birth is 8" to 10". After one year it is 2'–6" and by four years it is about 5 feet. The cobra matures probably after three years.

The bite of Cobra is usually a quick snap but may be tenacious. The poison may trickle on the skin as a drop or may be sprayed, and very little may penetrate through the actual puncture.

The venom of this snake is *neurotoxic* i. e., poison to nerve tissue. The bite is not often locally painful. After one or two hours of the bite the swelling occurs. The vision gets blurred and the victim develops ptosis (to pronounce to-sis) i. e., a condition in which the drooping of the eye-lids and the unsteadiness of legs occur. The tongue and the larynx swell. There is an excessive salivation. The person cannot swallow or speak coherently. As regards other

symptoms the person feels drowsy. Incoordination and respiratory difficulty soon set in. The sufferer may also go into a coma (unconsciousness) and convulsions. If the lethal dose of the poison is injected, the paralysis of the nerves set in within an hour and great respiratory difficulty occurs. The patient goes into a state of shock. If untreated, death may occur from respiratory paralysis about 5 to 6 hours after the bite. The diagnostic clinical symptoms of systemic poisoning due to Cobra bite are *ptosis and paralysis of the tongue and the throat.*

The *mode of action of* **Cobra venom** can be easily remembered from the word **COBRA**. **CO** stands for *cord* and **BRA** for *brain*, showing that, it is, the central nervous system which is mainly affected. Again the letters **C O B R A** stand for the following: '**C**' for *clotting*, '**O**' for *of*, '**B**' for *blood* and '**R**' for *reduced* i. e., *the clotting of blood reduced.* The last alphabet '**A**' gives us the mode of death in the word '*Asphyxia*' from the paralysis of the respiratory centre.

Cobra poisoning cases should immediately be referred to the hospitals. In cases of lethal dose of the venom being injected, the only remedy is the administration of antivenin under expert medical advice. The maximum dose of cobra venom lethal to man is 12 mg. The mantras, herbs and snake-charmers were actually given a trial on animals bitten by the Cobra. These could not save the animals. In case a person is involved, the greatest service is to put him under medical care where he may be treated scientifically. All the Cobra bites are not fatal. Even the persons with fatal bites if treated properly and in time can be saved easily.

Coral Snakes

Coral snakes are small snakes with beautiful colouration. In most of the snakes, part of the belly has a pink coral colour. The tail is round and the third upper lip shield, like cobra's, touches the eye and the shield in which the nostril is situated. They are all poisonous. The poison however does not do much harm to man. The gape of the mouth is narrow.

Callophis melanurus—Slender Coral snake :

Callophis melanurus is found in low hilly regions of Maharashtra, Nagpur district, Kerala, Dharwar district of Karnataka, Coimbatore and Annamalai in Tamil Nadu. It attains a length of 335 mm. The males are longer.

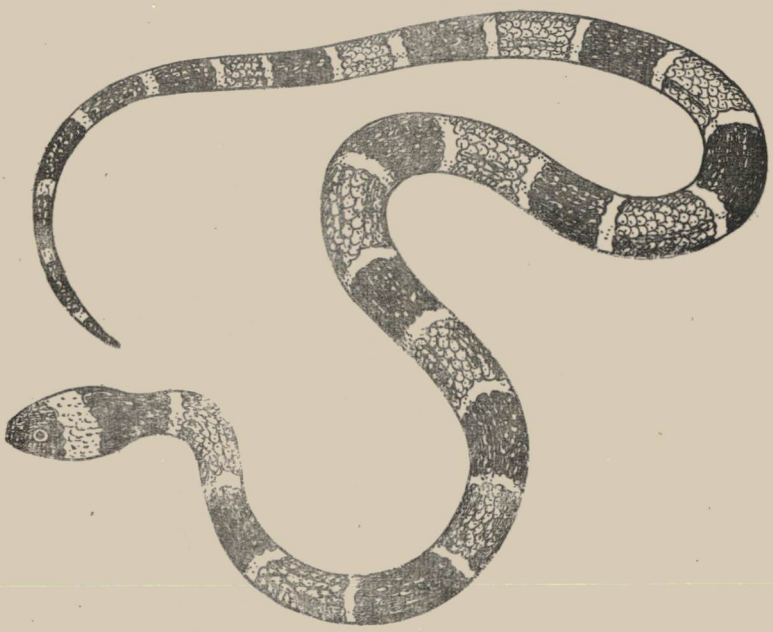


Fig. 15.16 A coral snake (*Micrurus fulvius*). It is a North American coral snake with brilliant red rings alternating with black and yellow ones. The snout is black. There are altogether forty species of Genus Micrurus in tropical America.

The dorsal surface of the snake is light brown and the centre of each scale is speckled with brown specks due to which a series of longitudinal lines all along the body are found. The head and neck are black above and have yellow spots. There are two black rings on the tail—one at the base and the other at the tip. The ventral surface of the snake is pink red. There are found 2 or 3 minute teeth behind the poison fangs. It has 13 rows of scales and there are 249—277 ventrals.

Callophis melanurus is a poisonous snake. In Maharashtra there is a belief that if a person is bitten by this snake at night, then he will die before the day dawns. Due to this belief the snake is called *Raat*. The venom of this snake like that of a Cobra is neurotoxic. This snake is oviparous.

Callophis nigrescens—Common Indian Coral snake :

Callophis nigrescens is found in Panchagani, Mahabaleshwar, (Maharashtra), Nilgiri, Shevaroy Hills, Annamalai and Kerala. It attains a length of 1,140 mm. The males are longer.

This snake has 30 rows of scales and in other characters is similar to *Callophis melanurus*. It is however pale reddish dorsally with 5 black stripes on the body, one in the vertebral region, 2 on the lateral sides and 3 on the tail. The top of the head is black with light regular markings. The ventral surface is red.

Bungarus caerulus—The Common Krait :

Bungarus caerulus occurs all over India. It attains a length of 1,500 mm. The males are longer. This snake is often found in plains but some have also been obtained at 4,500 feet altitudes. It is nocturnal in habits.

An enlarged chain of scales forming a *hexagonal pattern* extends all along the dorsal side. There are only four shields along either side of the lower lip. It has a large *fourth infralabial* shield. The plates under the tail are entire and not divided. They are 42–52 in number. The head is covered with shields. It is not distinct from the neck. There is no loreal shield. Post-oculars 2, pre-ocular 1, supralabials are 7. 3rd and 4th supralabials touch the eye. Eyes are moderate or small having round pupils. Scales are smooth and polished found in 15–17 rows. Ventrals on the belly are broad and 194–234 in number.

The Common Krait is distinctly *steel blue in colour* often shining. There are rows of *paired white stripes* across the body. The arrangement of these stripes however differs. The younger snakes

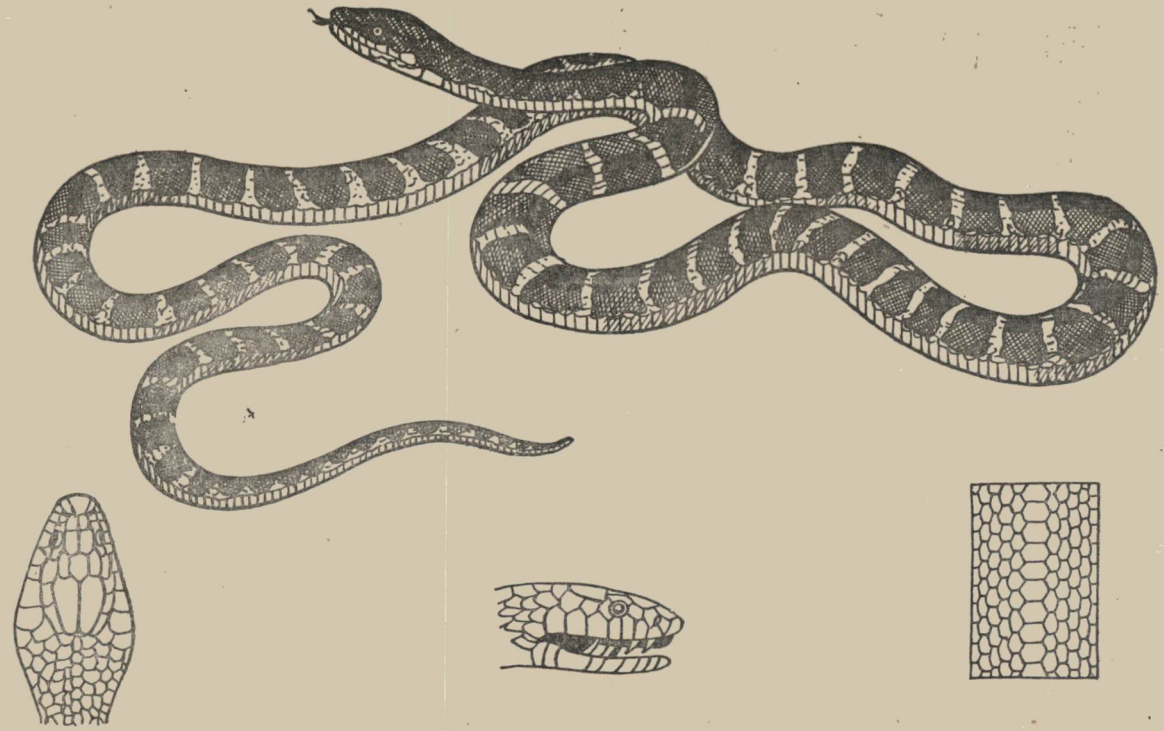


Fig. 15.17 **Bungarus caerulus—The Common Krait.**

do not have a distinct steel blue colour and the stripes are more or less very close.

Kraits usually go about in pairs. So if one is killed, a thorough search should be made for its mate as well. These snakes live in cracks in walls or in heaps of stones or bricks. They are usually nocturnal in habit.

The eggs are laid (8–15) between April and May. They hatch in about 45–60 days. The young ones emerging from the eggs are hardly 150 to 200 mm in length. It is suspected that the Kraits make a vocal noise specially in the morning.

The fangs of Krait are very small but it's venom is very toxic.

The Kraits are especially common in some parts of Kerala, Tamil Nadu, Andhra Pradesh and Madhya Pradesh.

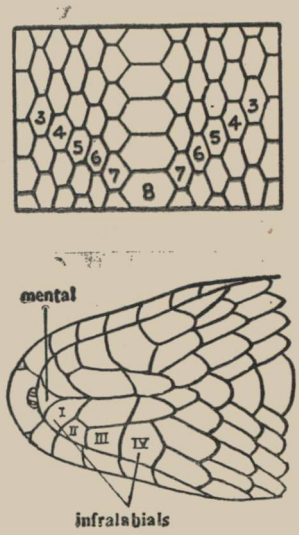


Fig. 15.18 Above: Middle row of large hexagonal scales. Below: The large fourth infralabial shield.

Bungarus caerulus is called *Karayat* in Hindi.

Bungarus fasciatus—The Banded Krait:

The Banded Krait is found in Assam, Arunachal Pradesh (Missimari and Chandwar), Madhya Pradesh, Bihar, Orissa and the Tarai region of Uttar Pradesh.

The banded Krait attains a length of 1,700 mm. Males are longer. The scales are in rows of 15, all along. The tail ends bluntly and the tip is swollen. There are about 200–234 ventral and 23–39 caudals.

Bungarus fasciatus is a banded snake. A jet black 50 mm wide cross band alternates with a dark yellow band of the same size. Such alternating black and yellow bands are found all over the body. A black mark is found on the neck and this

spreads upto the eye. There are median black spots and also sometimes they are found on the head. There is a marked continuous projection like a ridge on the dorsal side of the body. Along



Fig. 15.19 Bungarus fasciatus—The Banded Krait.

with this are also found the enlarged hexagonal central row of scales. The ventral row of scales beyond the vent are continuous. It feeds on other snakes due to which the villagers do not drive it from their farms. This snake is seen soonafter a few showers in Madhya Pradesh. It is a deadly poisonous snake. In Bengali this snake is called *Shankini*, in Hindi *Ahiraj* and *Raj sanp*.

Symptoms of Krait Poisoning :

The Krait venom also is neurotoxic like the Cobra venom. The convulsions are however milder while the drowsiness and intoxication is more intense. Albumen may also be detected in the urine in the case of this snake bite whereas in Cobra bite, it is not seen. There are usually no local symptoms or swellings. The symptoms only appear after several hours of Krait bite, after which the onset of the symptoms are very rapid. About 12 or more hours later the victim develops violent abdominal pain and also pain in the joints. If the victim is not treated, death may occur, as in Cobra poisoning from respiratory paralysis. The maximum lethal does of Krait venom for a man is 6 mg. Administration of antivenin is essential for neutralizing the effects of Krait poisoning also. This should be done under strict medical care and supervision.

Family Hydrophiidae

Hydrophis Caerulescenes—Sea Snake :

This sea snake is distributed all along the coasts of Peninsular India. The male is 820 mm in length and the females attain a length of 740 mm. The sea-snake is faintly sky blue above and white on the ventral side, there are about 50-60 broad dark cross bands dorsally which taper down the ventral sides. In older snakes the markings are much diminished. In adults, the head is deep grey while in the young it is black with a yellowish crescent mark. The head shields are broken up. Loreal shield is absent. 14–18 maxillary teeth are found behind the poison fangs. The tail is flat, compressed and paddle shaped. The ventral scales are more or less reduced, due to which the movements of these snakes on land is very slow. These snakes live in sea water and are usually caught in fishermen's nets or due to ebb tide are left behind on the sea shores. These snakes are very good swimmers. The sea-snakes feed on fishes, eels and some other sea food. They are egg laying.

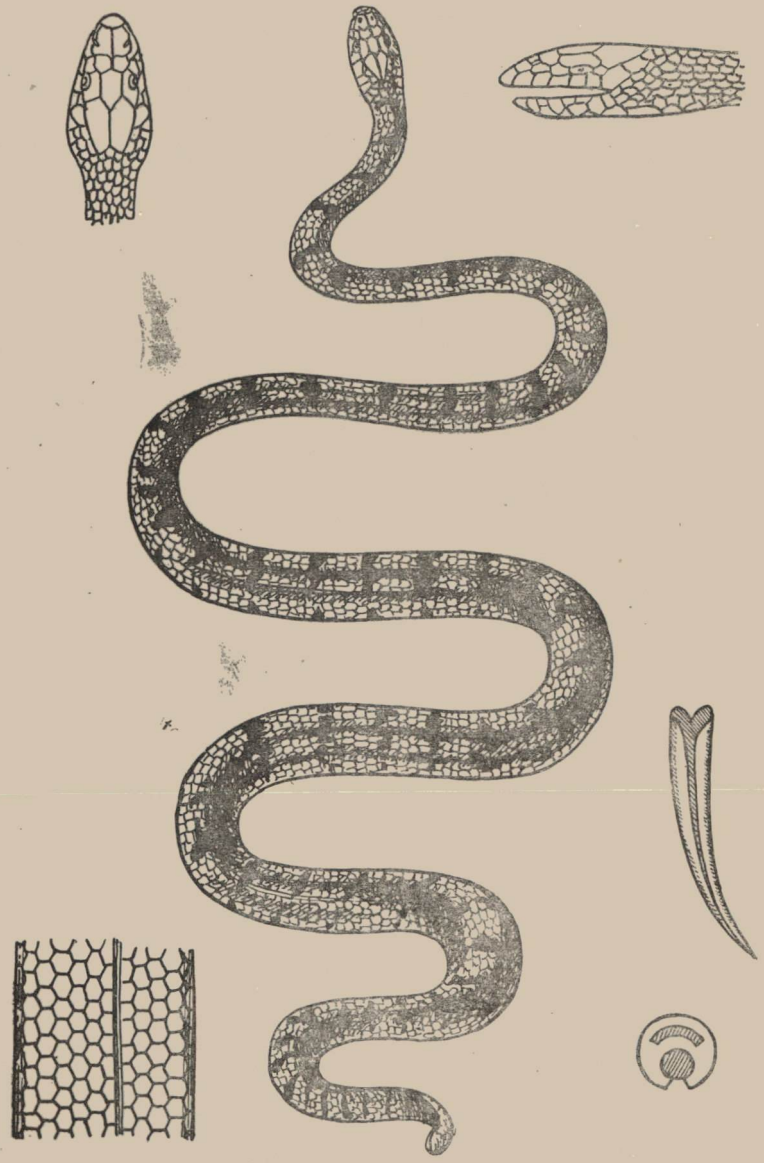


Fig. 15.20 **Hydrophis robusta.** This sea-snake about 6 feet long is found on the coast of the mainland of India. Head of this snake is of moderate size and width. The scales on the body are slightly imbricate.

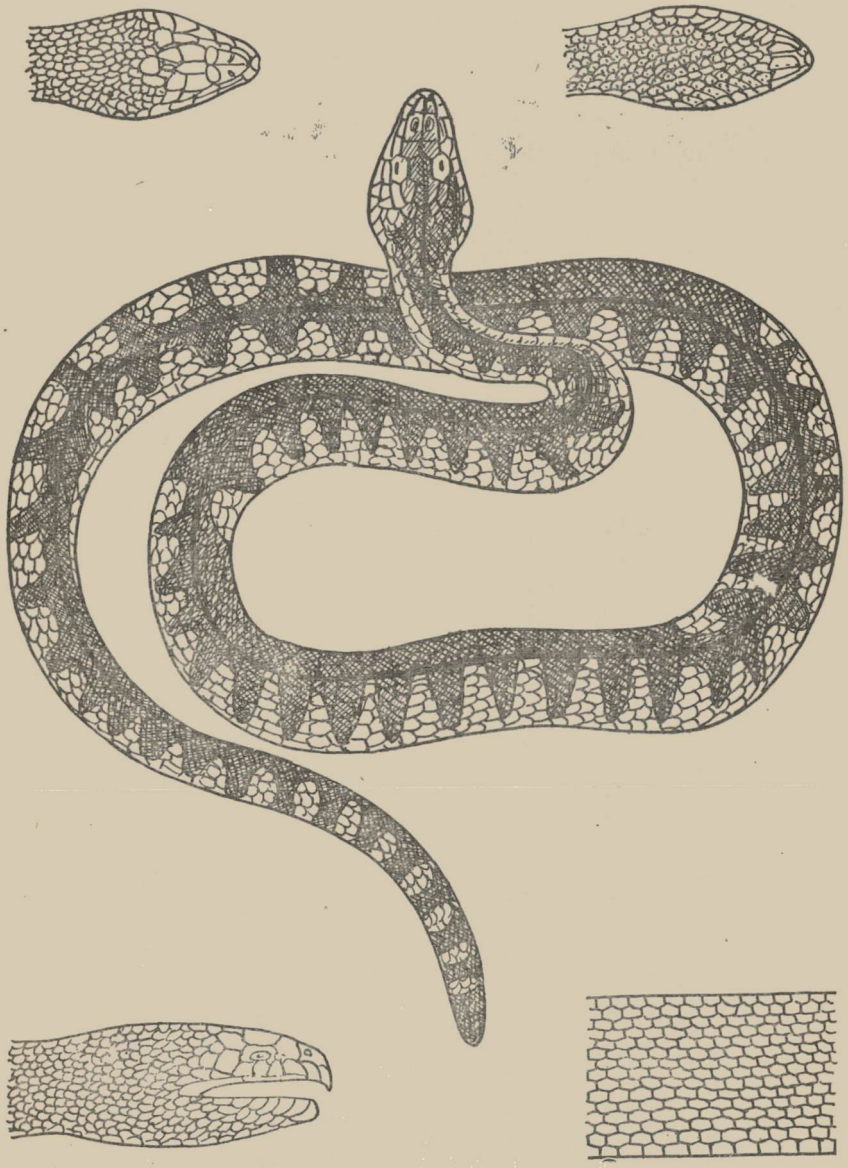


Fig. 15.21 Enhydrina bengalensis—This sea-snake is found in the tidal waters of the Sunderbans and in the Bay of Bengal. The body is somewhat compressed, the belly carinate and the tail is flat and compressed.

These snakes are a terrible menace in the gulf of Penang where an anti-venin is now reported to have been developed against the bite of this sea snake. In Hindi, Gujarati and Marathi this sea snake is called *Samudra Sarp*.

Symptoms of Sea-Snake bite:

The poison of this snake also is neurotoxic. Many a fishermen fall a victim to the bite of this sea-snake. As the bite from these snakes usually takes place in the sea, the venom gets much diluted. Further, the fangs of these snakes are bit behind due to which the snake does not always get a good grip to bite and inject sufficient quantity of poison.

There are no local symptoms of sea-snake bite There, however, develops general muscular pain. About three or five hours after the bite, the urine turns brown or red in colour—a condition known as *Myoglobinuria*. If untreated, death may occur due to respiratory failure 12 to 24 hours after the bite. There are no statistics available on sea-snake bites among Indian fishermen.

Family Viperidae

This family includes the poisonous snakes called the **Vipers**. The word Viper is derived from *Vivus* — alive and *parere* — to bring forth. Vipers are viviparous. The female brings forth the young alive. The vipers are of two types—(1) **The Pitless Vipers** and (2) **The Pit Vipers.**

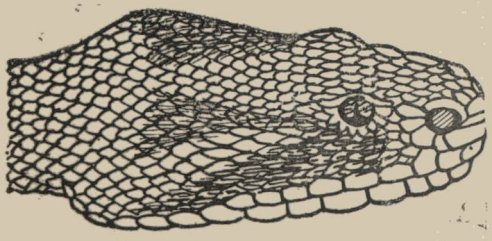


Fig. 15.22 **The small scales on the triangular head of Russell's Viper**

The Pitless Vipers have no pit between the eye and the nostril They have broad plates on the belly extending right across and small scales on the head (See fig. 15.22). Russell's Viper, Phoorsa or Saw-Scaled Viper of India and Puff-adder (*Bitis arietans*) of Africa are the familiar examples of Pitless Vipers.

All the Pit Vipers have—a triangular head and broad belly plates as in Pitless Vipers. They have a Pit in the loreal region i.e., between the nostril and the eye on each side (See fig. 15.23). The pit is a heat sensitive hole.

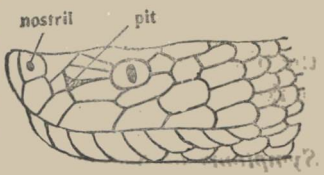


Fig 15.23 Lateral view of the head of a pit Viper. A conspicuous opening or pit between the eye and the nostril

The Pit Vipers are further divided into two groups. (i) Those where the head is covered with small scales. (ii) Those which have shields on the head as well as small scales.

In the former group of Pit Vipers, *the Common Green Pit Viper*, or *Bamboo Pit Viper (Trimeresurus gramineus.)*, is a familiar example found in India. *The Himalayan Pit Viper (Ancistrodon Himalayanus)* of India belongs to the latter group with shields on the head.

The Rattle snake (*Crotalus sp.*) is a good example of a Pit Viper found in America.

The Vipers have two poison fangs. The mechanism of biting in Vipers has reached a high level of perfection. The fangs are big, canalised, curved and above all erectile. They are enclosed in a sheath when at rest, lie in repose at the side of the jaw. At the base of each fang a number of fang buds are found. If any fang breaks, one of the buds at its base grows into a new fang.

The details about a few of the Vipers of India and the rattle snake (*Crotalus sp.*) are now given.

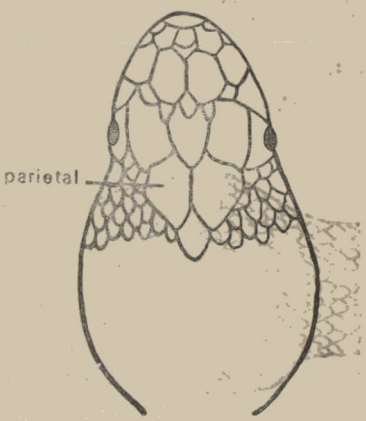


Fig. 15.24 Head of a variety of Viper having shields as well as small scales

Russell's Viper or Daboia or Chain Viper
Vipera russelli

Dr. Patrick Russell, in 1796, brought to the notice of the scientific world this species of viper.

Russell's Viper is found all over India from Sri Lanka to Himalayas in plains as well as upto the height of 7,000 feet. The females attain a length of 1,600 mm while the males are slightly longer. This snake has usually a thickness of 150 mm. It makes a loud and continuous hissing. It has large plates on the belly and small scales on the head.

The colour of the snake is brown and there are three rows of deep elliptical patches. One row of these patches is in the middle of the back and one on either side. The long row of spots look like chains, hence the snake is also called a **Chain Viper.** There are found black spots on the ventral side. On the dorsal (vertebral) side a maximum of 27–37 lateral patches are observed. There are about 84 black spots on the ventral surface.

The young vipers have about 25 dorsal and 22 lateral patches. There is however great variation in the patches, in colouration as well as form.

The viper is normally brown, but the South Indian vipers have a white border edged with black spots. The snakes got from Maharashtra region, during the breeding season show a faint amber colour with faint brown spots. These are males and the colouration usually disappears after the breeding season.

The head of viper is triangular and the scales on the head are very small, imbricate and keeled. The snout is angulate. The nasal opening is quite prominent. The eyes have white border. The pupil is elliptical and the iris is golden. There are 10–12 supralabials. The 4th supralabial is the largest and it does not touch the eye. The tail is small, and the shields under it are divided. The fangs are well developed, erectile and canaliculate.

The snake feeds chiefly on small mammals like rats and mice. Sometimes lizards and birds are also eaten.

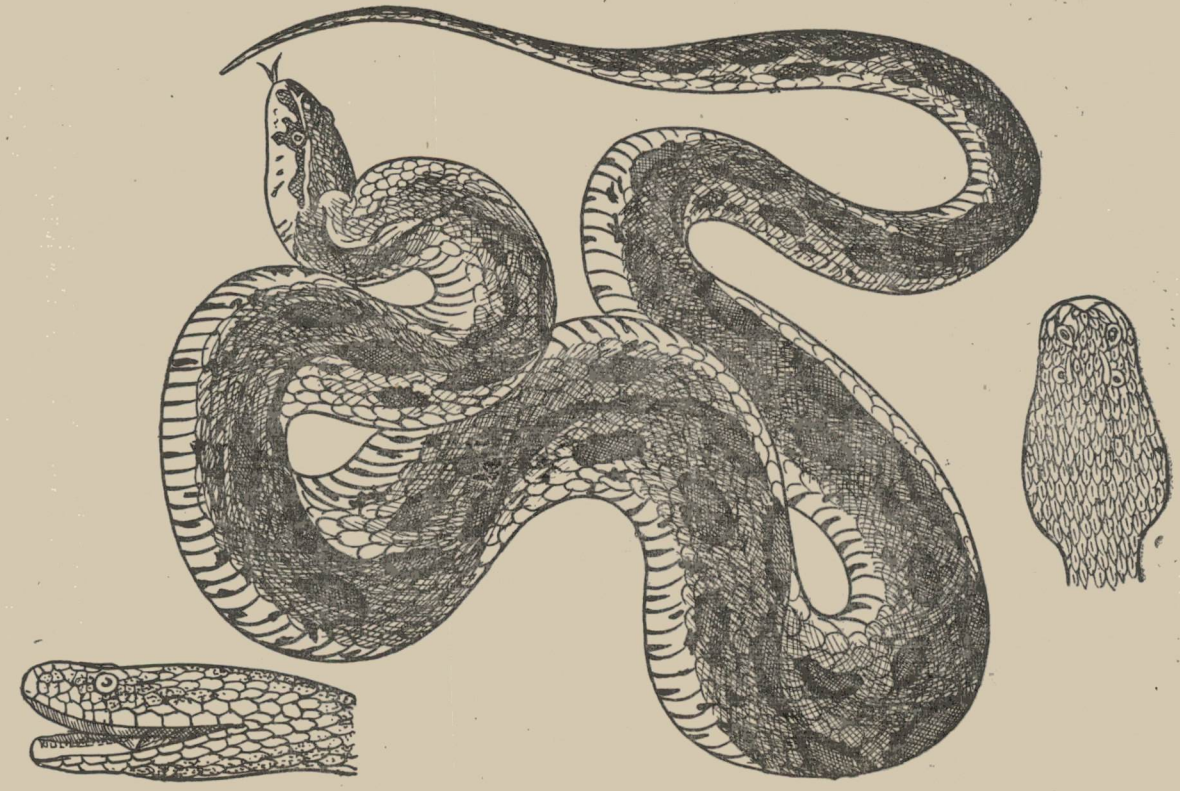


Fig. 15.25 **Vipera russelli** - Russell's viper.

The viper is found in rocky and bushy regions and the colouration of the skin always matches with the surroundings. It usually remains coiled with the head in the centre of the coil. Even with least disturbance, the tongue quivers, the head is raised, the body swells rhythmically and the snake starts hissing loudly and continuously reminding one of a leaking foot-ball bladder. The hiss of a Cobra on the other hand is intermittent and of a short duration. It now hurls itself at the victim. The big fangs, about 10 mm in length are pierced into the skin and the poison is injected. Very often the venom is also sprayed while the snake opens the mouth and withdraws the sheath, before it hurls itself for biting. Russell's Viper's venom is most deadly to rodents and birds. The bite is also frequently fatal to man.

Mating in these snakes has been observed in a *snake farm* in July–August. These snakes are viviparous, the young ones are born alive. One female gave 97 young ones in three days. At birth, the size of the young ones ranged from 110 to 130 mm. The spots were rather confluent. The shedding of the skin takes place on the first day, then on third, seventh and later after a month. The young ones are equally poisonous with the exception that the venom injected will be in a small amount.

This snake in Hindi is called *Kander*. In some places it is also called *Suskar*, probably owing to it's hissing as, *Sus-karna* means to hiss.

Echis carinatus

Side-winder or Saw-scaled Viper or Phoorsa

Echis carinatus is distributed all over India. It attains a length of 550 mm. The head of this snake is triangular and bears a typical white arrow mark on a brown background. The subcaudals are 24–25 in a single row thus differing from the Russell's viper.

The scales on the head are small, semi-circular and cover each other. The scales are keeled. These keeled scales behind the neck and at the sides have serrations, like that of a 'saw.' During

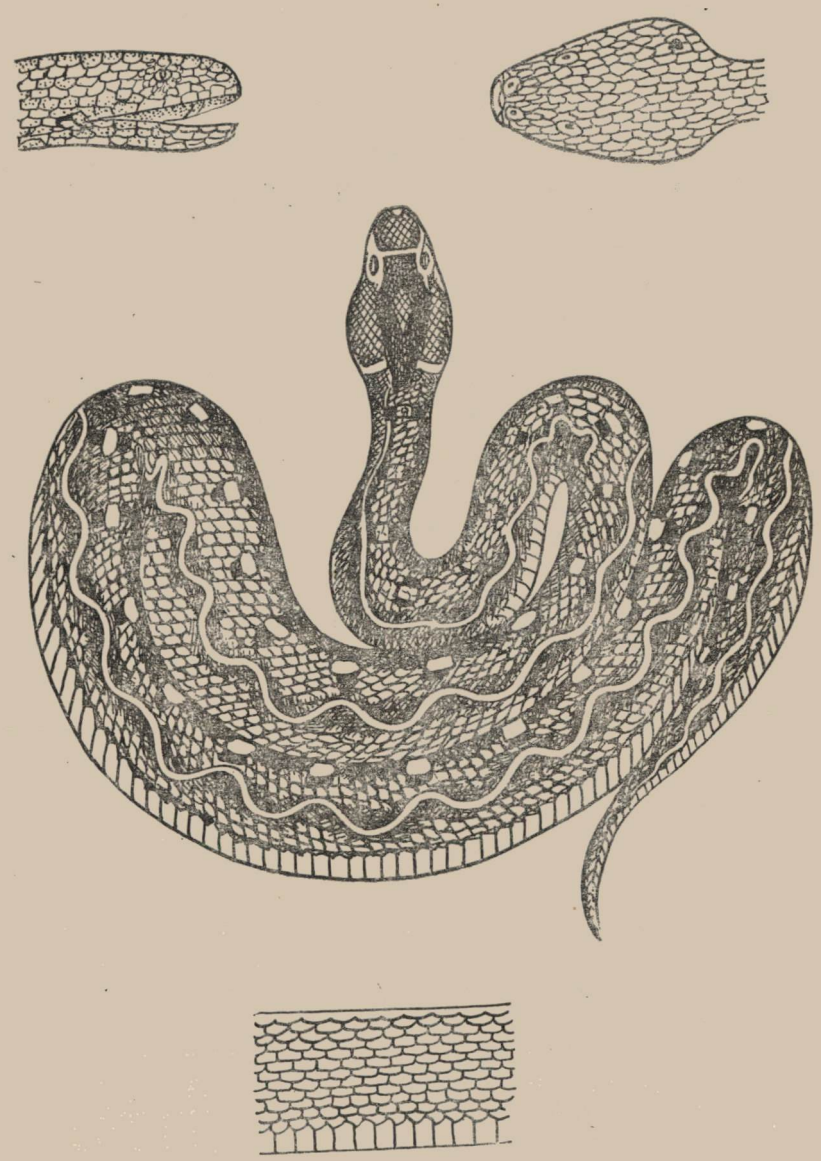


Fig. 15.26 **Echis carinatus — The saw-scaled viper**

movement, by the rubbing of these serrated scales a sawing noise is produced. The sound produced is something like a *fiss* or *phoo*. Hence the name 'Phoorsa' in the Konkan. The snake is often seen in a double curved position with head in the centre. The snake moves as a side winder and makes a sawing noise by rubbing the scales. On account of it's mode of movement it is also called a *side winder*. The eyes have elliptical pupils.

The body is greyish brown with a series of pale marks forming a curve over the body. The pale spots are 25–31. These are edged with dark spots all over the body. The ventral surface of the snake is white with black spots at the two ends of the scales.

These snakes feed chiefly on young frogs, lizards, snakes, scorpions and a large number of insects.

When disturbed, they usually raise their body upto a height of about eight inches from the ground and then strike. Even during their movement, the head is very often flipped for a strike. These are small snakes which usually lie under stones and in the soil and due to their colouration being similar to their surroundings, the people very often, get bitten, before they are aware of the presence of these snakes. These snakes are often a menace to the passers by due to their snappy nature and their fondness for warm roads after dark. They can be collected under the stones and in the red soil in Deogarh taluq.

These are viviparous snakes and lay their young 6–12 in number after the commencement of rains in the month of July. This snake in Hindi is called *Afai*; in Bengali *Bankoraj*; in Kannada *Kallu bawu*; in Kashmiri *Gunas*; in Marathi *Phoorsa*; in Punjabi *Afai* and in Tamil *Ratapambo Birian pankhu*.

Echis is one of the world's smallest deadly snakes. The amount of venom however injected by these snakes at times is not sufficiently lethal to man. There are always complications after a bite. There is swelling and oozing and within 24 to 36 hours the man starts bleeding from the gums, kidneys, nose, etc. The death occurs after a number of days due to complications. The bite of this snake as such is unlike the Cobra or Krait bite, in which case death occurs more or less on the same day.

Symptoms of the bites of the Russell's Viper and Echis:

The maximum lethal dose of Russell's viper's venom is 15 mg and that of Echis is 8 mg.

The Russell's viper and the Echis' venoms are chiefly *haemotoxic* i. e., the venoms are poisonous to blood and tissues. However, some Cobra venoms have haemotoxic properties too while some viper venoms possess neurotoxic properties.

The spot develops a severe pain within eight minutes after the bite. The area around the injury becomes red and painful.

The swelling starts within 15 minutes and there is usually a blood stain discharge from the wound.

The pulse of the victim becomes thready, there is intense cold and sweating from the body marked by a feeling of intense pain. The pupils after sometime become dilated and gradually get insensitive to light. A large dose of the venom destroys blood and tissue and causes clotting defects in blood. Severe haemorrhage and massive clotting occurs. In about an hour or two there is a marked collapse and often complete loss of consciousness. Saw-scaled viper venom produces a severe bleeding tendency in man. If not treated in time, death may occur. Antivenin should soon be administered under medical care.

In case the above symptoms show some signs of improvement, the local symptoms start playing an important role. A large extravasation of blood is seen followed by an oedema all round the wound with a general increase in the swelling. Towards the end of this phase there is an extensive suppuration and sloughing followed by malignant oedema. In the case of Echis bite, this oedema is soon followed by severe heamorrhages from the rectum and other orifices in the body. *There is no paralysis in the case of these snake bites.*

Crotalus sp.

The Rattle Snake of America

The Rattle snakes are pit vipers. They are most abundant both in regard to the number of species and the number of individuals

in the deserts of the South Western United States but almost every part of America is inhabited by one or more species.

The Rattle snake can easily be distinguished by the presence of a rattle found at the end of its tail. The rattle is made up of a number of loose horny segments or rings which form inter-locking joints. The rattle snake makes a rattling sound when shaken. The rings or bells of the rattle increase in number with the age of the snake.



Fig. 15.27 Left : External view of a dry cornified rattle.
Right : The section of the rattle to show how the segments are held together loosely.

A rattle snake usually consists of 6 to 16 rings or bells but some may have even 20 rings. Some of the rings of the rattle are lost from time to time so that the number of segments in a rattle affords no guidance to the actual age of the snake. It is said that when a rattle snake waggles it's tail everyone in the proximity of the snake becomes aware of it and if by chance the snake is in a room, the noise of its rattle makes conversation impossible. When the snake is agitated, the tail is oscillated with great rapidity resulting in the production of a rattling sound. This sound is some-what like that of an alarm clock and at times very loud.

The rattle snake, like other Pit vipers has a pit between the eye and the nostril on each side of the head. In this pit, the pit organ is located consisting of highly vascular tissue with many nerve endings. This is a heat sensitive organ and the snake can detect the movement of a moderately warm body from a distance of several feet.

The rattle snake has a wide head and a vertically elliptical pupil. The tail at its extremity is blunt and ends with the characteristic rattle described above.

The rattle snakes like other vipers have erectile poison fangs. They strike their victim from their S-shaped posture of the body. The fangs are inserted deeply in the body of the victim and then the snake's lower jaw clamps upward. Muscles over each poison gland force the venom through the hollow fangs into the flesh and later the snake withdraws its head. The entire process is done with amazing rapidity. Antivenin against rattle snake bite is also available.

The rattle snakes feed upon small mammals hunting for them at night. During day time the snake usually basks in the sun. During the rainy season, the snake retires into a hole occupyiug usually the hole of a rat or a ground squirrel.

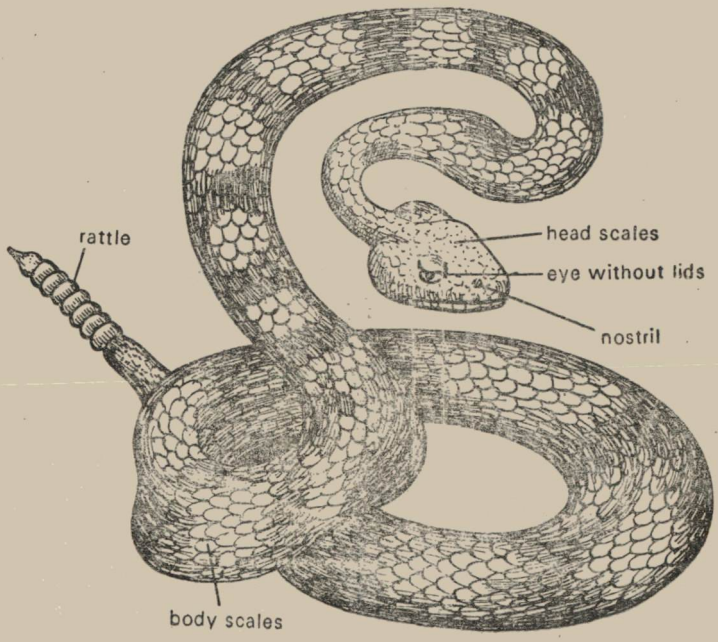


Fig. 15.28 Crotalus sp.—The Rattle Snake.

The Rattle snake is sluggish and is usually not inclined to bite except when disturbed or when the snake itself is in search of a prey. The lengths of the rattle snakes vary from 5 to 8 feet.

Snake-bite Cases in India :

The accurate figures on mortality from snake-bite in India are not available.

In a country like India, where the major population in villages moves about bare-footed, the snake bite cases are no doubt more. But one should also remember this fact that all cases of snake-bite are not fatal. There are many examples of cases where causes of death was not due to the snake venom but on account of fright. It is very often seen that many persons faint or become hysterical just at the sight of a snake whether it is a poisonous or a non-poisonous one. It should always be remembered that the fear and shock are more hazardous than the effects of snake venom itself. While dealing with the cases of a genuine snake bite of a venomous snake, the patient should always be saved from going into a state of shock and proper treatment under expert medical advice should be given forthwith.

Snake Venom :

As described earlier the chief poisonous snakes of India are *Cobras*, *Kraits*, *Vipers* and *Sea-snakes*. They all have **poison glands** which are **modified parotid glands.** The venom or poison produced in the poison gland is injected into the body of the prey through the poison fangs.

We shall now discuss the properties of the venom of the poisonous snakes. The **snake venom** is extracted primarily to prepare **antivenom serum** or **antivenin.** The antivenom sera are prepared at *Haffkine Institute, Parel, Bombay,* and the *Central Research Institute at Kasauli in the Punjab.* The term *milking* is applied to the process by which the venom glands are emptied under pressure and the venom is collected. In order to extract the venom from the snake the following procedure is adopted.

In the case of Cobra, the venom is extracted at Haffkine Institute by allowing the Cobra to bite a plastic cloth tightly stretched over a wine glass.

The Russell's viper's venom is extracted by allowing the erectile fangs of this snake to adjust squeezing inside the uncovered petri dish.

The venomous snakes have poison from the very first day of their life.

The venom is acidic with a specific gravity ranging from 1·030 to 1·070. When dried, the venom settles down in the form of fine needle-like crystals. The crystals can readily be dissolved in water. The solubility of the crystals is retained for a long time.

The venom *contains 80 percent water, the rest proteins, enzymes and some inorganic salts.* The venom of a snake is a highly concentrated digestive juice.

Uses of Snake Venom :

The snake venom in India is primarily in demand for the manufacture of *antivenin.* This, as mentioned, is manufactured at the Haffkine Institute at Bombay and Central Research Institute at Kasauli in the Punjab.

The snake venoms have their other important uses as well. When the toxic properties of the snake venoms are sufficiently diluted, the venom can be life saving. A drop of diluted cobra venom reduces pain. It is as such widely used to check intractable pain, in the treatment of arthritic pain and migraine. A fraction of Cobra venom is also reported to be much effective in improving the condition of neurotic patients.

The venom of Russell's viper is used as a haemostatic agent. In case of haemophilia, the graded intra-muscular injections were given. These were much helpful in stopping the bleeding. It has been regarded as a standardised medicine against haemophilia. The diluted solution of Russell's viper venom is frequently used by dentists to stop excessive bleeding. The snake venoms are also a good source of highly concentrated enzymes and toxins.

Antivenom serum (Antivenin) :

Antivenom is prepared by immunising horses to snake venom. The antivenom serum so prepared is called an *antivenin.* The antivenin is prepared in the following manner.

Small amounts of Cobra, Krait, Russell's viper and Saw-scaled viper venoms are injected into horses in the first instance. The

dosage of the venom is gradually increased over a period of months. The horses during this period build up antibodies to the venoms. When the serum of the horses reaches a certain strength (titre), it is drawn from the animals. The horse serum is then processed, freeze-dried and packed into ampoules as antivenom serum.

The antivenom so prepared by hyper-immunizing the horses against the venoms of Cobra, Krait, Russell's viper and Saw-scaled viper is called *Polyvalent anti-snake venom serum.*

The administration of the antivenin should be done under expert medical care. Some persons have the tendency to develop shock by serum therapy on account of their sensitivity to the serum.

Economic Value of Snakes:

One should no doubt take all precautions to see that the poisonous snakes are not allowed to reside in or around our houses. In such cases they should be killed. We should also bear this fact in mind that snakes are nature's most effective killers of rats. The rats are responsible for destroying as much as 20 percent of grains produced in India. Indiscriminate killing of snakes as such may lead to the increase in the number of rats which are harmful to food grains. The uncontrolled use of snakes' skins is also responsible for the mass killing of snakes. The importance of their venoms in the field of medicine and their habit of feeding on rodents, the snakes are no doubt reptiles of great economic value.

Revision questions

1. How can you distinguish a poisonous snake from a non-poisonous one?
2. Write what you know about Cobra, Krait, Russell's viper and Sea-snake.
3. Write short note on snake venom and polyantivenin.
4. Write notes on :
   (a) Rattle snake.
   (b) Dhamin.
   (c) Pythons and Boas.
   (d) Natrix piscator.

CHAPTER XVI

CLASS AVES

BIRDS—FEATHERED BIPEDS

Birds share with the mammals the distinction of being the highest and most recent vertebrates to inhabit the earth. Both these groups have diverged from each other at the beginning of reptile evolution. Each has become a dominant group of animals.

As a class, birds are strikingly uniform. The most obvious features of birds are **feathers** and the possession of the horny **bill** or **beak.** The description of a bird as a '*Warm blooded* (*homoiothermous*), *feathered biped*' is quite apt and precise.

General Characters of Aves :

Birds are warm blooded vertebrates. They can maintain a constant body temperature despite changes in the temperature of their surroundings. The normal body temperature of birds is often high i.e., 100°—112° F.

Eggs :

The birds like the majority of reptiles are oviparous They lay large heavy eggs full of yolk and covered by a hard calcareous shell.

Feathers :

The most obvious avian features are the **feathers.** The covering of feathers on the body of a bird is a single external feature that distinguishes birds from other vertebrates. The feathers represent the epidermal exo-skeleton of birds.

Beak :

The upper and lower jaws of birds have undergone curious modification to from the **bill** or **beak.** The bony frame-work of the upper and lower jaws is covered by a horny sheat called the

rhamphotheca. In all the modern birds the teeth in the jaws are lacking. The bills or beaks serve many purposes including for example, the procuring of food, defence, nest building and the preening of feathers. The beak therefore varies greatly in different groups of birds, depending upon their habits.

Preen Gland :

The skin is loose and dry and almost the only *skin gland* present in birds is called an **oil** or **preen gland** which lies dorsally at the root of the tail. The preen gland secretes an oily fluid, which some birds use in preening their feathers. The preen gland is absent in Ostrich, Emu, Cassowary and in a few carinate birds.

Flying and Flightless Birds :

The capacity for flight has arisen three times in the course of the evolution of vertebrates i.e., in **birds**, the **Pterodractyles** (Mesozoic flying reptiles now extinct) and the **bats** (the flying mammals).

Flightless Birds: The flight has however been lost independently in a number of groups of birds e. g., Ostrich, Rheas, Emus, Cassowaries, etc., These flightless birds are grouped in the super-order **Palaeognathae** under the sub-class **Neornithes.** The loss of flight results in the reduction of wing size. *The existing flightless birds are all descended from true fliers.*

Flying Birds : The majority of birds are normally capable of flight. The evolution of flight in birds helped them in escaping enemies and exploiting new environments. The flying birds are included in the super-order **Neognathae** under the sub-class **Neornithes.**

The Adaptations of Flight :

1. The flying bird has a perfectly **streamlined spindle shaped body** evolved to offer minimum resistance to the air. The attachment of the wings high up on the thorax, the high position of such light organs as lungs and air sacs, the low position of the heavy muscles, the sternum and the digestive organs, the consequently low centre of gravity, are also structural facts of importance.

2. The fore-limb in birds is modified as a **wing** with a large surface area provided by feathers.

3. There extends from the mid-ventral line of the sternum or breast-bone a deep projection called the keel for the attachment of the muscles of flight (See fig. 16·2 [above]).

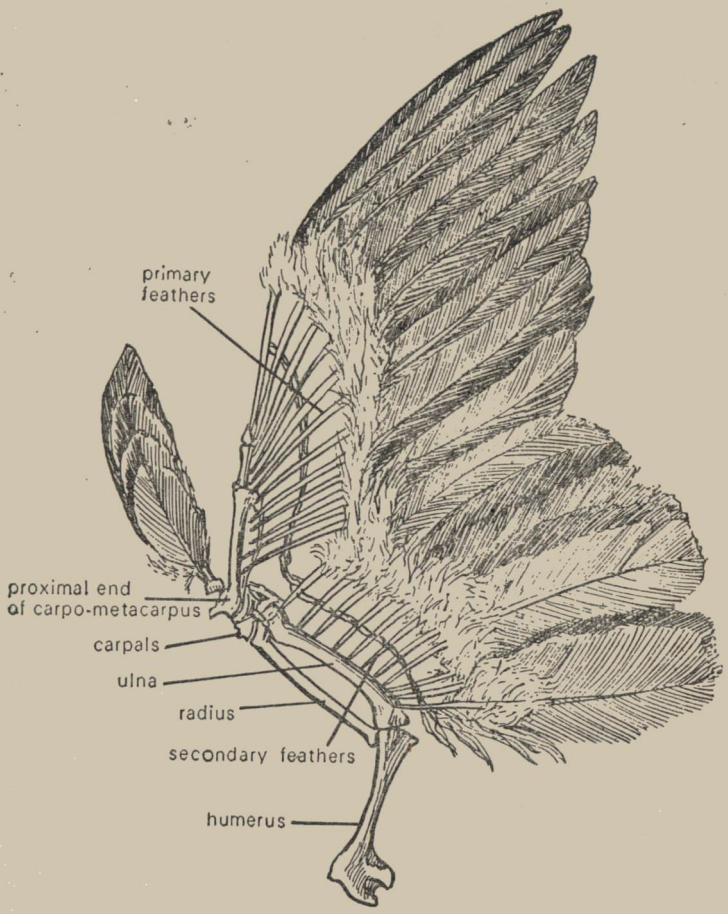


Fig. 16.1 The wing of a bird

4. The important muscles of flight are the breast muscles which include **pectoralis major, pectoralis minor** and **coracobrachialis.** These muscles enable the bird to fly in the air. The pectoralis major alone may constitute as much as one-fifth of the total body weight of a bird. This muscle is enormously developed in a flying bird. It is concerned with the powerful down stroke of the wing. By this

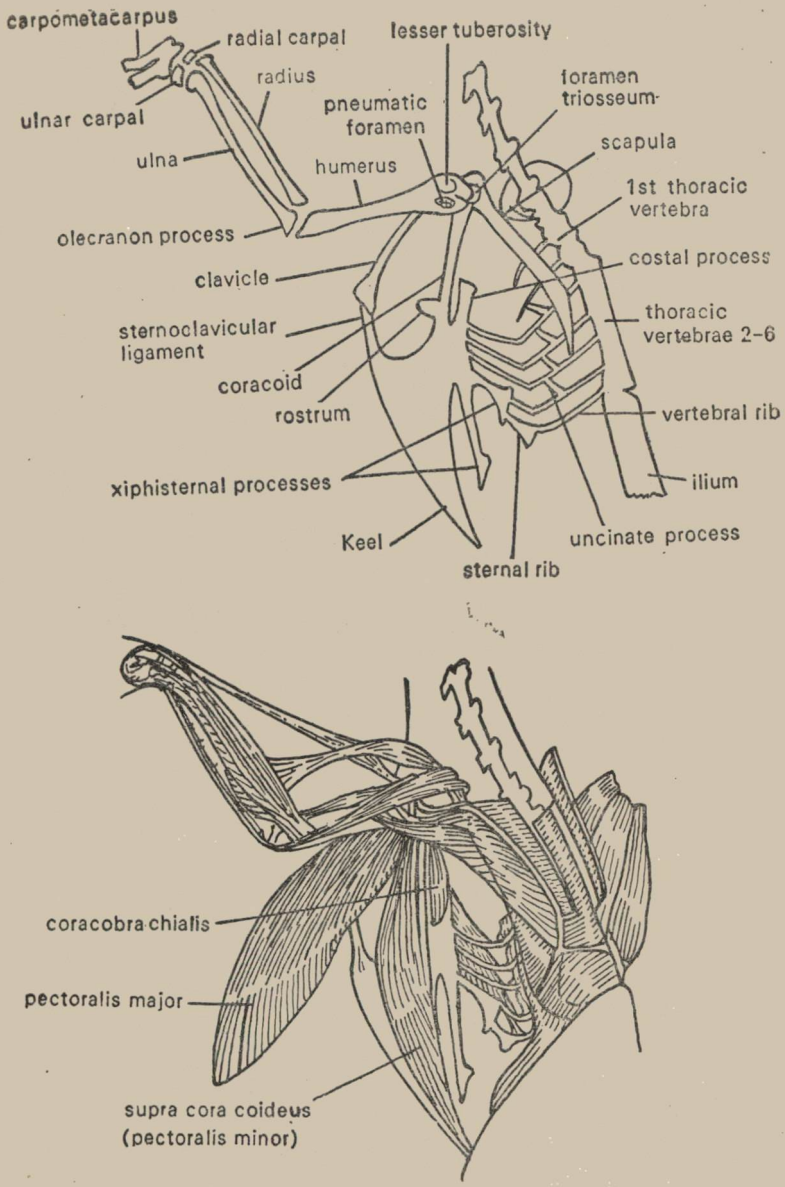


Fig. 16.2 Above : Skeleton of the wing and other associated bones of the shoulder and breast regions of a bird. Below : The principal muscles of flight. The names of the other muscles of the forelimb are not given for the sake of clarity. The wing shown here is in a depressed state.

action it lifts the bird up and carries it onward. The pectoralis minor raises the wing for the next stroke.

5. The lungs of birds are paired. They are relatively small and are permanently attached to the dorsal thoracic wall where they are embedded in the ribs. The lungs of the bird open into a number of air sacs.

The birds on account of their aerial mode of life have a very high rate of metabolism as compared to the mammals. There are no

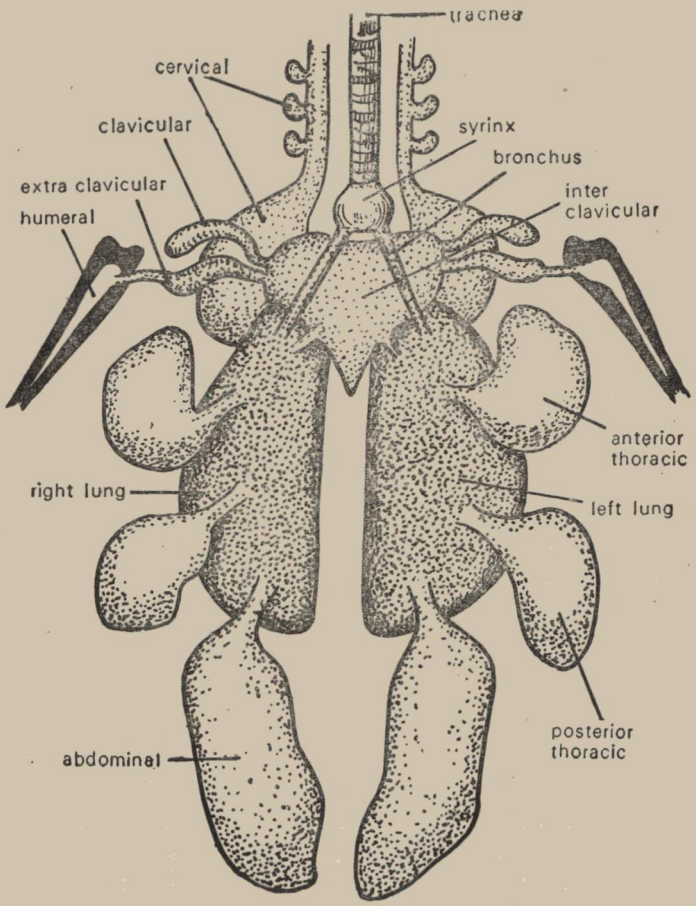


Fig. 16.3 The respiratory organs of a bird.
i. e., the trachea, syrinx, lungs and air sacs are shown.

sweat glands in birds. The intense activity of birds generate extra heat. The extra heat generated under torrid climatic conditions may result in over heating, fever and death but the birds are capable of eliminating this extra heat generated through the lungs and air sacs as fast as it is produced. One of the functions of the air sacs is to promote *internal perspiration*. Water vapour diffuses from the blood into the cavities of the air sacs and passes out via the lungs with which the air sacs are indirectly connected. The air sacs of birds thus increase the bird's respiratory content, secure more perfect aeration of the lungs, and assist in internal perspiration, thus helping in the regulation and maintenance of the body temperature. The air sacs are not concerned with gaseous exchange and they have a relatively meagre blood supply. They no doubt have a **bellows-like action.**

6. Many of the larger bones of birds are hollow and often have air sacs running into them. In many small birds of powerful flight, however, all the larger bones, or all except the humerus are not pneumatic and contain marrow. The Hornbill which has no great power of flight, is one of the most pneumatic of birds.

7. Another factor of great importance in flight is a general tendency for various bones to fuse with each other, conducting to increased rigidity of the skeletal frame. Due to the fusion of the vertebrae the dorsal part of the backbone becomes rigid. This is of great advantage in affording a firm fulcrum for the wing strokes. The arched clavicles meeting in an inter-clavicle to form the *merry thought* or *furcula* are often fused in front to the sternum and the strong coracoids. They are thus well adapted to resist the inward pressure of the down stroke of the wing. The keel or the breast-bone serves partly for the insertion of the chief muscles of flight and its size bears some proportion to the strength of flight. The importance of keel also lies in its contribution to the T—shaped girder (the sternum) which bears the weight of the abdominal organs. The keel as stated, is absent in the running birds like the ostriches and has undergone degeneration in the New Zealand parrot (*Stringops*) which has ceased to fly and taken to burrowing.

The Synsacrum (which is formed by the multiple fusion of lumbar, sacral and few caudal vertebrae) supports the weight of the body when the bird is walking.

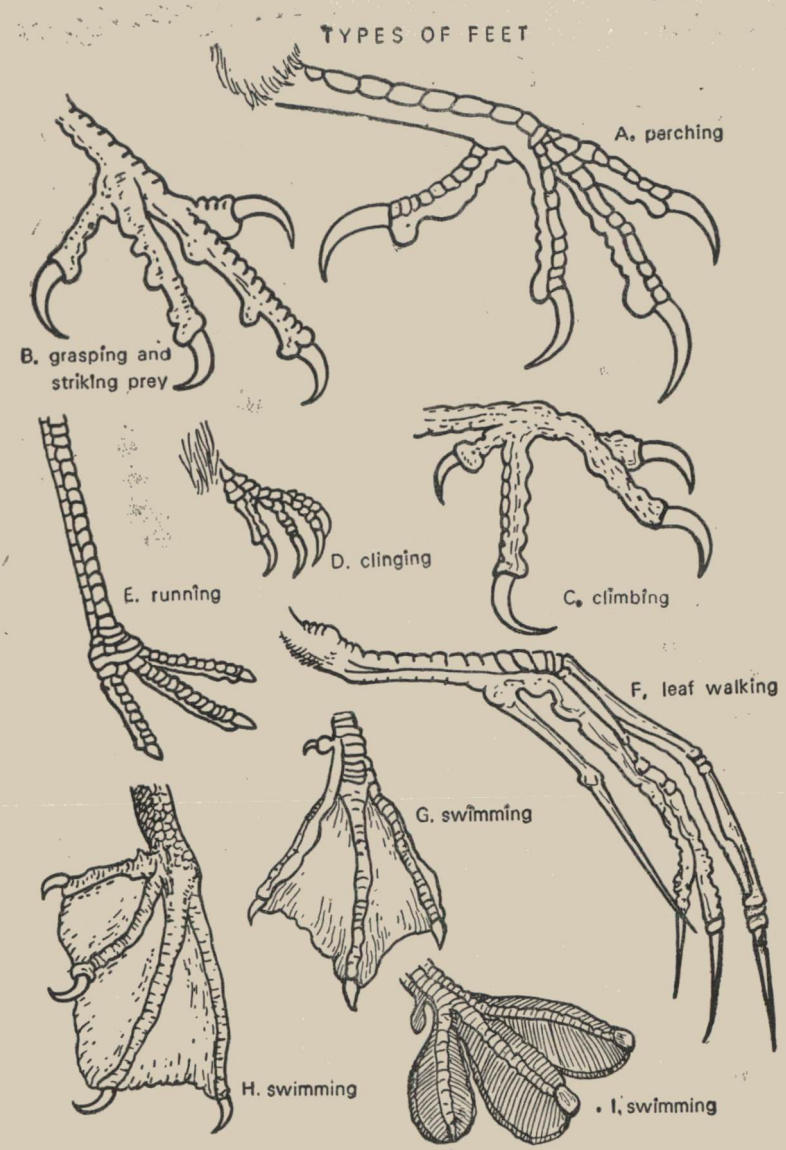


Fig. 16.4 Some adaptive variations met with in the feet of birds.
(A) Jungle Crow (*Corvus macrorhynchos.*) (B) Sparrow Hawk. (C) Wood Pecker (*Brachypternus bengalensis.*) (D) Swift (*Micropus affinis.*) (E) Courser (*Cursorius coromandelicus*) (F) Jacana (*Metopidius indicus*) (G) Sea Gull (*Larus ridibundus.*) (H) Cormorant (*Phalacrocorax niger*) (I) Dabchick or Grebe (*Podiceps ruficolis*)

In birds, thus, the fusion of bones and their construction after the mechanical design affords the greatest strength with the smallest amount of material. This has contributed to combine strength with lightness—one of the first essentials for successful flight.

8. The body of a bird in a standing position is entirely supported on the hind limbs, the articulation of which is thrown forward. The maximum number of toes is four. Each toe is provided with claws. The first toe is turned backwards while the other three are directed forward. Some adaptive variations are also met with in the feet of birds (See fig. 16·4). The bird is a digitigrade animal as it walks on its toes. The hind limbs of birds also assist in **perching**. A bird flying at a great speed can perch on the branch of a tree without stopping violently and at the same time without being thrown forward and falling over. Perching is accomplished by the action of muscles and tendons of the hind limbs. The bending of the mesotarsal joint (between the shank and tarsus) brings about a simultaneous pull upon four tendons passing under the toes. Due to this the toes get a firm grip over the perch. In this act, the first toe goes behind and the other three in front. When the bird is in a sitting posture, the pull is maintained by the mere weight of the body acting downwards so that a bird can even go off to sleep on the perch without fear of falling. As the bird rises from the perch before taking to air, the mesotarsal joint is extended and causes other tendons passing over the toes to be pulled. The toes by the action of these tendons release their grip on the perch. In birds, thus, the weight of the body is balanced most efficiently on the legs in standing, perching and walking postures.

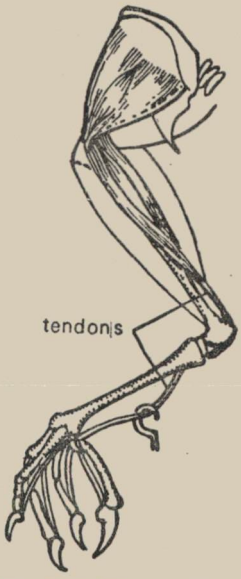


Fig. 16.5 The tendons involved in the perching mechanism of a bird are shown

9. Good vision is most essential for flight. As compared to mammals, the eyes of birds are extremely large. The birds are able

to see the distant objects, as well as the nearer ones with much clarity. The eyes of the birds can be adjusted almost instantaneously to see the distant as well as the near objects. Their eyes, thus, have the most efficient capacity of having a telescopic and also a microscopic vision. The focus in the eyes of birds can be changed from a distant object to a near one almost instantaneously. As an American naturalist puts it, *'in a fraction of time the eye of a bird can change itself from a telescope to a microscope.'*

The Common or Domestic Pigeon

(Columba livia, var. Domestica)

There are many varieties of the common or the domestic pigeon. These varieties differ from one another in size, proportion, colouration and the details in feather arrangements. The pouter, carrier, trumpeter, tumbler, etc., are all the extreme forms which have arisen by artificial selection. The wild ancestral species of pigeon *Columba livia* – the Blue Rock pigeon is widely distributed in the Palearctic and Oriental regions. As a result of artificial selection, forty different breeds of pigeons have been obtained by the breeders. All these varieties are the descendants of the common Blue Rock pigeon *Columba livia.*

The Common Dovecot—the Rock pigeon although often feral, restricts itself to cities and so retains its association with man.

The systematic position of the common pigeon is as follows.

Phylum	Chordata.
Sub-phylum	Gnathostomata.
Class	Aves.
Sub-class	Neornithes.
Sub-order	Neognathae.
Order	Columbiformes.
Species	*Columba livia.*

External Characters :

The pigeon's body is boat shaped. The body is distinguished into three regions—the **Head**, the **Neck** and the **Trunk**. The **tail** is a

mere stump which bears a fan of long tail feathers. Wild ancestral species is slate-blue in colour. The head is small with a rounded cranium. There is a prominent beak which consists of an upper maxilla and a lower mandible, both being covered with a *rhamphotheca* or a horny sheath. At the base of the beak on its upper surface is a patch of naked, swollen skin, the **cere**. It has been suggested that the cere is an extero-receptor organ but experimental evidence is however lacking. There are two oblique slit-like nostrils situated between the beak and the cere. On either side of the head is an eye with the upper and lower eye-lids. There is, in addition, a well developed third eye-lid or nictitating membrane which can be drawn across the eye ball from the inner angle outward. Below and behind each eye is an external auditory aperture which leads to the tympanic membrane. The auditory aperture however is concealed by the auricular feathers.

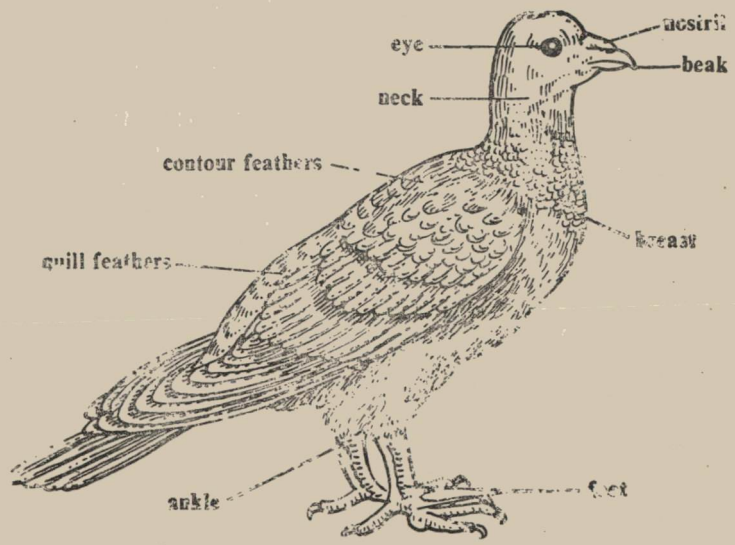


Fig. 16.6 The external features of pigeon.

The neck is long and mobile. The entire body of the bird is covered by feathers. Upon the removal of feathers, it can be seen that they are arranged in very definite tracts called **pterylae**. Between the pterylae, there are extensive bare patches which are referred to as **apteria**.

When the feathers have been removed one can see the true tail in the form of a short, conical projection of the trunk known as the **uropygium.** From the uropygium originate a series of large feathers called the *rectrices* to which the term 'tail' is usually applied. These

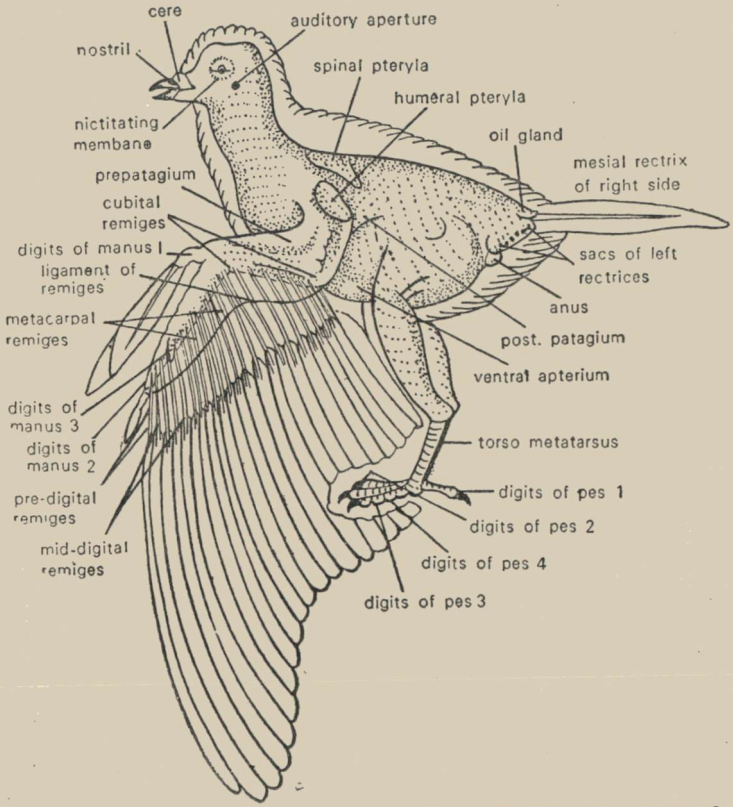


Fig. 16.7 The domestic pigeon seen from the left side. Most of the feathers are removed.

feathers in fact are the tail feathers which extend backwards from the real tail, the uropygium. There is a papilla on the dorsal surface of the uropygium. On the summit of this papilla is the opening of a **preen, coccygeal** or **oil gland**. As mentioned, this is the only skin gland found in birds. The secretion of the oil gland is used in preening the feathers. There is a large transversely elongated aperture called the **anus** or **cloacal aperture** situated on the ventral surface, at the junction of the uropygium with the trunk.

The wing of a bird shows all the three typical divisions of the fore-limb i.e., the upper-arm, fore-arm and the hand. The parts of the hand are however closely bound together by the skin. In the hand only the three imperfectly marked digits, the third (III) much larger than the second (II) and the fourth (IV) can be distinguished. When the wing is at rest, the three divisions of it are bent upon one another in the form of a 'Z'. In the course of flight, the wings are however straightened out and extended so that the axis of the entire

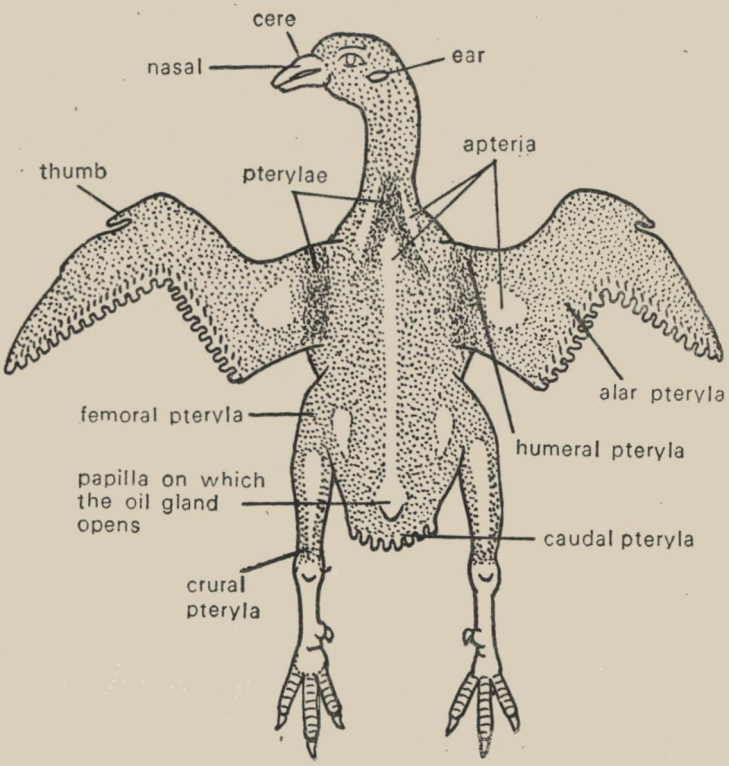


Fig. 16.8 Columba : Dorsal surface after the removal of feathers. Dorsal pterylae and apteria are seen.

wing is at right angles to that of the trunk. The anterior or pre-axial border of the limb has a fold of skin, called the **alar membrane** or **pre-patagium**. This stretches between the upper-arm and the fore-arm. Another fold of skin which is much smaller is called

the **post-patagium.** This fold extends, post-axially, between the proximal portion of the upper arm and the trunk.

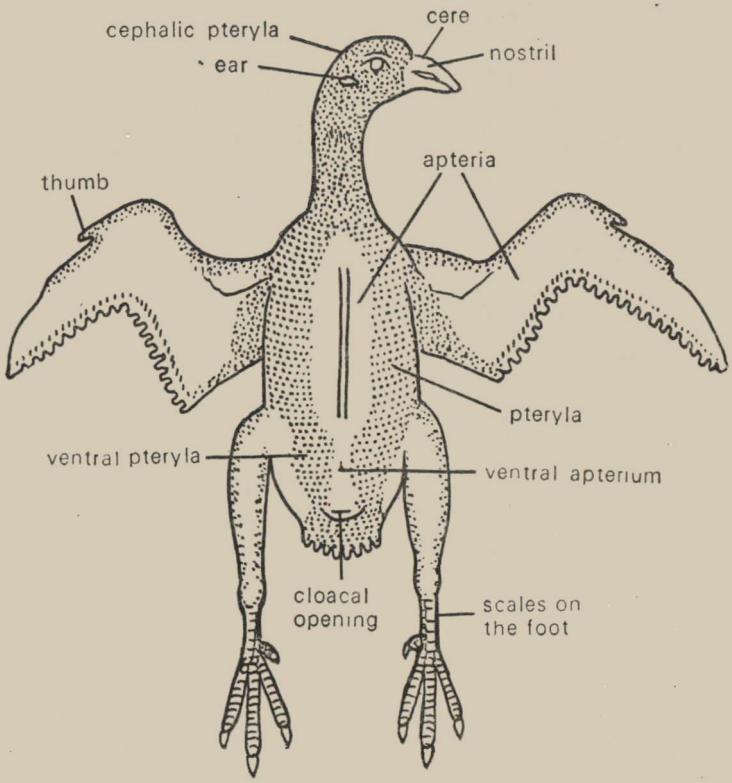


Fig. 16.9 Columba : Ventral surface after the removal of feathers. Ventral pterylae and apteria are seen.

As regards the pair of hind limbs, the thigh is short and closely bound to the trunk. The thigh does not stand well out as in a reptile, but directed downwards. The long shank extends from the knee downwards and backwards. The foot is distinguished into a proximal portion, the tarsometatarsus and four digits. The hallux or the first digit is directed backwards and the other three i. e., the 2nd, 3rd and the 4th are all directed forwards. The entire hind-limb lies in a plane parallel with the sagittal plane of the trunk.

The Structure of Feathers :

Birds are covered by an exo-skeleton of feathers on the greater part of the body. The feathers of birds, scales and claws on their feet are all epidermal in origin. Feathers are believed to be homologous to reptilian scales but resembles them only in the very earliest stages of formation. No stages intermediate between the scales and the feathers are known.

Parts of a Typical Feather (Contour Feather) :

A typical or a contour feather consists of the main axis known as the **shaft.** The proximal portion of the shaft is in the form of a hollow stalk called the **calamus** or **quill.** The remainder of the shaft is referred to as the **rachis.** The rachis is filled with pith and possesses on either side of it, the **web** or **vane** or **vexillum.** The quill of a feather is fixed in a pit or follicle of the skin. At this point of attachment, each feather is provided with it's own basal musculature which enables the bird to ruffle or raise it's feathers away from the body, to facilitate their arrangement when bathing and preening and also to increase the insulation value of the feather-covering during cold weather.

At the base of the quill there is a little aperture called the *inferior umbilicus*—through which a nutritive papilla of dermis is continued into the growing feather. The second extremely minute aperture called the *superior umbilicus* occurs at the junction of the quill with the vane or rachis on the inner or ventral face of the feather (i.e., the face adjacent to the body). This aperture has no importance except that parasites sometimes enter by it.

In some birds there arises an accessory feather called an **aftershaft** from the back of the shaft at the junction of the rachis and the calamus. In many birds, the aftershaft is in the form of a mere tuft, but in some birds the aftershaft is more or less a complete second feather.

If the web or vane is examined under a microscope it will be seen to be composed of barbs. The barbs are delicate thread-like structures which extend obliquely outwards from the rachis. In an uninjured feather, the barbs are closely connected so as to form a

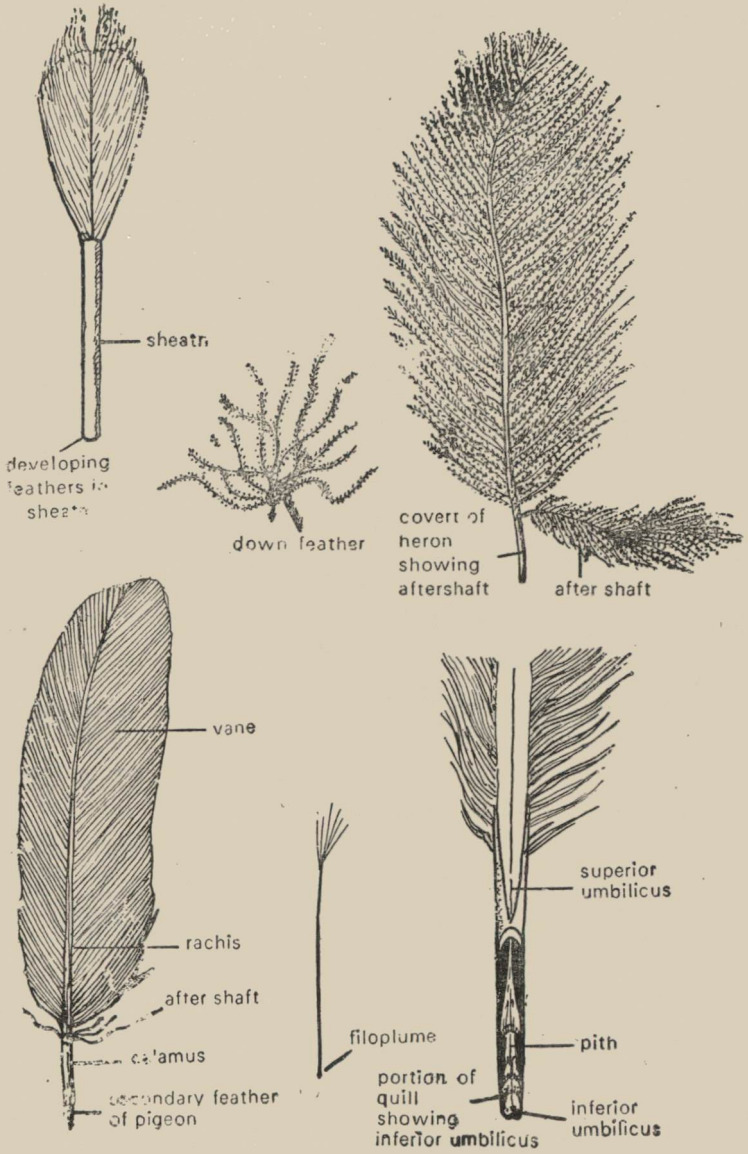


Fig. 16 10 Various types of feathers. Above : Left : Developing feather in sheath Middle : Down feather. Right : Covert of heron with aftershaft. Below : Left : Secondary feather of pigeon. Middle : A filoplume. Right : Portion of a quill showing inferior umbilicus, superior umbilicus and pith.

continuous sheet. From each barb in turn extend out laterally the barbules. Barbules are extremely delicate oblique filaments which have the same general relation to the barbs as the barbs themselves to the rachis. The adjacent rows of barbules overlap one another. The tip and the under side of each barbule possesses small filaments called **barbicels** or **hamuli** which further help in holding the overlapping barbules together.

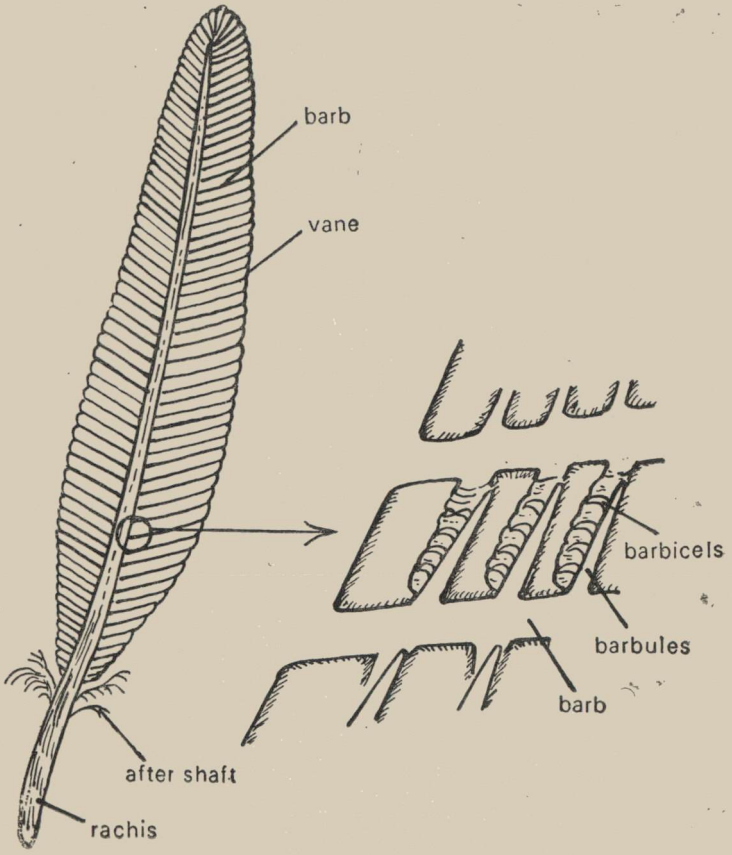


Fig. 16.11 Plume feather of a bird.

The barbs, barbules and barbicels thus form a firm interlocking system and give rise to the vane or vexillum forming the expanded part of the feather helpful in flight.

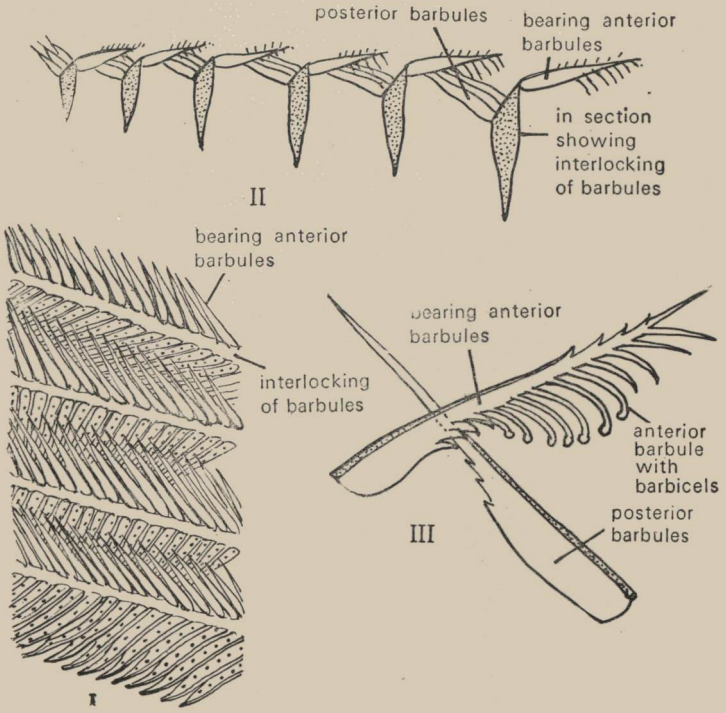


Fig. 16.12 The parts of a feather. I. Four barbs are shown bearing anterior and posterior barbules. II. Six barbs in section showing the interlocking of barbules. III. The anterior barbules with barbicels.

Types of Feathers :

The type of feather, the structure of which is already described, is called the *contour feather* or the *outer feather* of a bird. The contour feathers form the main covering of the body of a bird. The other types of feathers are as follows :

Filoplumes :

On plucking the contour feathers of a bird one can notice a number of hair-like structures scattered over the body and distributed amongst the contour feathers. These hair-like structures are the **filoplumes** or **hair feathers**. Each filoplume if examined carefully can be seen to consist of a slender shaft with a few barbs present at the tip. **The barbs are free and devoid of locking apparatus.**

Down feathers or Plumules:

Nestling pigeons and certain adult birds are covered with a temporary investment of **down feathers** or **plumules.** The down feathers lack the rachis and the slender barbs emerge from the end of the calamus. Although tiny barbules are present, they, however lack barbicels to hold them together so as to form a web. The down feathers forming the natal plumage of young birds are called *neossoptiles* in contrast to *teleoptiles* or *adult down.* Any one who has plucked ducks will be familiar with the permanent down (teleoptile) feathers found in the adults.

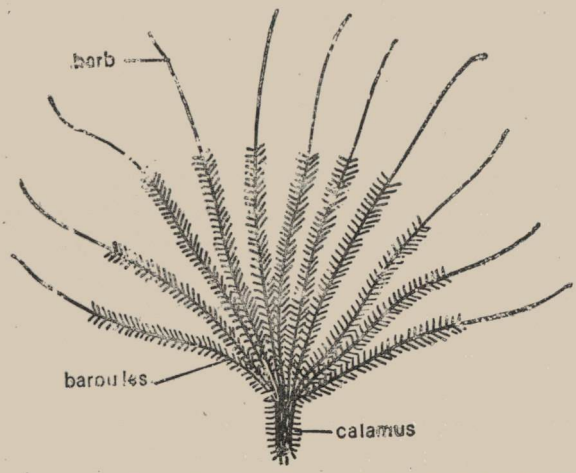


Fig. 16.13 A mature down feather of a newly hatched chick. The sheath is split and the barbs and barbules are free. The shaft is absent. The barbs are arranged in a circle around a short calamus.

Powder down, Semi-plumes and Bristles:

On the breast of heron-like birds, a specialised type of feather called the **powder down** are found. In structure, a powder down resembles a down feather but its barbs keep disintegrating into fine talc-like powder. The exact function of powder down is not known. It is suggested that the powder may be used in preening to lubricate the feathers. It may aid in insulating the body and that it assists in warming the eggs during incubation. **Semi-plumes** are those feathers which do not have the barbs held together. The *semi plumes*, like

the *filoplumes* and *down* are hidden beneath the contour feathers in adult birds. **Bristles** represent only the feather shafts. The bristles which extend beyond the contour feathers are found in a number of groups of birds. In Caprimulgids and flycatchers the *rictal bristles* are found on either side of the head. There are also bristles covering the nostrils of the wood peckers. The bristles occasionally may have a few remnants of the barbs near the base of the shaft rather than at the tip, as in a filoplume.

The wing feathers are called **remiges** (singular: remex). In pigeon there are 23 wing feathers or remiges (also called **wing quills**). The tail of a pigeon bears 12 large feathers called the **rectrices** or **tail quills.**

Functions of the Feathers:

The feather in the course of evolution of birds developed as a *heat conservation device and later on as an aid to flight* while gliding from trees or while volplaning off the ground at speed. The **principal function** of feathers in birds is the **conservation of body heat.** The layer of still air retained within the feathers provides insulation against heat loss from within and the penetration of cold from outside. The depth of the layer of the still air is controlled by raising or lowering the feathers. On a cold day a resting bird may have it's feathers fluffed out to increase the layer of insulation just as we put on heavy clothing to accomplish the same object. When it is warm the birds are seen to press their feathers tightly against the body to reduce the depth of the insulating layer. Feathers give protection to the body of birds in a number of ways. The powerful wing feathers in the birds of flight help them to fly atonce in case of any danger from their enemies. The feathers also give direct **protection against injury.** The skin of birds as compared to other vertebrates is very thin and can be injured by contact with twigs and branches. The covering of the skin with the feathers thus saves it from injury. The ducks and geese are **almost impervious to small shot** because of the thick covering of feathers on their bodies. The colour of the feathers of birds **often matches with the surroundings** and thus plays an important part in the protection of many species. It should also

however be remembered, that the **brilliant plumage** of certain birds make them very conspicious. The bright colour is a characteristic of male birds. Sexual dimorphism on the basis of colouration of feathers is believed to aid in sex recognition within the species. In most of the birds the colour of plumage of the sexes is identical and sex recognition in such cases appears to depend upon differences in the behaviour patterns of the males and the females.

The other important function of feathers in water birds is to help in **increasing buoyancy.** Most swimming birds have their under surfaces densely covered with feathers between which there are pockets of air. These water birds, thus, rest on their **own life rafts.**

Revision questions

1. Describe the general characters of the common pigeon, *Columba livia.*
2. Describe in detail the various types of feathers, their structure and functions.

CHAPTER XVII

CLASS MAMMALIA

The Mammals—(The Hairy Vertebrates)

The mammals like the birds are *warm blooded animals* Man himself is included among mammals.

The General Characters of Mammals :

1. The most diagnostic mammalian character is that *all mammals—and only mammals alone—produce milk with which the females feed their young.* The very word mammals characterizes the class, since it is derived from the Latin, *mamma* meaning '*breast.*' The ducts from the mammary glands open into the elevated **nipples** or **teats** or **mammae.**

2. The other important mammalian character is the **hair.** Hairs are integumentary structures, derived from the epidermis. In most of the mammals the hairs form a thick covering. The hairs are however scanty in sirenians and the hippopotamus. In cetaceans the hairs are almost absent. In these mammals they are only restricted to early embryonic stages.

3. The chest cavity containing the heart and lungs is separated totally from the abdominal cavity by a complete muscular partition called the **diaphragm.** The diaphragm plays an important part in respiration.

4. There are usually seven cervical vertebrae in the neck.

5. A bony plate, formed from premaxillae, maxillae and the palatines separates the buccal cavity from the nasal passages. This hard palate is also responsible for the posterior position of the **internal choanae** or interal nostrils. The lower jaw or the mandible of mammals on each side, consists in adult life, of a single bone called the **dentary.** The teeth in most cases are borne in sockets by the premaxillae, maxillae and the mandible. The teeth are differentiated in specialised series. The teeth grow in two sets—the *milk teeth* and the *permanent teeth.*

6. The external opening of the ear is guarded by **pinna** which helps in funneling sounds into the auditory canal. The middle ear contains three ear ossicles i.e., the **stapes, the incus** and the **malleus** which are *sound conductors.* The **stapes** is derived from the *columella of reptiles.* The **incus** is derived from the *quadrate* and the **malleus** is obtained from the *articulare.* The **cochlea** which is essentially straight in reptiles and birds is generally much coiled in mammals to accommodate its increase in length.

7. As compared to other vertebrates the nervous system in mammals is highly developed. The **cerebral hemispheres** obtained from the telencephalon have convolutions on the surface. The ridges of these convolutions are called the **gyri** and the depressions, the **sulci.** A broad white commissure called the **corpus callosum** connects the right and left cerebral hemispheres. The mid-brain comprises the optics lobes consisting of four folds or prominences called the **corpora quadrigemina.**

The mammals like other amniotes have **twelve pairs of cranial nerves.** The spinal nerves possess dorsal and ventral roots which unite to form a main trunk before emerging inter-vertebrally.

8. Mammals like birds have a four chambered heart. The two upper chambers are called the **atria** and the lower ones, the **ventricles.** Due to the presence of interatrial and interventricular septa, there is a complete separation of venous and arterial blood as in birds. The right atrium is separated from the right ventricle by a **tricuspid valve,** whereas the left atrium is separated from the left ventricle by a **bicuspid** or **mitral valve.** There is only one aortic trunk which curves over the left bronchus.

There is no *renal portal system.* The *hepatic portal system* is however present. The erythrocytes when fully formed are non-nucleated and appear as slightly biconcave discs with a circular outline. In camelidae, however, the red blood corpuscles are elliptical.

9. The respiratory system of a mammal is much less complicated than that of birds. The lungs are invested with pleural

membranes and lie in the chest cavity. Within the lungs the bronchial tubes divide repeatedly into finer and finer branches terminating in tiny **alveoli** or *blind sacs* where the exchange of gases takes place. At the top of the trachea, there is a complex **larynx** with the vocal cords.

10. With the exception of monotremes in which there is a cloaca, the alimentary canal ends in the anus.

11. The ureters open into the **urinary bladder** except in monotremes in which they enter a *urinogenital sinus*. Likewise with the exception of monotremes the outlet or urethra of the bladder unites in the male with the genital duct to form the **urinogenital canal**. In females, however, except monotremes and a few other cases, the urethra and the genital duct open into a common vestibule.

12. In more primitive mammals the testes lie in the abdomen but in a majority, the testes descend permanently into a single or paired **scrotal sacs** outside the abdomen lying except in marsupials, behind the penis. The male possesses a single copulatory organ, the **penis**, which in the monotremes is situated on the floor of the cloaca. The vascular tissues of the penis i.e., corpora cavernosa and spongiosum allow it to become erect during mating.

13. The ovaries are paired and both are generally functional. The oviducts or fallopian tubes are also paired. In the egg-laying mammals i.e., monotremes, the fallopian tubes open separately into the cloaca, although it has been reported that only the left one is functional. In marsupials and placentals the lower part of the fallopian tube is enlarged into a **uterus** in which the embryonic development of the young takes place. In marsupials, the uteri remain separate but in the placentals there are various degrees of fusion from the **duplex uterus** to a **simple one**.

14. The eggs of monotremes are large and rich in yolk. In all other mammals they are small and almost yolkless.

The embryo is protected by the foetal membranes, *amnion allantois* and the *chorion*. In placental mammals, the **placenta** is

formed by which the developing young is virtually connected to the wall of the uterus. The placenta is of great importance in the nutrition of the embryo.

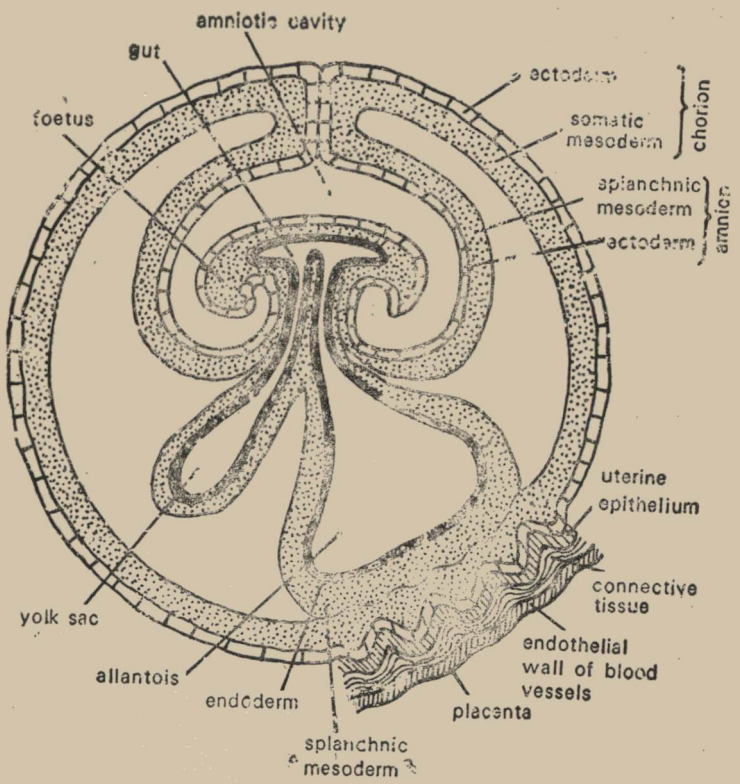


Fig. 17.1 Diagram of a mammalian foetus with its foetal membranes, amnion allantois, yolk sac and allantoic placenta.

The **placenta** is an organ which places the mother and the foetus in physiological communication. It acts like a double vascular sponge, partly embryonic, partly maternal, by means of which the blood of the mother nourishes and aerates that of the embryo. It is formed by the interlocking of foetal and maternal tissue.

Most of the marsupials nourish their young ones through a yolk sac placenta which develops from the large yolk sac during the brief period of gestation. Some marsupials have no doubt developed

an efficiently vascularised allantoic placenta. *Perameles* develops a true chorio allantoic placenta. *Phascolarctos* and *Phascolomys* too develop allantoic vascularisation.

The development of a highly organised allantoic placenta is the chief characteristic feature of Eutherian mammals. The young ones of eutherians as such can be nourished in the uterus for a comparatively long time and are born in a far more advanced stage of growth than those of the marsupials.

The functions of the placenta are to provide for the respiration, nutrition and excretion of the foetus. Nutrients and oxygen pass from the maternal blood in the sinuses into the foetal capillaries, while the excretory materials and carbondioxide pass in the opposite direction. The placenta also stores much glycogen, a reserve of carbohydrate for the use of the embryo while it still has no liver. The placenta also secretes a number of hormones e.g., chorionic gonadotrophins, progesterone, etc.

15. Monotremes lay eggs whereas the marsupials bring forth their young in an immature stage after a short period of gestation. The eutherian mammals have a longer gestation after which the young ones are born.

The General Survey and the Outline Classification of the Existing Groups of Mammals:

The outline classification of class mammalia including only the existing groups of mammals is given below.

Class Mammalia :

Sub-class **Prototheria (Monotremata).**

Order 1. Monotremata (Pleistocene—Recent).

Sub-class Theria :

Infra class **Metatheria** (Marsupialia, Didelphia).

Order Marsupialia (Cretaceous—Recent).

Infra class **Eutheria** (Placentalia, Monodelphia), (Upper cretaceous — Recent).

We will now discuss below the general characters and important characteristics of certain existing mammals belonging to the three groups *Prototheria, Metatheria and Eutheria.*

Sub-class Prototheria :

1. The Egg Laying Mammals (Monotremes) :

Prototherians or Monotremes are most primitive mammals and are closely related to reptiles e.g., Platypus ; Echidna.

The essenial mammalian characters present in monotremes are the milk glands, hair, complete diaphragm, four optic lobes, etc.

Monotremes show a wide cleft also with other mammals. They lay large yolked eggs. The milk glands nodoubt produce milk but remain unspecialised and are devoid of nipples. The milk comes out of small pores in the abdomen of the animals and the young then lap up the milk. There is no uterine gestation. There are two uteri. They possess a cloaca. The erectile penis bears a groove transmitting spermatozoa, but not urine. The urine enters the cloaca through a special urinary canal. The pectoral girdle not only retains well developed coracoids but also an *interclavicle* like the reptiles.



Fig. 17.2 A nursing duckbill or Platypus (a monotreme). The milk of the Platypus seeps from a number of pores in her abdomen and is lapped up by the young ones.

The brain is relatively simple and there is no *corpus callosum.* The body temperature is comparatively low (25° to 28° C as compared with 35° to 40° C in the higher mammals). *True teeth are absent in the adults. During development, temporary molar milk teeth are present but disappear in the adult stage.*

The monotremes like the marsupials have a pair of bones which rise from the anterior edge of the pelvis into the abdominal muscles. These are rudimentary or vestigeal *marsupial bones* analogous to

those which support the marsupium in opossums and kangaroos. In Echidnas the marsupial pouch develops only during the breeding season and a single egg laid is placed in the same. It is also suggested that monotremes are probably derived from primitive marsupial or pre-marsupial stock. Their peculiarities are thus said to be due to degeneration, neoteny and specialisation. They have thus retained some marsupilian characteristics also.

Duck bill; Platypus *(Ornithorhynchus)* :

Platypus is a native of the rivers of Tasmania and South Eastern Australia. It is also known as a *water mole*. It has a short velvety fur which is reddish brown above and greyish below. It is about 20 inches long. It lacks *pinna*. It is an egg laying mammal.

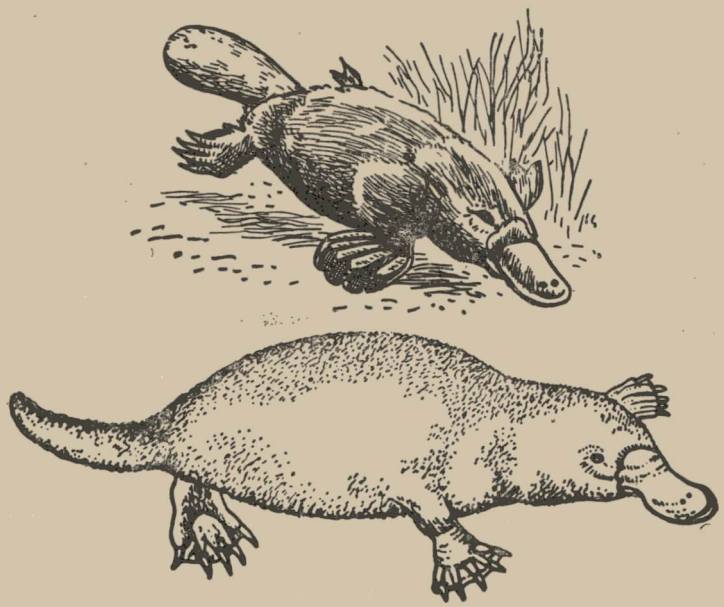


Fig. 17.3 Above : Duckbill platypus in water.
Below : Duck bill platypus side view.

The eggs have soft sticky shells. Each egg is about half an inch in diameter. The female curls about the eggs and thus incubates them for about 10 days until the *baby platypuses* hatch, each of them

breaking through the shell with an *egg tooth** which soon drops off. The new born youngs are weak, hairless and blind. It is about four months, before they can see. The young ones after hatching from the eggs are held by their heads into a fold of abdominal skin of their mother. The upper jaw of platypus is produced into a depressed beak like a muzzle with soft but tough skin. The muzzle is moist and flexible unlike the dry horny bill of a bird. This organ is pitted with tactile organs and also bears the nostrils. The eyes and ear openings are situated in a facial furrow which can be closed under water.



Hatching Platypus

Fig. 17.4 The young one of platypus hatching from the egg.

The fore-limbs are short but powerful. There are five digits ending in claws. The claws are set in a web which joins them together and then projects below and beyond the nails. This flap can be folded back and the limb as such can be used for walking, digging or swimming. Each hind foot in the males has a horny and mobile spur. The spur is pierced by a narrow canal lending from a poison gland. A slash from this spur can cause a painful wound. The duckbill besides being a good swimmer is chiefly a burrowing animal. It makes its burrow in the river bank.

The platypus feeds mainly on worms, crustaceans and tadpoles. The food along with mud and sand, is sieved into the buccal cavity between the serrations in the lower lips. The sand particles assist in mastication. This arrangement in the 'beak' of platypus is an interesting convergence with the beaks of certain ducks and other animals.

The platypus is now a rigidly protected animal and although rare, can be seen in secluded streams, a short distance from cities.

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*A small sharp protuberance which appears at the tip of the upper jaw of baby platypus at the time of its hatching

The Echidna (Tachyglossus) *The Spiny ant eater* :

The Echidna is a native of New Guinea, Eastern Australia and Tasmania. The body is covered above with strong sharp spines or quills between which are found course hair. The lower surface of the body is however covered with hair only. The fur is brownish grey. The jaws are weak and produced into a sensitive *pointed rostrum. Teeth are absent in all stages of development.* It possesses a long sticky tongue to snatch ants and termites upon which it feeds. The nostrils open in the dorsal surface of the rostrum. The eyes, like platypus, are small and the ears are deviod of *pinna.* The tail is vestigeal and is protected by terminal tuft of spines.

The limbs are short and the feet are provided with strong spade-like claws. The second pedal digit in both the sexes is equipped with an elongated *toilet claw*—which enables the animal to scratch deep through hair and spines.

The Echidna can burrow vertically into the earth at amazing speed. In digging, it uses all its four feet simultaneously and thus sinks into the ground. During attack from an enemy it begins to burrow underground. Within a few moments, its only exposed portion is a *spiny back* with which no attacker wants to come in contact. Alternatively, the Echidna can roll up like a Hedgehog (*Erinaceous*), offering thereby nothing but spines to an attacker.



Fig 17.5 The Echidna or Spiny Ant-eater (*Tachyglossus aculeatus*)

The sexes are externally alike. The one or two eggs laid by the female are placed in a rudimentary ventral or marsupial

pouch (**incubatorium**) which develops during the breeding period. The egg hatches in the pouch. The baby is nourished by the milk conveyed through ducts that open into the pouch. The baby undergoes its growth within the pouch until its spines become troublesome to the mother. It is then about 10 cm. long. This animal, like the Platypus is rigidly protected in Australia.

Infraclass Metatheria (Didelphia) :

2. The Pouch Bearing Mammals (Marsupialia) :

The marsupials get their name from a Latin word meaning '*pouch*' because most female marsupials have pouches in which they carry their young.

The marsupium is an abdominal pouch in which the nipples are lodged. In the jumping and arboreal marsupials, the pouch opens forwards i.e., upwards. In running and walking types, the opening is often to the rear. Sometimes the pouch is no more than mere folds in the skin.

The marsupials have the shortest period of gestation. The period ranges from 8 to 12 days for the marsupial cat; from 38 to 40 days for the largest Kangaroos. The young are however born in a very immature condition and pass through a second phase of development in the mother's pouch. *The young one of the great Kangaroo at birth is only an inch long, while that of the common American opossum is the size of a honey bee with a weight of only two grammes. Twenty new born oppossums can thus fit into a tablespoon.*

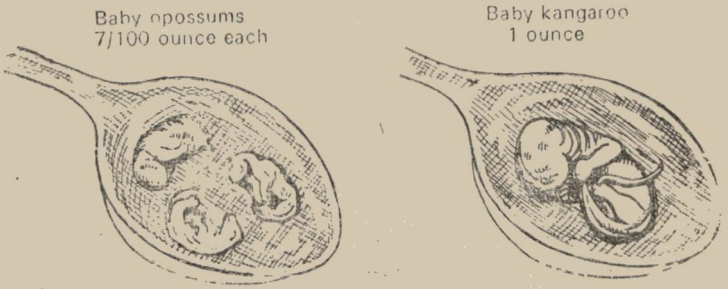


Fig. 17.6 Left : Few of the baby opossums of tiny size at birth shown in a spoon. Right : The baby kangaroo at birth which can be accommodated in a spoon.

After birth the immature tiny young ones reach the pouch under their own efforts. From the vaginal orifice of their mother the immature young ones climb the pouch with a swimming motion of fore-legs and head through the fur and ultimately enter the opening of the pouch. The mother usually makes the way smooth by licking the fur which nodoubt facilitates the young ones to enter the pouch.

On reaching the pouch the young one grasps a nipple in its mouth and does not leave it during the whole period of lactation. The nipple is ringed by a powerful muscle. As the young one is incapable of sucking the milk, the muscle around the nipple by contraction squirts milk into its mouth from time to time.

As regards the other important characters of marsupials, the anal and urinogenital apertures are surrounded by a common sphincter muscle. The vaginae are distinct and each opens separately into the urinogenital sinus. *In Marsupials, the ureters in both the sexes pass between the genital ducts whereas in Eutherian mammals the ureters pass outside the genital ducts.* The male possesses an erectile penis, which is sometime bifid. An allantoic placenta is rarely developed. In *Peramelidae* an *allantoic placenta* occurs but it is of relatively simple structure and functions but for a brief period. The brain is devoid of *corpus callosum.* The olfactory bulbs are large. The cerebral hemispheres are small and do not extend posteriorly over the cerebellum.

Marsupials in general may be said to represent a somewhat lower grade of organization than the Eutheria. They share with the more primitive Eutherians like insectivora, certain primitive characters such as a small brain occupying but a comparatively small portion of the skull and disproportionately large olfactory bulbs.

Present day marsupials are confined to Australasian region (with the exception of New Zealand) and South America and a few species over flowing into the United States.

Marsupials of Australia :

Kangaroos (*Family* : *Macropodidae*) :

Kangaroos are found in Australia and besides this continent they are also found in Tasmania, New Guinea and a few of the neighbouring islands.

The kangaroos are specially adapted for swift terrestrial locomotion. The head and neck are relatively small. The forelimbs are short and each is provided with five digits. Kangaroos use their forelimbs when fighting and playing among themselves. The hind-limbs on the other hand are long and powerful They are Z-shaped like those of the frog and other jumping animals. The foot is narrow and has four toes, a hallux clear of the ground.



Fig. 17.7 The Kangaroo (*Macropus sp.*)
a pouch bearing animal of Australia.

The two inner (second and third) toes are small and united by an integument. The middle toe is very long and powerful. It is a good defensive organ capable of disembowling a dog. The tail is very long and usually thick. It helps support the body while at rest. The progression of Kangaroo is very rapid and is effected by great springing leaps. During leaps the body is inclined forwards and the forelimbs clear of the ground. Kangaroos possess a large marsupium. Reproduction is very slow and as a rule only one offspring is born

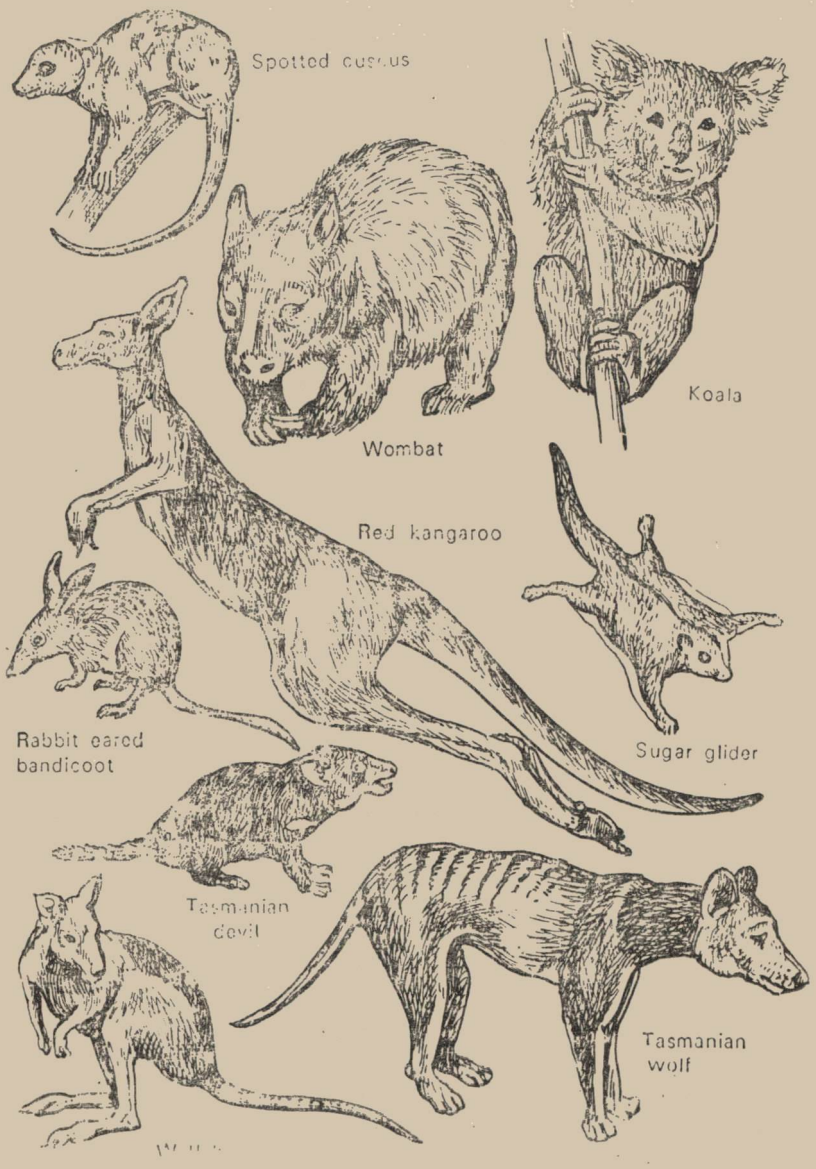


Fig. 17.8 A few of the marsupials belonging to the Australian region.

each year. There is forty days of uterine gestation after which the immature young born (hardly 1" long) crawls up through the fur until it reaches the pouch and attaches itself to a nipple. There it remains uninterrupted for two months. During the third month of its development it begins to go out and look for food, returning to the pouch between its expenditions. Kangaroos often gather in herds called '*mobs*.' Their diet chiefly consists of vegetable matter. Their average life expectancy is about fifteen years. A kangaroo normally hops from 5 to 10 feet.

The famous eighteenth century English explorer, Captain James Cook gave these marsupials the name kangaroo. The captain while pointing to one of these animals, asked an Australian native what it was called "Kangaroo" replied the native which in his language meant 'I don't know.'

The two largest species of the plain dwelling kangaroos are the Red kangaroo (*Macropus rufus*), which has a blue-grey doe, and the Great Grey kangaroo *(Macropus giganteus)*.

The Australasian zoogeographical region excluding New Zealand contains more than four times as many marsupials as occur in South and North Americas. In the highly diversified mainland of Australia, marsupials prospered and now exhibit many beautiful examples of convergence with the more advanced emergent eutherians. Here the marsupials have become differentiated into, *arboreal, fruit eating, grazing, gnawing, digging, burrowing, ant-eating, insectivorous* or *carnivorous types.*

Marsupials of America :

The only marsupials existing in North, Central and South America are the **opossums.**

The American opossums are mostly insectivorous or carnivorous though they also eat grain, carrion and fruits and cause considerable damage to crops.

The common or virginian opossum (*Didelphys virginiana)* inhabits southern and eastern regions of the United States and Argentina. It is rat-like and grows bigger than a cat. Its snout is pointed. The tail is long almost bare and prehensile.

The opposum usually attacks fields, orchards and farm yards. Its diet is composed of carrion, insects, small vertebrates, mushrooms, fruits, berries, grain and rarely poultry.

The opossum when confronted with danger falls immediately into a *death-like coma*, lying inert with tongue lolling out and eyes closed. As a result, some of its attackers may leave it for dead. When the danger passes the animal revives its activities. This peculiar behaviour of opossums while facing danger is known as **'playing possum.'**

High fecundity is seen in opossums. The female opposum often bears two litters of nine each year generally in February and June. Uterine gestation is of thirteen days after which the newly born young-hardly bee size, climb through their mother's fur and enter the pouch, each one attaching itself to mother's nipple. They stay within the pouch for nearly three months. Afterwards they climb on their mother's back where they are carried for several weeks. When the mother feels that they can look after themselves, the young opossums are shaken loose from the back.



Fig 17.9 The Opossum (*Didelphys*)

The natural enemies of opossums are hawks, owls and foxes. Man hunts it as it is destructive to poultry and eggs. Its flesh is also considered a delicacy is some areas and its fur is valuable. The

opossum is the friend of the farmer in other sense as it destroys insects and harmful rodents.

3. Sub-class Eutheria :

The higher mammals or the true mammals include man, and many domesticated beasts. The young ones of eutherian mammals stay longer in the mother's womb where they are nourished through a well developed *allantoric placenta.* These mammals are therefore called **placental mammals.**

Few of the examples of eutherian mammals will now be described.

The Insect Eating Mammals *(Insectivores)* :

The insectivores are small mammals feeding primarily on insects and other small invertebrates such as earthworms and spiders. They were the earliest placental mammals.

Insectivores are found in the temperate and tropical zones of both the hemispheres, but not in South America (except in the Northern Andes) nor in Australia, New Zealand or Papua.

Among the living mammals this group includes, shrews, moles, hedgehogs, etc They look like rats and mice, but there are some important differences e.g., the canine teeth are always present in the insectivorous mammals but never in rats.

Shrews are the smallest mammals. *Sorex araneus* is the common shrew of Europe and North Asia. It is about two to two and half inches long. Its new born young are smaller than honey bees. Shrews spend their lives under leaves and in runways which they dig under the soil. When a shrew is excited, its heart will beat as much as 1,200 times a minute !

Moles (*Talpa europea*), the *European Common mole* lives under-ground. The head is pointed and the body is cylindrical. The body is covered with a black fur which is thick, short and velvety. The eyes are buried in the fur and are only the size of a pin's head. Eyes in moles and shrews just serve to distinguish between light and darkness. The moles have powerful forelimbs

with which they dig the ground. The tunnels made by moles are more or less in the form of a *fortress*. The pushed up earth, while digging the tunnels forms a little mound called a **mole hill**

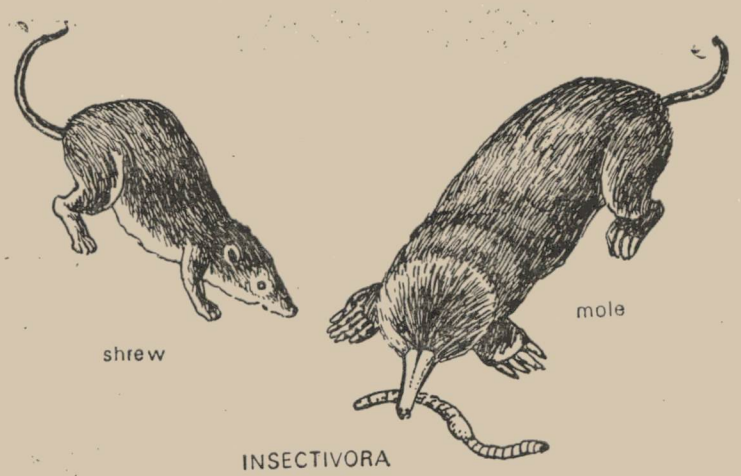


Fig. 17.10 The mole and shrew.

Hedgehogs are found in Europe, Asia and Africa. The hairs of the dorsal surface have become converted into **spines** or **quills** and

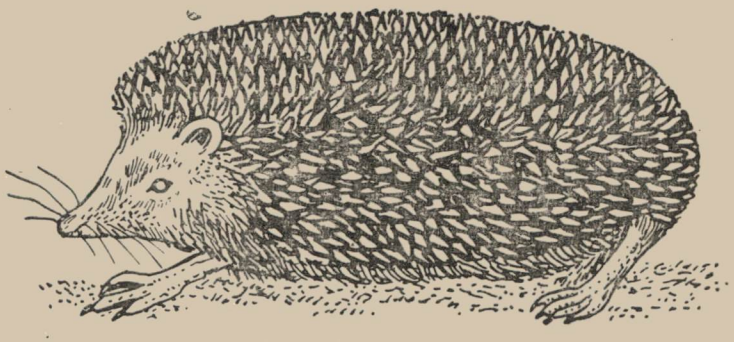


Fig. 17.11 The Hedgehog

owing to a remarkable development of the dermal musculature, the animal can roll itself into a *spine covered ball*. They are nocturnal. During daytime, they lie hidden under bushes, in hollows at the base of the trees or in crevices in rocks.

The Flying Mammals—Bats (*Order : Chiroptera*) :

Bats are *true flying mammals.* The wing of a bat consists of a thin membranous fold of integument which even stretches to the hind limbs. The membranous fold of the integument is supported by the long digits of the fore-limb. The first finger—the thumb or pollex much shorter than the other digits is free and clawed. It is used as a *grasping organs.* The other fingers of the hand i.e., II, III, IV and V with their corresponding metacarpals have become long, thin and flexible. They are thus all involved in the support of the wing membrane and usually have lost their originally clawed end joints. In the microchiroptera, however, the second digit also is usually clawed, but the other digits are always clawless. As the wing expanse is broken by the long digits, the wing of a bat is evolved as a more flexible and less easily damaged structure.

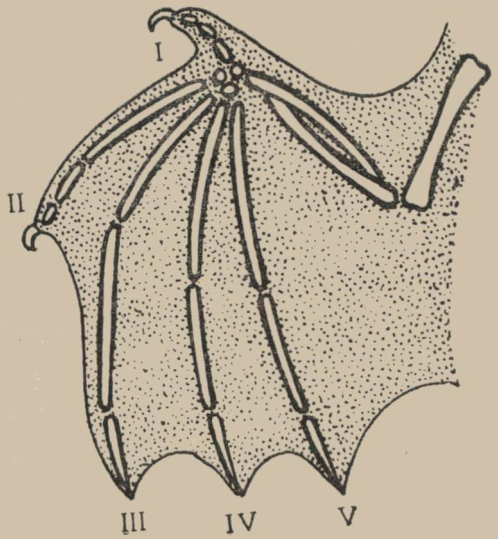


Fig. 17.12 The skeleton of the wing of a bat.

Bats are nocturnal creatures. As in most nocturnal animals, the retina has only rods Bats are believed to see a short distance and only moving objects. *They are never blind.*

Bats can fly with confidence in apparently totally dark caves and experimentally blackened rooms by means of an **echo-location**

device. The vibrations produced by the bat are reflected back as echoes from nearby objects. They are able to avoid collisions by noting these echoes. The bats that are blind-folded do not collide with objects placed in their line of flight. However, when the ears of bats are obstructed, they collide with the obstacles. They find their way by means of echoes from **ultrasonic squeaking** i.e., the bats produce a series of shrill cries which are inaudible to the human ear. These shrill cries have a frequency of 50,000 vibrations per second.

Pteropus (Fruit bat) :

Pteropus giganteus or the **Indian flying fox** inhabits India Burma and Sri Lanka (Ceylon). It is twelve inches long with a wing span of fifty inches.



Fig. 17.13 **Pteropus**—The nocturnal, large-eyed, fruit bats or flying foxes of Indo-Malaya and Australasia (excluding New Zealand). *Pteropus giganteus* is as large as a small cat. They destroy fruit crops and eat flowers as well.

During day time, the flying foxes hang in trees and depart on feeding expeditions only at night.

Vampire bats live in the tropical Americas and drink the blood of mammals including the man. *Desmodus rotundus* is a true vampire hardly three inches long. Actually very little blood is lost from the bite of a vampire. Vampire bats however transmit diseases including rabies which may infect man and destroy fowl and other domestic animals. Many legends and stories have been coined about bats and vampires. These are however quite imaginative and untrue.

Ant-eaters, Sloths and Armadillos (*Order* : *Edentata*) :

Ant eaters, sloths and armadillos are included in *Order Edentata* which means 'toothless.' This name of the order however is not

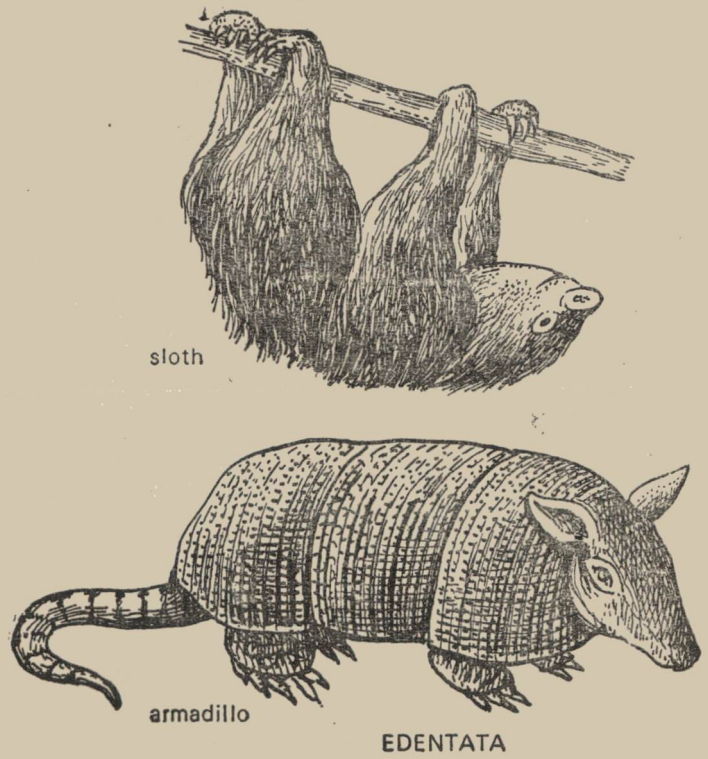


Fig. 17.14 Above : Sloth, Bradypus is the South American edentate that has become arboreal. Below : The Armadillo. The hair coat is replaced by strong, bony plates bearing horny scutes, an unusual feature in mammals.

literally correct as all the animals included in this group are not toothless. Enamel on the teeth no doubt is entirely absent in the existing forms. In armadillos, the teeth are transformed to pillar-like persistently growing stumps. In sloths, the teeth are however reduced in number. The teeth may be altogether absent in the ant-eaters (*Myrmecophaga*). The edentates are exclusively the New World creatures.

Pangolins *(Order : Pholidota)* :

The **Pangolins** or **Scaly ant-eaters** are distinguished from all other mammals by their covering of scales. The back, sides, top of the head, upper part of the limbs and both the surfaces of the tail

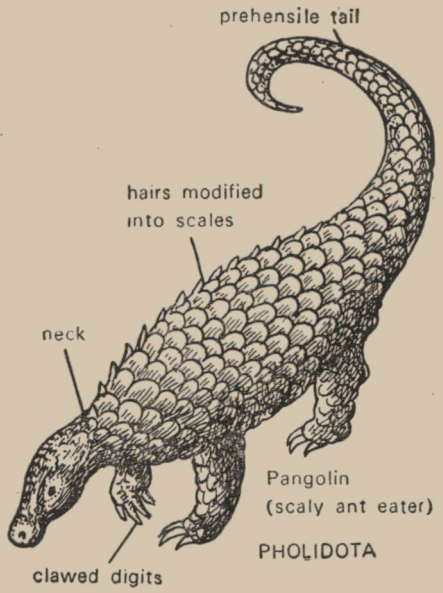


Fig. 17.15 The Pangolin (*Manis sp*). **Scaly ant-eater.**

are completely covered by numerous scales arranged in longitudinal and transverse rows. The lower body surface is hair covered. The scales on the body are formed of modified hair and overlap like tiles from front to back. The scales are so arranged that the animal can roll itself up into a ball as a protective measure. The popular name *Pangolin* comes from the Malay word *'Peng-goling'* meaning *'roller.'*

Pangolins are plantigrade. Each foot has five digits ending in powerful claws. The central claw of each front foot is greatly enlarged for burrowing. It is also used for demolishing termite hills during search for food.

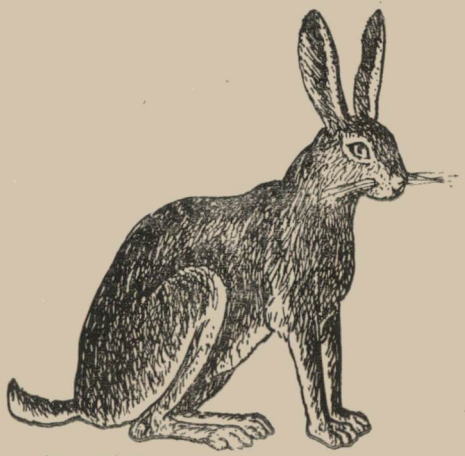
The head of a Pangolin is narrow and triangular and is produced into a short pointed muzzle. The mouth is small and the teeth are entirely absent. The tongue is long, extensile and vermiform. It has a viscous coating used for catching ants and termites. Pangolins have no external ears and their nostrils can be closed. This is a protective device against ants and termites. The eyes have thick lids which can shield them from the bites of ants. The tail is long and very mobile despite the covering of the scales. The tail in several varieties is prehensile and can be coiled round a branch and used in climbing.

Various species of Pangolins occur in Africa and South-East Asia. The Indian Pangolin (*Manis grassicaudata*) is mainly a terrestrial animal. The female Indian Pangolin is reported even to envelop her young in her own protective covering when danger threatens.

Hares and Rabbits (*Order* : *Lagomorpha*) :

The hares and rabbits are included in a separate order called *Lagomorpha* (literally, hare shaped). They can be distinguished from rodents in the following respects.

1. Lagomorphs have two pairs of upper incisors instead of one.
2. They have long ears.
3. The hind limbs are considerably more developed and elongated than the fore limbs.



17.16. The Rabbit (*Oryctolagus*)

Rabbits can be distinguished from the *hares* by certain distinct characters and habits, few of which are given below in a tabular form.

Rabbit (*Oryctolagus sp.*)	Hare (*Lepus sp.*)
1. The ears of the wild rabbit are always shorter than the head and are devoid of black patches at the tips.	1. The hare has very long ears with a black patch at each tip.
2. In rabbits the upper front incisors have a prominent longitudinal groove on the outer surface.	2. There is no longitudinal groove on the outer surface of the upper incisors.
3. The rabbits are particularly gregarious animals. They are found only in large numbers.	3. Hares have solitary habits.
4. The burrows made by rabbit are complex. They are ramifying from one to another and with many entrances.	4. Hares simply make a depression in the grass called the 'form' in which they rest during day time.
5. New born rabbits are naked and blind.	5. The young are born with their eyes open and their bodies covered with hair.

The Gnawing Mammals—Rodents *(Order : Rodentia)* :

Rodents are *gnawing animals* as they grind the hardest and most varied foods between their teeth. They have a single pair of large chisel-shaped incisors in each jaw. The incisors in rodents project at the front of the mouth and bear enamel only on the front surface. The posterior surface of the incisors is devoid of enamel.

The incisors have persistently open roots due to which they grow throughout their life and are always of great size. Canines are absent. The jaw muscles are very greatly enlarged and provide the rodent with the necessary power for gnawing.

Rodents include the squirrels, beavers, porcupines, rats, the mice and the Guinea pigs etc.

Squirrels : There are some seventy species of true squirrels distributed in all parts of the world except Madagascar and Australia. These are small arboreal rodents having a bushy *plum-like tails* and ears often *tufted*. *Funambulus* is the **Indian palm squirrel**. There are 3 to 5 longitudinal stripes on the back, the median stripe being the longest. The pinnae are small covered with soft fur, with no ear tufts. The tail is bushy and flat and is about the same length as the head and body.

Beavers have a thick-set-body with short strong legs. The head is short followed by a sturdy and very flexible neck. The nostrils and auditory canals are provided with valvules which close the apertures when the animal is immersed. The hind feet are webbed for swimming. The fore feet are not webbed ; they are flexible enough to function almost as hands. The tail is broad and flat like a paddle and covered with epidermal scales. The beavers are good '*builders*' unparalleled in the animal kingdom. With the help of their teeth and hands only, they are capable of constructing their '*lodges*' usually on the side of a lake or on a small island.

Porcupines are the rodents where the body is covered with *spines* or *quills* in addition to the ordinary hair. The spines or quills are sharply pointed hairs of enormous size. When erectile they serve as organs of defence. **The Common or Crested Porcupine** (*Hystrix cristata*) is found in Southern Europe, North Africa and Asia Minor. It is about 28 inches in length and sixty pounds in weight. The tail is short. The salient feature is the crest of white tipped grey quills besides the general covering of the quills on the surface of the body. They are loosely implanted and can easily become detached. This porcupine is wholly terrestrial and lives in communal burrows, feeding at night on roots, bulbs and fallen fruits.

Rats are rodents characterised by the possession of gnawing incisor teeth. **The Brown Rat** (*Ratus norvegicus*) is the common rat found in most cities of the temperate zone. The female is very fecund and can breed when eight weeks old. Gestation period is of three weeks and as many as twelve litters are born in a year.

The black rat (*Rattus rattus*) came originally from Southern Asia and spread through Europe during the middle ages. The black rat differs from the brown rat not so much in colour as in shape of the body. In the black rat the tail is longer than the body and the ears are more than half as long as the head. In the

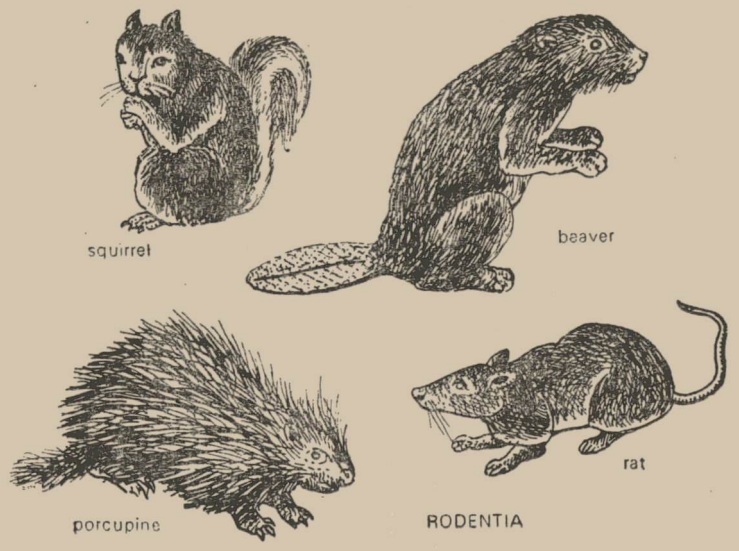


Fig. 17.17 A few of the rodents

brown rat the tail is shorter than the body and the ears one-third the length of the head. The brown rat is bigger than the black rat, reaching a length of upto ten inches without the tail and a weight of over one pound. Rats are responsible for destroying crops, poultry and stored products. The House Mouse (*Mus musculus*) is a species of domestic rodent. Though charming it is a formidable pest. Mice are normally grey but albinos are bred in captivity.

Guinea pig (*Cavia*): The name guinea pig is a misnomer for it is not a pig but a rodent. Further, it does not come from Guinea but from South America. Guinea pigs however grunt in a rather piggy way. They have short glossy fur, usually dark brown with black, white and yellow patches. Guinea pigs breed very rapidly. They begin breeding at 10 months of age. Each brood consists on an average of six or eight.



Fig 17.18 Guinea pig (*Cavia porcellus*)

The Flesh Eating Mammals (Carnivores):

The flesh eating mammals are called *carnivores*. The word carnivore is derived from the Latin words '*canis*,' meaning "flesh" and '*vorare*,' meaning "to devour."

Carnivores use their sharp claws and long, sharp teeth to catch and tear the prey they hunt. In each of their upper and lower jaws are two teeth that are longer than the rest. They are called *canine teeth*. The Latin word for dog is *canis*, and canine teeth were so named because of their presence in dogs. The main diet of carnivores is flesh, though many, including *bears* and *racoons*, also eat fruits, berries and other plant foods.

The Cats — Felines:

Many kinds of cats in the world belong to the group called *felines*. This name is derived from the Latin word *felis* for 'cat.' All felines (e.g., tiger, lion, leopard and cheetah) except the domestic cat, are wild animals.

Tiger *(Panthera tigris)* :

The tiger is confined to east Asia. There are no tigers in North or South America, Australia or even Africa. The Indian type is also known as the *Royal Bengal Tiger*. The tiger has a golden fawn body with dark, black vertical stripes which run on either side from its spine down to its belly. The stripes vary from brown to

black. They are lighter on the under parts of the body. The belly and the chest of the tiger are white. The tiger's whiskers are hard and white. The back of each ear is black with a white spot in the centre. The most famous of all Indian varieties is the *white tiger* found in *Rewa*. It has a muddy white coat with chocolate-brown



Fig. 17.19 The tiger (*Panthera tigris*)

stripes. The *Siberian tiger* is the largest, 13 feet in length. Normally a tiger does not exceed 12 feet in length including the tail. The period of gestation is 105 days and the number of young born are 2—4. Life span is about 15 years. The tiger neither dislikes nor avoids water. Tiger will eat any kind of flesh, in any state. The tiger normally fears, man. Occasionally, however, a tiger becomes a *man eater*. There are not many tigers left in India. The hunting of tigers has been banned. Tigers can breed in captivity and in a few instances, crosses between a lion and a tigress called *Ligers* have been obtained.

Lion *(Panthera leo)* :

The lion is smaller than a tiger. It is buff coloured and has no stripes. Its tail is hairy and short. The male has a fluffy *mane* on its neck. It should however be remembered that not all males grow a mane. The lion is found in Africa, in the south of Sahara It is rare in Asia. The lion is almost extinct in India. The only specimens found are in the Gir forests near Junagadh. Shooting of lions as such is forbidden. Like the tiger, lion eats meat. Cow, bull, buffalo and deer are usually eaten by the lions. The lion often turns into a man-eater. The lion is a very docile animal and

can be tamed. They are not afraid of men whereas tigers are frightened by man's size and appearance. Lions live and hunt in family groups known as '*Prides.*' Lions are the noisest of cat family, and seem to find delight in joining in a chorus of *roars*. The period of gestation is 108 days and the number of young ones born is 4. The cubs are spotted.

Leopard *(Panthera pardus)* :

The leopard is found in almost all countries. In India the leopard is spread everywhere. The leopard has a golden brown body. It's under belly is white but the rest of the body has *black spots* with *floral pattern*. The spot on the paws, neck, head, tail and abdomen are a darker shade of black. In Assam and Kerala, the leopard is jet black. Nevertheless if one looks closely one can see the floral spots under its black coat. The leopard's paws are padded. The fore-paws have five claws and hind-paws four. When the leopard is walking, its claws are sheathed in their pads. The

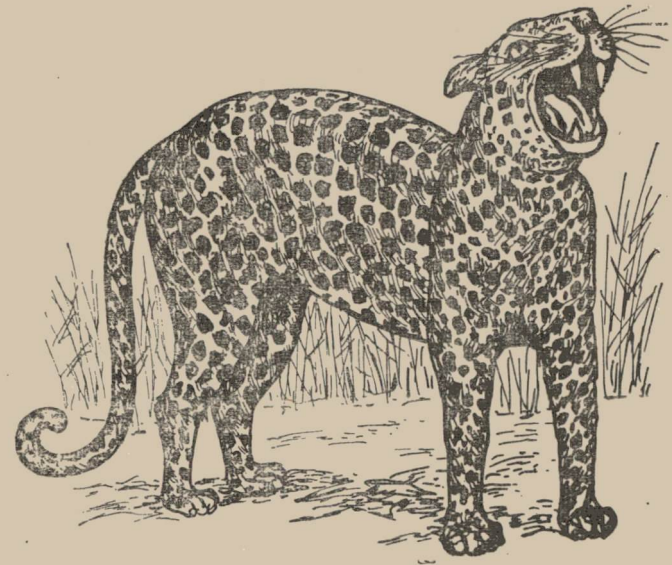


Fig. 17.20 The Leopard (*Panthera pardus*)

leopard does not roar; it only *grunts*. *The grunt is like the sound of a saw on the timber.* Leopard is scared of water. The leopard eats all kind of animals but prefers dog flesh. The leopard falls on its

prey like lightning. It is the cleverest of all the beasts of prey of the Indian jungle. The leopard can turn a man-eater. The period of gestation is 90 days and number of young born are 2 – 5.

The Cheetah *(Acinonyx jubatus)*:

The cheetah resembles a dog more than a cat. It's legs are long like those of a dog. The cheetah is taller than the leopard. The colour and spots of the cheetah's coat resemble those of the leopards, except that the cheetah's spots are a solid deep black. It's head is proportionately smaller than its body, and the face is flatter than a leopard's. From the edges of cheetah's eyes, *two black stripes*, like tears, run to the nose and on to its mouth, from either side. It has small ears and the pupils of the eyes are round. Its fur is coarse and its neck is fluffy. The claws of a cheetah are not sheathed and

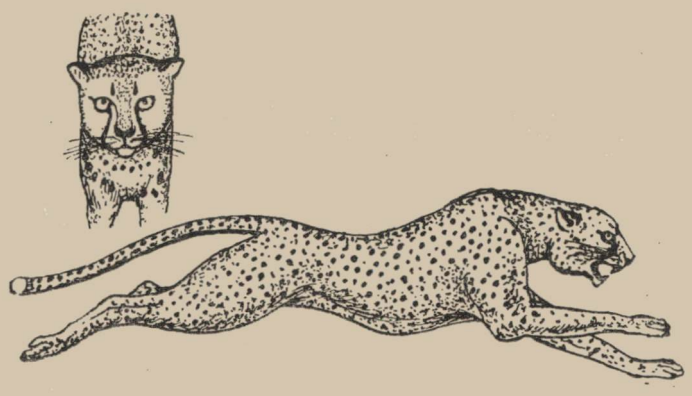


Fig. 17.21 The cheetah (*Acinonyx jubatus*)

unlike a cat it cannot draw them in, completely. The cheetah is the fastest land animal over short distances. When it sees the quarry, it bounds forward at a speed close to 100 kilometres per hour. Cheetah being docile and amenable to discipline, can easily be tamed. In earlier times the cheetah had been trained to hunt gazelles and antelopes. It is, therefore, called the *'hunting leopard.'* At one time the cheetah was found in our country in the region stretching from the Western Plains to the uplands of Central India down to the Deccan. The cheetah may now be considered extinct in India. Cheetahs however abound mostly in the plains of Africa.

The Dog and the Dog-like Mammals—Canines:

This group of wild mammals includes wolves, jackals, coyotes, wild dogs and foxes, all of which generally resemble the domestic dog. Canines have long muzzles and powerful jaws. In addition to four canine teeth which are used to hold the prey, the members of this group have flat teeth for crushing bones, as well as "shearing teeth" (Carnassials or flesh teeth—last premolar in the upper jaw and the first molar in the lower jaw become enlarged and bear cutting edges) for cutting cartilage and sinew. Canines can move their erect ears in the direction from which a sound is coming. Their best developed sense is smell. Canines perspire through glands in their tongues. When these dog-like animals are over heated, their tongues hang out and drip perspiration.

Dogs are universally distributed throughout the world. There seems to be no wild form in existence from which it can be claimed that the domestic dog (*Canis familiaris*) has been derived. Many dog breeds have been obtained such as hounds, toy dogs, spaniels, terriers, non-sporting dogs, ship dogs, watch dogs, etc. *Dingoes* are the dogs restricted to Australia where they are the only wild carnivores. They are believed to be domestic dogs brought to Australia in prehistoric times and have reverted to wild state. They are about 2 feet tall and four feet long, and often prey on sheep herds.

Canis dutchunensis, formerly known as Dhole is the *Indian wild dog* which lives in forests.

Wolves are widely distributed in a wild state and live across Europe, Asia and North America. The coat is a tawny colour, with white markings on the underside and black markings on the shoulders and tail. The ears are small and pointed, and are always held erect. The wolf differs from the dog in *howling* instead of *barking*. Two subspecies of the common wolf are known as the Indian wolf. They are the **woolly wolf** *(Canis lupus chanco)* found in the Himalayas and Central Asia and the small Indian wolf *(Canis lupus pallipes)* occurs in the plains.

Bears *(Family: Ursidae)*:

Bears have a fully plantigrade foot and non-rectractile claws. The shearing carnassial teeth are not found. The molar teeth are

large, elongated and much tuberculated. Bears sometimes produce grotesquely over sized composite foot prints. Such prints are formed by super imposing the hind foot partly over the print made by the adjacent fore leg.

Bears have heavy bodies with short, strong legs and are able to stand upright and grasp things with the front paws.

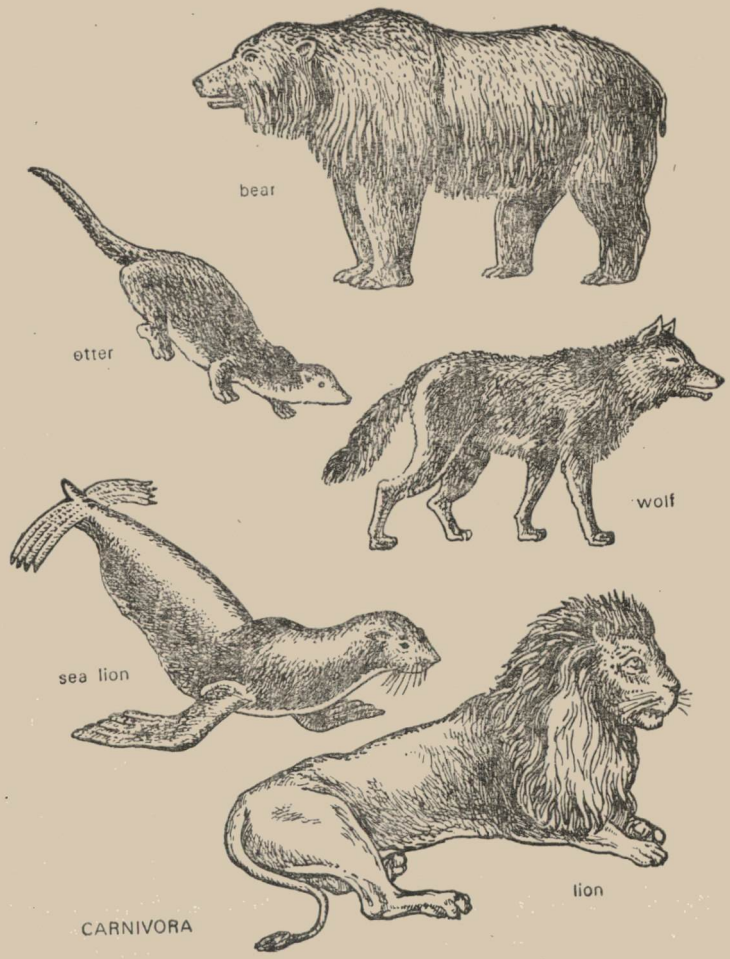


Fig 17.22 A few of the carnivores

Selenarctos thibetanus is the **Himalayan Black Bear.** It is found from Persia to the Himalayas and in Burma, Indo-China, Manchuria, Korea and Japan. It has a pointed snout and a black coat with a V-shaped mark of pure white on the chest. The chin is also white. The height hardly exceeds six feet. It is a forest dweller.

Otters:

Otters are more completely adapted to an aquatic mode of life and they have certain characters which correlate with moving under water. The head is flattened and the vibrissae or whiskers are stout as in seals. The ears are small and provided with a membrane to close them when diving. The feet possess five toes which are webbed for three quarters of their length. The claws are non-retractile. The broad flattened tail is said to be used for steering in water. As a matter of fact, the tail takes part with the body in the sinuous swimming movements. The fur is short and dense and is impermeable to water. The fur is dark brown and glossy on the back and slightly paler on the throat.

Lutra lutra is the **Common** or **Old World Otter** found in Europe including the British Islands, North Africa, Northern Asia and parts of India. In India it cohabits with the somewhat smaller **Indian Small Clawed Otter** *(Anonyx cinerea)* which also inhabits East Indies, Himalayas and China. **Smooth Coated Otter** *(Lutrogale perspicillata)* is another otter of India and Malaya. The hole in which the otter lives is known as a *holt* which is burrowed out of the bank of a lake or water course. The otter's movements on land are clumsy. In water it swims with a serpentine movement of the body and tail, the limbs being pressed to the sides. It feeds on fishes and crustaceans. The common otter's cry is a sort of half-scream, half-grunt, which it utters only rarely.

Aquatic Carnivores:

Pinnipedes are the aquatic carnivores. They are abundant in the oceans and in more or less enclosed seas such as the Baltic, Mediterranean, and the Black Sea. There are seals even in inland waters like the Caspian Sea and the Lake Baikal.

Sea Lions *(Eared seals)*:

Sea lions possess pinnae. Their necks are longer. Palms and soles are naked. The digits are devoid of nails. The fore-limbs are long and supple. The hind-limbs can move away from the tail. They are capable of quadrupedal locomotion. Sea lions are also called hair seals. The southern Sea lion *(Otariabyronia)* inhabits Galapagos Islands, ranging down the coast of Peru and Chile. The males are over seven feet long and have a mane.

The Mammals with Trunks—*Elephant* (Order : Proboscidea):

The elephants are the largest of the present day land mammals. They possess a *trunk* or *proboscis*. The nostrils and upper lips form the *elongated proboscis*.

Elephants have extremely specialised teeth. Canines and lower incisors are absent. A single pair of **upper incisors** are developed into enormous **tusks** which grow continuously from persistent pulps throughout the life of the animal. They are of elongated conical form, and usually become curved. The valuable *ivory* is obtained from the tusks.

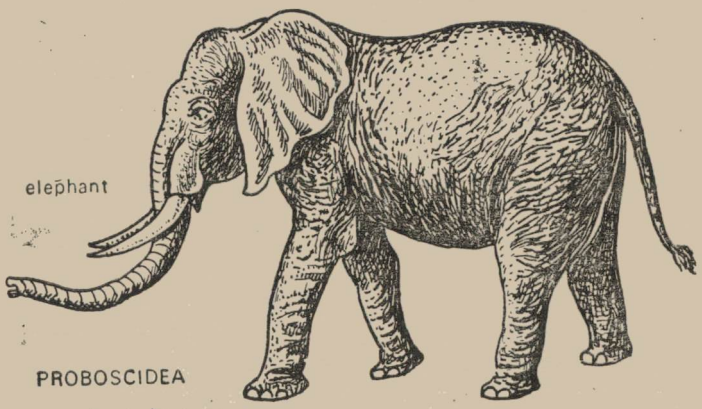


Fig. 17.23 An elephant

Elephants have five digits on each foot and have thus retained the pentadactyl limbs of the ancestral mammals.

The African elephant *(Loxodonta africana)*, can reach a height of eleven feet and a weight of nearly six tons. It has an arched fore-head, large ears, two triangular appendices or lips at the end of the trunk. They inhabit both forest and Savanna. **The Indian elephant** *(Elephas maximus)*, inhabits the forests of the lower Himalayas and Nilgiris, Western Ghats, Karnataka and Coorg. It is also found in Sri Lanka, Assam, Burma, Thailand, Cambodia, Laos, Vietnam, the Malay peninsula, Sumatra and Borneo. It can be distinguished from an African elephant in possessing a concave fore-head, knobby head, small ears, single appendix or 'lip' at the end of the trunk. It can rarely exceed ten feet in height.

Elephants usually live in 'herds' composed of several hundred individuals. There are also solitary or 'rogue' elephants which have been chased out of the herd. The period of gestation is twenty to twenty two months, and there is only one calf at birth.

Manatees and Sea Cows *(Order: Sirenia)*:

Order Sirenia, includes the dugongs, manatees and their allies. They are fully aquatic.

The order includes the *Manatees* (*Trichechus=Mantus*) which live in fresh waters or along the coasts of America and Africa and the *dugongs* or *Sea Cows* (*Dugong=Halicore*), of the Indian Ocean, South Pacific and Australian Coasts. Manatees and dugongs are strictly vegetarian and are confined to tropical and sub-tropical waters.



Fig. 17.24 A manatee (Sirenia)

Many traditional sailor's stories about the Sea Cows which suckle their young, have been coined. Sea cows have been referred to as *mermaids* inhabiting distant seas.

The Hoofed Mammals (*Ungulates*) :

The term **hoofed mammals or ungulates** is used for those animals where the toes are encased in horny casings called the *hooves*. The hooves protect the toes of the animals that usually live in an open country and do much running. The ungulates form a heterogenous group comprising pigs, hippopotami, camels, cattle, deer, tapirs, rhinoceros, horses, hyrax, etc.

Hoofed mammals are divided into two main groups: those that have an odd number of toes on each foot, such as horse and zebra (one toe) and the rhinoceros and tapir (three toes); and those hoofed mammals that have an even number of toes such as deer, giraffes, camels, goats, hippopotamus, cows, etc. The hooves of even toed animals are split into two parts. They are as such called *cloven hoofed* (cloven = split into two.).

Odd toed Ungulates—Horses, Asses and Zebras (*Family* : *Equidae*) :

All these animals are monodactyles. The functional digit is the third one occupying a middle position. The second and third digits nodoubt exist but are only in vestigeal form as thin, tapering *splint bones*, situated closed to the upper end of the metacarpus or metatarsus of the third digit. These vestiges are of great anatomical importance as they provide a proof that horses, asses and zebras are the descendants of an earlier type of animal with three digits.

Equus cabalus is a wild horse represented by only one race, the Mongolian wild horse or *Prezwalskis horse* (*Equus cabalus prezwalskii*). It is the only existing true wild horse and survives in small numbers in Central Asia. It attains a length of four feet six inches at the shoulders. It is confined to Mongolia and Sikiang.

Horses have been domesticated and man has been able to obtain many useful breeds. A pure breed Arab horse is considered the most ancient breed which forms the basis of nearly all present day horse breeds.

A *mule* is a hybrid obtained from a cross between a he-ass and a mare. A cross between a she-ass and a stallion pony is called a *hinny*. The mule is generally bigger than the hinny.

The African Wild Ass (*Equus asinus*) differs from the wild horse in having long ears, shorter upright mane and narrow hooves. The tail has only the tuft of hair and there are no 'chestnuts' on the hind legs. The ass *brays* instead of *neighing* and is less graceful than a horse. The Nubian ass is believed to be the parent of the present day domesticated donkey. Donkeys are placid and hardy.

Zebras : Like wild asses, the zebras are native to Africa. The Mountain Zebra (*Equus zebra*) formerly inhabited the mountainous areas of South Africa. It is striped all over the body except its under part and inside the legs. The Common Zebra or Burchell's Zebra (*Equus burchelli*) is distributed between Ethiopia and the Orange River. The common zebra lives in herds of 50 to 100 animals. It is quite a vicious animal and difficult to tame.

Tapirs (*Family* : *Tapiridae*) : Of all the living hoofed mammals, the tapirs are the least specialised. In the fore-foot there are four toes and the hind-foot has three. The third digit however in each case is somewhat enlarged. They have a short movable trunk.

Tapirus terrestris or the **Brazilian Tapir** stands three feet at the shoulder and is six feet in length. The skin is without folds and the coat is short and thick. It is dark brown with a white fringe on its ear. It looks at first glance like an enormous pig.

The **Malayan Tapir** (*Tapir indicus*) is common in Thailand and Sumatra. It differs from the American species (*T. americanus*, *T. roulini* and *T. clowi*) in its particular coat, which is black with a sort of white blanket over the loins and rump.

Tapirs are strictly nocturnal in habits. They are gentle, timid and mistrustful of man. They are solitary and silent and grunt when disturbed They emit a piercing whistle in the rutting season.

Rhinoceroses (*Family* : *Rhinocerotidae*) :

The chief characters of rhinoceroses are the massive body and limbs. The skin is very thick and appears like an armour plating. Two, one or no horns may be present. These horns are

peculiar in being formed of a fused keratinous substance allied to hair. The horns are attached to the roughened part of bone and are situated on the median line of head. The substance of the horn has been valued in the Far East for its alleged aphrodisiacal properties. It possesses in fact no such properties. Rhinoceroses are tridactyle and possess three hooves, the middle one being the most developed.

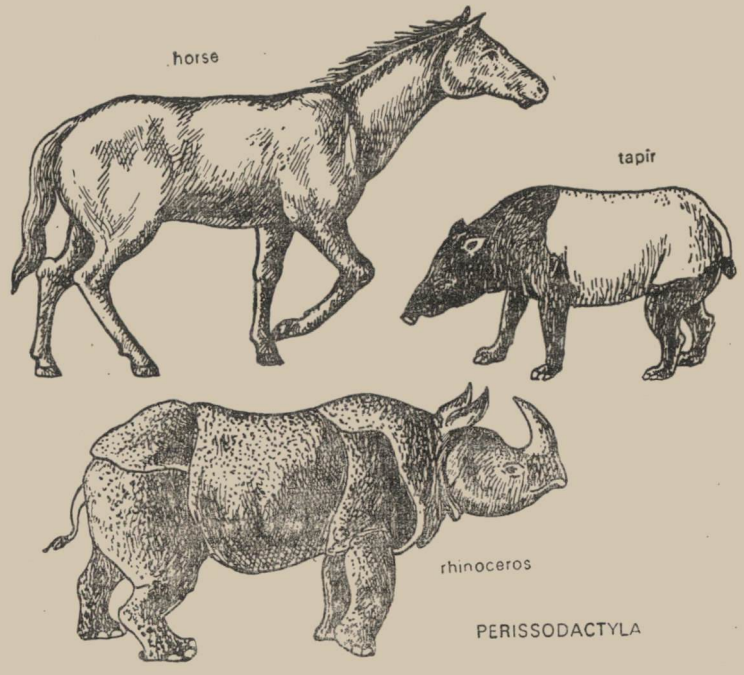


Fig. 17.25 A few examples of odd toed ungulates.

The Indian Rhinoceros (*Rhinoceros unicornis*) is a single horned species which may attain a length of fourteen feet and a height of nearly six feet. The horn may measure upto two feet. It is the largest rhino of Asia. Its skin is very thick. It has deep folds and is covered with granulations imitating scales. The colour of the skin is uniformly grey brown.

This rhinos is now confined to the plains of Assam, Nepal and Bhutan.

Cloven hoofed Ungulates (*Even toed*) :

This order includes cloven hooved or even toed herbivorous animals such as pigs, pecaries, hippopotamuses, camels, giraffes, sheep, oxen, deer, antelopes, etc.

Wild Pigs (*Family* : *Suidae*) :

Amongst the wild pigs, the principal and the best known species is the **wild boar** (*Sus scrofa*) which still ranges over a wide area, from Europe to Central Asia and from the Baltic to North Africa.

The **Indian Wild Boar** (*Sus scrofa cristatus*) is a sub-species found in India and Sri Lanka. Various breeds and varieties of domestic swine are derived from the wild boar.

Hippopotamus (*Family* : *Hippopotamidae*) :

The Hippopotamus has become more at home in water than on land. It is called the '*river horse*.' There is very little hair on the hippopotamuses. A few hairs are thinly scattered about all over the skin and the tails have a terminal tuft of bristles, stiff as wire. The hippopotamus is found throughout Africa, South of Sahara and lives by the rivers and lakes. They are entirely herbivorous. The period of gestation is eight months and only one young is born.

The Great African Hippopotamus (*Hippopotamus amphibius*) attains a length of five feet at the shoulder. The legs are however less than two feet long. The total weight may be about four tons. The skin is thickly lined with fat and is deeply folded at the neck and chest.

The hippopotamuses swim easily. Nostrils, ears and eyes are placed high on the head, so that the animals can respire and keep watch while the rest of the body is submerged. The nostrils have muscular valves which close them. The large upper lip completely seals the mouth when the animal is submerged. The feet end in four digits enclosed in round hooves. The canines are curved and stick up like tusks. They use them to pull up water plants. The great African hippopotamuses are almost confined to the big African rivers and the lakes. They live in small herds and spend most of the day dozing.

Camels and Llamas (*Sub-order* : *Tylopoda*) :

Camels and Llamas have only two functional toes on each foot. The legs are long and slender. Beneath the toes is a broad, callous and elastic pad. The hooves are under-developed and are more suggestive of nails. The feet are well adapted for walking on desert sands or for the ascent of slippery and dangerous paths. The upper lip is deeply cleft. The neck and head are both elongated. The camel is also called "*the ship of the desert*" because of the *rolling motion* when it walks. This swaying is caused by the fact that the camel moves the legs on one side one after the other, instead of the front leg of one side followed by the hind leg on the other side, as other four legged mammals do.

The Bactrian Camel (*Camelus bactrianus*) possesses two humps of fatty tissue, one over the shoulders and the other over hind quarters. The coat is thick, woolly and of a ruddy brown colour. There is a deep fringe of hair under the neck and the upper parts of the fore legs are shaggy. It attains a length of about six feet upto the shoulders. It is stronger and more heavily built than the Arabian camel. Its long shaggy hair also enables it to endure the colder climate through Central Asia, from China to Turkestan. It is the steed of the whole of Central Asia, and it also provides milk, meat and leather.

The **Arabian** or **One humped Camel** is often called the Dromedary (*Camelus dromedarius*). It has long slender legs well adapted for speed. It inhabits the hot, arid deserts of North Africa and the Near East. The hump containing fatty tissue can be used as a food reserve. It is taller than the Bactrian camel. It has woolly coat. Its colour is fawn or beige matching with the colour of the environment. Dromedary is well adapted for the life in the desert. The adaptations of desert life are, the broadened feet, eye lashes that protect the eyes from wind blown sand, nostrils that can be closed, the thickened lips to withstand the coarsest plants. They are further able to survive for long periods without water. *In India*, only the one humped species of the Arabian camel is found.

Llamas differ from camels in being much smaller and having no dorsal hump. The Guanaco or Huanaco (*Lama huanacos*) lives in herds on the plains and mountains of South America.

Ruminants *(Sub-order : Ruminantia) :*

The Ruminants are sometimes divided into two principal groups or Infra orders—the *Tragulina* (Chevrotains and their allies) and the *Pecora*, the true ruminants including deer, giraffes, cattle and sheep.

In *Tragulina*, there are four complete toes on each foot, but the second and fifth are slender e.g., **Indian Chevrotain** *(Tragulus meminna, mouse deer)*.

In *Pecora* or **true ruminants**, the third and the fourth digits are complete. The third and the fourth metacarpals and metatarsals are fused to form the '*Cannon bones*.'

Frontal bones are usually found in the form of paired outgrowths and are capped with horny sheaths to form the **horns**. The ruminants such as buffaloes, cattle, sheep, goats and antelopes are called *hollow horned ruminants*. In these there is a bony core over which the horn is laid down. The horns are nourished from the interior and continue to grow throughout the life. They are often present in both the sexes. The horns are valuable weapons in defence and offence.

Almost all deer possess **antlers** in the form of single or branched bony appendages. These are covered at first by a soft, hairy, deciduous skin called *velvet* which is responsible for laying down the bone. Later, this skin dries and falls away, the horn remaining hard and clean until it is shed in the following spring. The whole process, then begins again with more elaborate branches or tines. The shedding of the antlers is due to an organic growth at the base of each antler, causing in the constriction of all blood vessels carrying blood to the antlers. With the exception of reindeer *(Rangifer)* and Caribou, only males have the antlers.

The most important feature of the ruminants is the possession of a stomach consisting of four chambers helpful in the process of **rumination** or **chewing the cud**.

True ruminants are divided into the following families :

1. Cervidae : This family comprises the *Cervus*, Old World deer, *Rangifer* the reindeer, *Alces*, the elk or moose, *Capreolus*, the roe-deer; Hydropotes, the water deer, without antlers. Moschus,

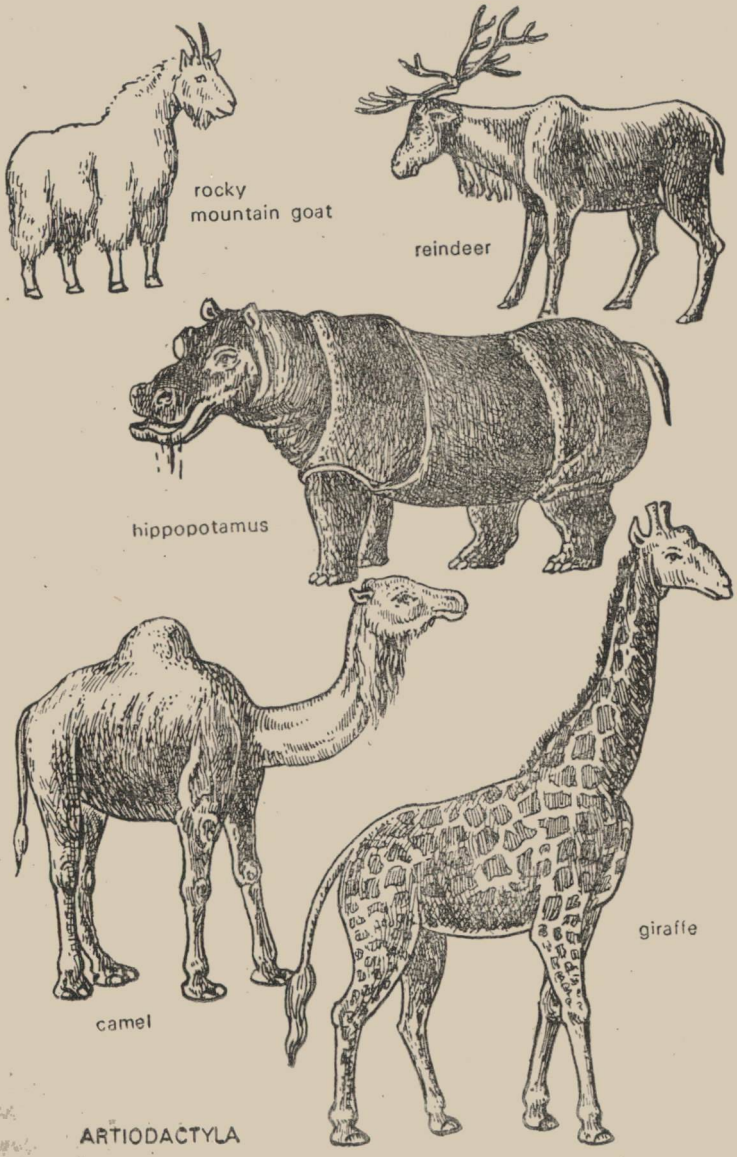


Fig. 17.26 A few examples of even toed (cloven hoofed) ungulates

the musk-deer is also without the antlers, and with long sharp upper canines and large musk glands in the males. The antlers if present are deciduous and are usually confined to the males. In Reindeer, they are possessed by both the sexes.

2. *Giraffidae* includes the Giraffe (*Giraffa camelopardalis*) which is a tall animal of Ethiopian region. It has elongated cervical vertebrae and long limbs. It is gregarious and feeds on leaves of trees. In both the sexes, there are on the fore head, short erect prominences over the union of parietals and frontals. There is a short mane along the back of the neck. The front legs are only slightly longer than the back ones. The males do not exceed eighteen feet and the females are some three feet shorter.

The **Okapi** (*Okapia sp.*) occuring in West African forests is unquestionably a cousin of the giraffe. It has a shorter neck and the horns are on the frontals. Only the males have horns. The stripes on the hind quarters contrast well with the rest of its hazel coat.

3. *Antilocapridae* is represented today solely by Prongbuck or Prong horn (*Antilocarpa americana*). It is a North American animal with most of the characteristics of Bovidae. The horny sheath bears one branch, and is periodically detached from the bony core.

4. *Bovidae*: It includes the hollow horned ruminants, widely distributed throughout the world, but without indigenous representatives in Australia, South or Central America. The horns are not deciduous and are found in both the sexes. The family includes *Bos indicus*, the Zebu, Brahman, or oriental domestic cattle, Bison or Buffalo (*Bison bison*), Musk-Ox (*Ovibus moschatus*), Big-horn or Rocky Mountain sheep (*Capra bex*), Black buck or Indian Antelope (*Antilope cervicapra*), Gazelle (*Litocranius sp.*) and the Impalla (*Aepyceros sp.*) which ranges from Kenya to South Africa.

Sea Living Mammals—Cetaceans:

The cetaceans are true aquatic mammals. They include the whales, dolphins and porpoises. All these are completely adapted for life in water. The body has a fish-like appearance and the forelimbs have become the *swimming paddles*. The hind-limbs are totally absent. There are no external ears and the hairs are present

only in the embryos. They have under the skin a thick layer of fat called the *blubber*. The blubber retains the warmth of the body. The whales and dolphins are mostly found in the cold seas. From very ancient times people have been catching the whales for flesh, bone and oil.

Whales: There are two main kinds of whales—the *baleen* or *whale bone whales* and the *toothed whales*. The baleen whale has hundreds of long, thin blades of a horny substance—called whale bone or *baleen* hanging from the roof of its mouth in two rows one on each side.

The whale bone completely fills the whale's mouth. These mammals feed on plankton that live near the surface of the ocean. The whale opens the mouth and takes in a great amount of sea water. Then the whale closes its jaws and shoves out the water through its lips with its tongue. The fringes of the whale bone serve as a strainer to hold in the plankton while the water is forced out. *Whales eat a ton of plankton a day.* Whales when they return to the surface of water are usually seen *blowing out the air* from the nostrils. The blown out air is called the "**spout,**" which may be some times 20 ft. high. In the outside air is cool, the *spout* condenses to form a visible water vapour.

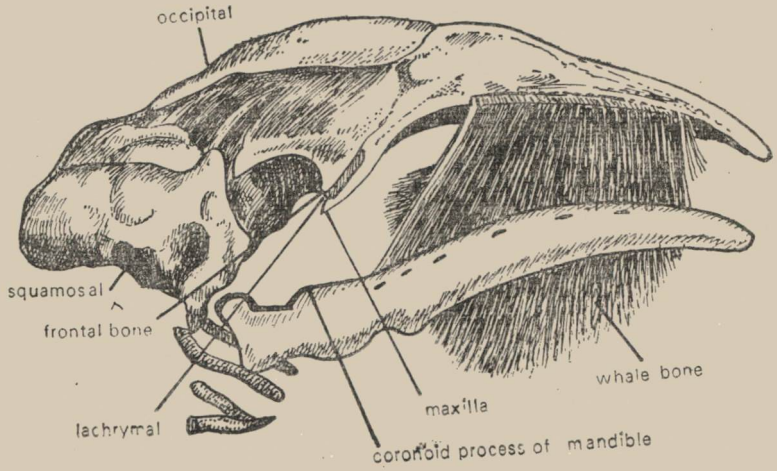


Fig. 17.28 Baleen or Whale bone

The toothed whales have cone shaped teeth with which they catch and hold fish, squids, shell fish, seals, other whales and sea birds.

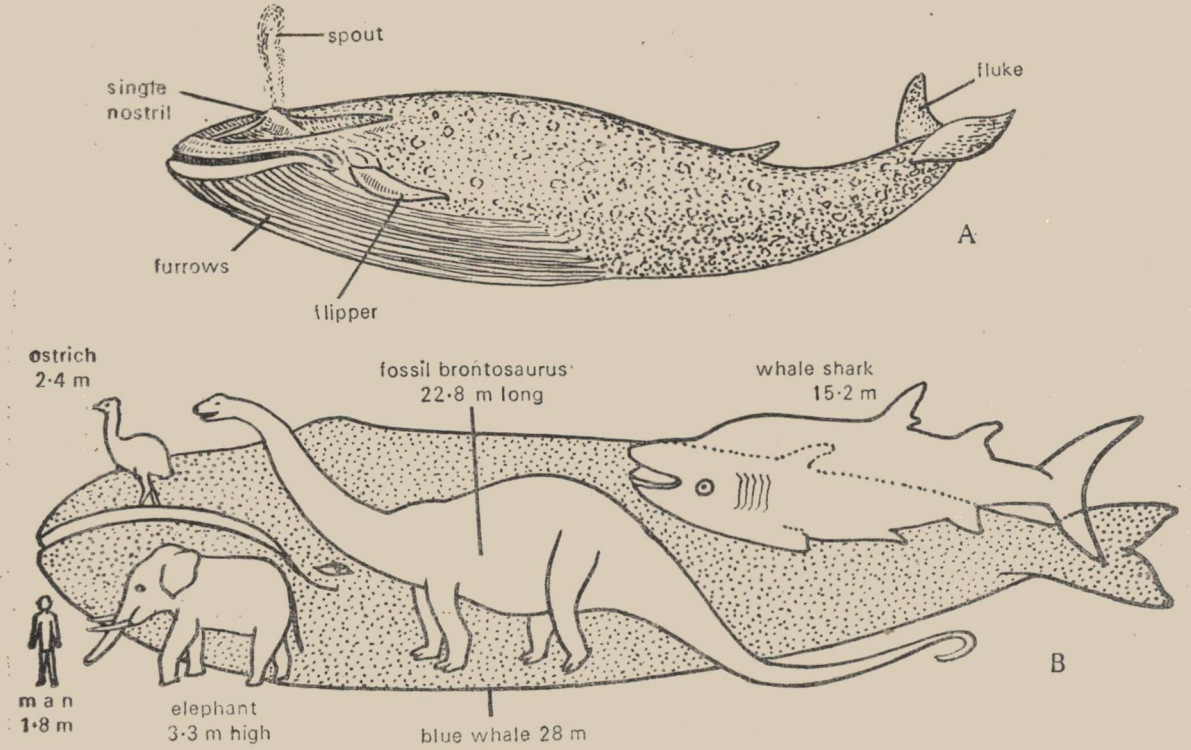


Fig. 17.28 (A) The Blue Whale, Rorqual or Sibbald's Whale *(Balaenoptera musculus)*. **Largest animal attaining a length of 109 feet and weighs 119 tons. Slate blue in colour. Baleen plates in mouth jet black. Dorsal fin small. It has been taken from Iceland, Alaska, Japan, Mexico, Chile, California and South Africa but now mostly from the Antractic. Migrates annually north and south. Food almost exclusively shrimp-like animals which whaler's call 'Krill.'**
(B) The sizes of various animals in comparison to the blue whale.

The Blue Whale or Rorqual or Sibbald's Whale *(Balaenoptera musculus)* is the largest whale attaining a length of ninety to hundred feet and may weigh about 120 tons. It is the largest animal in the world. It has a deeply furrowed throat. It swims about 25 miles an hour. The blue whale is also called '*Sulphur bottom*' because of the yellowish ventral colouration imparted by an adherent diatom population. The blue whales are almost world wide in distribution but they do not occupy all the area at every season.

The **Sperm Whale** *(Physeter catodon)* is a toothed whale. It's lower jaw contains a row of pointed teeth, about eight inches long and over six pounds in weight. Sperm whales have no real dorsal fin but a series of low humps on the rear third of the body. They inhabit temperate and tropical waters from about 40° N to 40° S. The sperm whale is also the source of *ambergris*, a light weight material offensive in odour. It was formerly used in Europe in pharmaceutical preparations, and still used in the Orient in cooking. When used in minute quantities it adds to the pervasive and absorptive qualities of toilet, washes and perfumes. This substance is often said to be formed as a biliary concretion in sick whales. Its exact formation is still in doubt. This substance is considered to arise from intestinal irritation by the horny beaks of the squid (the principal food of the sperm whale).

Porpoises: The Common Porpoise (*Phocaena phocaena*) is the cetacean of European waters measuring only five to six feet and never weighing more than a hundredweight. The head is beakless. It is black above, with white shade below and has a low triangular dorsal fin, slightly behind the middle of the body. The flippers are not large. They are oval and blunt at ends. It is however an excellent swimmer. It has 100 spade shaped teeth. It is widely distributed over the North Atlantic, English Channel, North Sea and the Baltic. It is regarded as edible in some northern countries.

Dolphin: The Common Dolphin *(Delphinus delphis)* has a pronounced beak separated from the snout by a groove. It is dark blue above, white below, with wavy lines down each side, and a dark line from the eye to the corner of the long and pointed beak. It measures about eight feet and has 100 teeth.

River Dolphins: River Dolphins are old forms of cetaceans that have survived owing to their adaptation to a fresh water existence. They are kept in a separate family *Platamistidae*. The river dolphins vary in length from five to ten feet. All have a long, almost bird like beak, but furnished with teeth. The **Gangetic dolphin** (*Platanista gangetica*) inhabits the Brahmaputra, Indus and the Ganges. It is quite blind, the eyes are in the form of mere vestiges.

The Primates (*Order* : *Primates*) :

The **Primates** is the order of mammals to which man also belongs. The two exceptional features of primates are, a *voluminous highly evolved brain and a supple hand with opposable thumb i.e., the thumb is somewhat free from the rest of the fingers and can be opposed to them in order to hold and manipulate things with ease.* The feet of primates excluding only the man, are also of a grasping type. The primates were originally *arboreal* and for the most part they are still so. Their return to a terrestrial habitat is a secondary or rare feature.

Lemurs (*Family* : *Lemuridae*) :

True Lemurs exist in Madagascar only. They share a number of generalised characters with the Tupaiidae (Tree Shrews), insectivores with whom they seem to have a common origin. The tree **shrews** (Tupaiidae) *in fact may more appropriately be placed among the primitive primates rather than the insectivores.*

The lemurs are easily distinguished from true monkeys by their fox-like muzzles, which are covered with hair like the rest of the body. They have a large and inexpressive eyes. Arms are much longer than their legs. The fur is soft and woolly. They are usually nocturnal in habits. Physically they are excellently adapted to arboreal existence. The thumb and great toes are opposable to the other digits and are of unusual size. The lemurs also differ from monkeys and apes in having a bicorned uterus, a diffused placenta and in many species, additional teats placed abdominally.

Ring tailed Lemur (*Lemur catta*) is greyish with dark rings round the eyes and a long ringed tail. It is four feet long. It is kept as a domestic animal in Madagascar and Mauritius. It eats

fruits. It lives on rocky plains in wild state. It loves basking in the sun. It gives birth to only one offspring at a time after a gestation of two months.

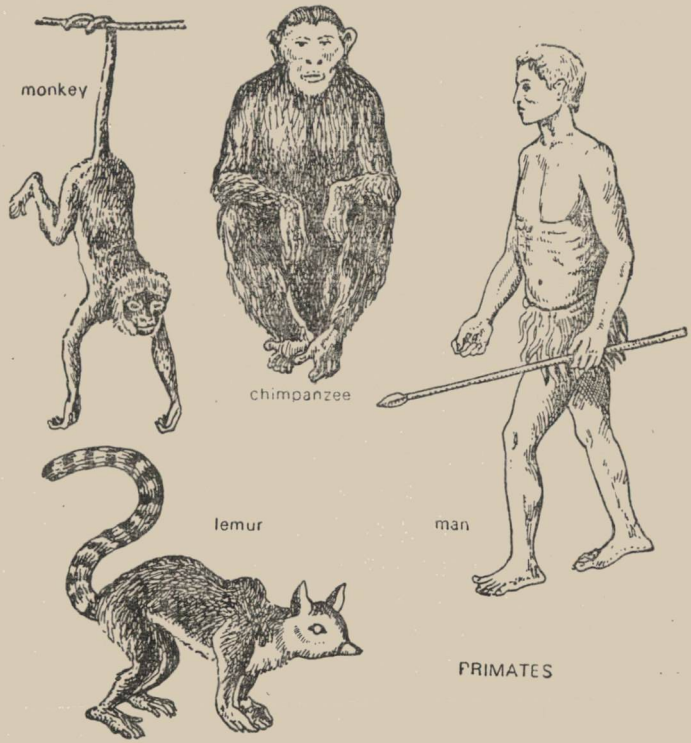


Fig. 17.29 Monkey, Lemur, Chimpanzee and Man.

Monkeys and Apes *(Sub-order : Anthropoidea=Simiae) :*

Monkeys, apes and man are included in the sub-order *Anthropoidea.* The anthropoids are frugivorous primates, with flattened bare faces, small eyes and with orbits completely closed laterally. The digits always end in nails. The teats are exclusively pectoral. They are diurnal in habits.

Monkeys possess tails, whereas apes do not. All the four-limbs of monkeys have roughly the same length. In the case of apes, the fore-legs are much longer than the hind-legs. Monkeys

always walk on all fours, although apes often walk in an upright position.

The Super order Anthropoidea is divided into the super families, *Ceboidea (Platyrrhina)* (**New World Monkeys**), *Cercopithecoidea* (**Old World monkeys**) *and Hominoidea* (Apes and men).

The New World Monkeys *(Ceboidea, Platyrrhina)* **:**

The Ceboidea includes *'flat nosed monkeys'* with widely separated nostrils and a broad septum. They are hence called *platyrrhines.* They are more primitive than the Old World monkeys. The tail in platyrrhines is almost always primitively long and is sometimes prehensile. The thumb is relatively unopposable and usually atrophied. There are three premolars which are retained. The tympanic bone is not more than a ring. There is no bony external auditory meatus. They lack cheek pouches.

Howling Monkeys (*Alouatta*) (*Family* : *Cebidae*):

The howler monkeys have developed a large ossified laryngeal chamber which acts as a resonator. They are the largest and the noisiest of the New World monkeys. They usually *howl* just after sun set and before sun rise as well as at the approach of rain. They are bearded and have prehensile tails, longer than the body, e.g , *Black Howling monkey* (*Alouatta caraya*) and the *Red Howling monkey* (*Alouatta semiculus*).

The Spider Monkey (*Ateles*) :

The spider monkeys are slim with long limbs. The arms are longer than the legs. They possess a very long strongly prehensile tail. The generic name *Ateles* means *'imperfect'* and refers to the absence of thumbs. Even with only four fingers, all working in the same direction, they are wonderful climbers comparable only in this respect to the gibbons. Like the gibbons, they jump from branch to branch swinging from hands and feet. The digits of the hand and feet are more or less permanently bent. The tail almost serves as a fifth hand with the help of which they hold on to the branches. When they hang by their tails with all the limbs free they resemble the *spiders*.

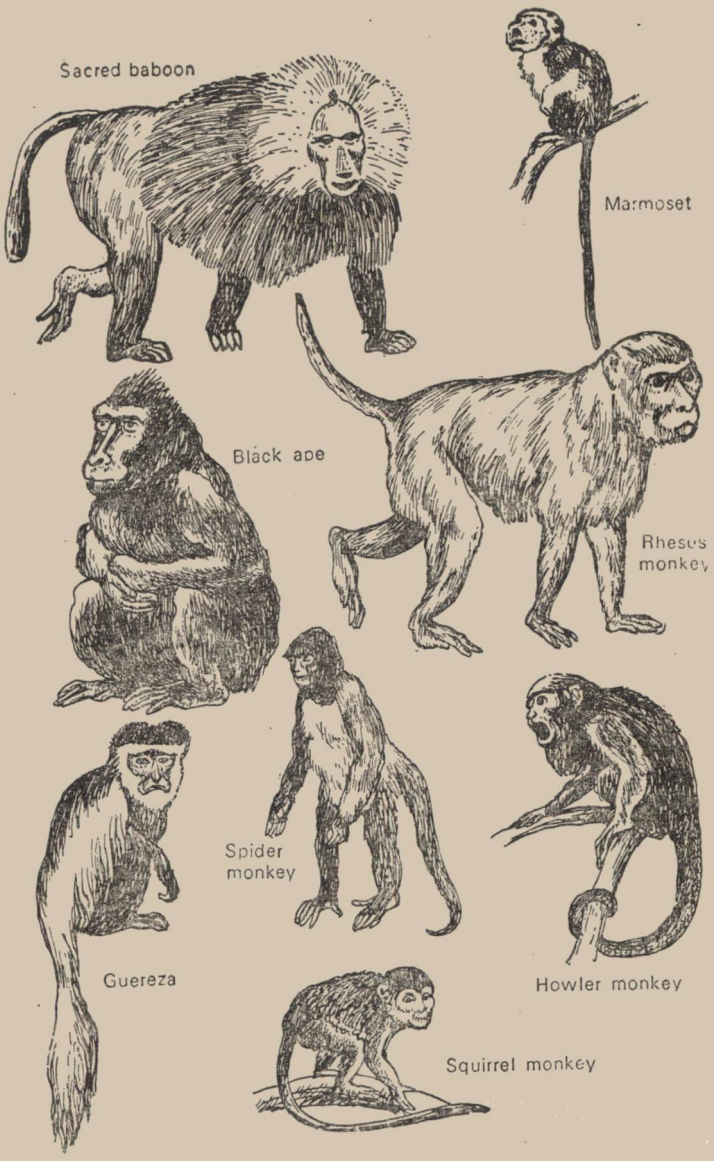


Fig. 17.30 A few of the Old World monkeys

Several species of Spider monkeys e. g., *Black faced Spider monkey* (*Ateles ater*) and *Long haired spider monkey* (*Ateles belzebuth*) live in Brazil, Ecuador and Peru.

Marmosets (*Family* : *Callithricidae*) :

Family Callithricidae has preserved more primitive features than the Cebidae such as the presence of claws on most of the fingers and a non-prehensile tail etc.

The Common Marmoset *(Callithrix jacchus)* is about nine inches long with a bushy tail over one foot long. The fur is soft. Each hair is black at the base, yellow in the middle and white at the tip. The general colouration impression is a greenish yellow, set off by white ear tufts. It inhabits the mouth of Amazon, and eats fruits and insects.

The Old World Monkeys *(Super-Family : Cercopithecoidea)* :

The Old World monkeys (*Catarrhina*) are *narrow nosed creatures with close set nostrils* and *narrow internarial septum.* The nostrils are directed downwards. There are two premolars and a long tubular bony auditory meatus. The thumb is opposable. The cheek pouches are present except in Guerezas and Langurs.

The Guereza *(Colobus abyssinicus)* :

This beautiful monkey is black with white round face and long white hairs on flanks and tail. *Colobus* monkeys are the natives of Africa. The thumb is extremely reduced. They have a long silky fur, hanging down their sides like a sumptuous garment. The tail ends in a beautiful, long tuft. They have been much hunted for their fur.

The Rhesus monkey (*Macaca mulata*) is widespread in Northern India and South East Asia. The long haired coat is greyish in colour. There are red *ischial callosities.* It is gregarious and very agile. It is intelligent and curious. It soon learns to manipulate simple tools and distinguish colours and shapes. Wild macaques move in '*troops*' and are as much at home on the ground as on the trees. Breeding occurs at any time of the year.

Cynopithecus niger is the so called *Black ape* of Celebes. It has a crest of stiff hairs on the top of its head which can be erected at will. *Although known as an ape, this animal is, in fact a monkey.* It is a shy gentle creature. It lives in coastal mangrove forests, feeding upon fruit, leaves and sea foods.

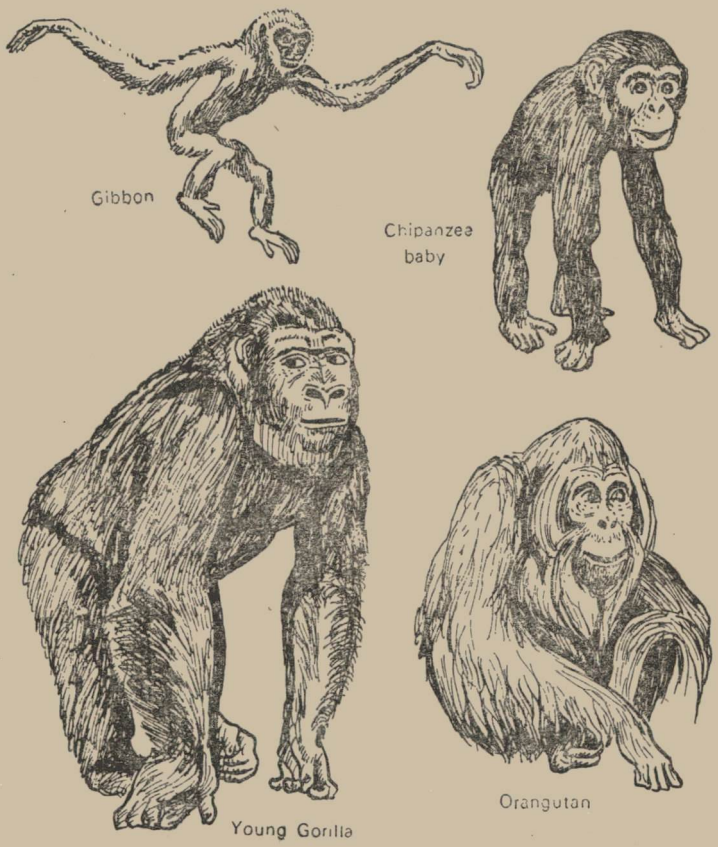


Fig. 17.31 Gibbon, Chimpanzee, Gorilla and Orangutan

Baboons : These Old World monkeys are confined to Africa, except for one species of Baboon. The **Sacred Baboon** *(Popio hamadryas)* is found in Somaliland and on both the sides of the Red Sea and lives gregariously on mountainous regions. The males are pale-silver with a flowing mantle-like mane, the females are smaller

and browner. The ischial callosities are bright red. They live in troops headed by a powerful male.

Langurs: Langurs live in the forests of Borneo, Java, Sumatra, Sri Lanka, India and Tibet, where they may be found at altitudes upto 13,000 feet. They live in troops. Langurs are very slim monkeys somewhat resembling the spider monkeys but without a prehensile tail.

The Entellus Monkey or **Hanuman** (*Presbytis entellus*) is a large monkey with a silver haired body, black face, ears, hands and soles of the feet. The face is fringed by grey white whiskers. The **Entellus monkey** is sacred to the **Hindus**. The Himalayan Langur (*Presbytis entellus schistaceus*) is the race of the Hanuman which lives at altitudes of 6,000 feet.

Super-family Hominoidea:

The extinct apes and man are now separated from the other narrow-nosed (Catarrhine) anthoropoids (i. e., super family Cercopithecoidea) and are included in a separate *Super family Hominoidea*. They differ from Cercopithecoidea in many respects. The tail has disappeared. The thorax is broad, with a flattened ventral surface. The sternum has become short and wide. There are no ischial callosities except in gibbons and the cheek pouches are also absent. The hair on the fore-arm points towards the elbow instead of towards the wrist. Two families included under this super family are (i) Pongidae and (ii) Hominidae.

Family Pongidae:

Pongidae includes the anthropoid apes. **Gorilla** and the **Chimpanzee** (*Pan*), are found in the forests of Africa. **Gibbons** (*Hylobates*) occur in Southern China and Indo-Malaya. **Orangutan** (*Pongo*) inhabits East Indies, West of Wallace's line. Apes are specialised in the elongation of the fore-limbs, which specially in the gibbons, are used in swinging from branch to branch (*brachiation*). Gibbons can walk in an upright position using the fore-limbs as balancing rods but all other apes use their long fore arms as crutches to help swing the trunk over the ground.

Gorilla :

Gorillas (*Gorilla gorilla*) are found in the thick forests of West and Central Africa. It is the largest of the ape family. The adult male grows to about six feet tall. They may weigh upto 600 lbs. The face is hairless and wrinkled which gives them a rather gloomy expression. The chest and shoulders are huge with comparatively short legs. With the exception of face and chest, the rest of the body of gorilla is covered with black hair, which tends to go grey with old age. Gorillas live in family groups (10 to 15 animals) and are supposed to be extremely loyal to each other. An old male dominates the family and is probably *polygamous*. Although tremendously strong they are not aggressive by nature. They spend most of their life on the ground and walk on all fours. They nodoubt build nests in the trees, but these are usually occupied by the females and babies, while the male sleeps on the ground to protect his family. Gorillas do a great damage to the African banana plantations, and many are consequently shot. They prefer a mixed diet which includes fruit and foliage seeds. The life span of gorillas is 30–50 years and the period of gestation is 250 days.

Chimpanzees (*Pan satyrus*) is the only one species of Chimpanzees which lives in the forests of Central and West Africa. They can even come to the ground and walk on all fours.

The chimpanzee is the most intelligent of the ape family. It is generally considered to be the most intelligent animal next to man. An adult male may reach a height of 5½ feet and weigh as much as 15 lbs. The females are slightly smaller. The hair of chimpanzee may either be black or brown, and may be long and thick or short and thin. The skin colour also is variable. It may be black, brown, yellow or pink.

Chimpanzees live in family groups and are very sociable creatures. A single male is the head of a *harem* of several females. The male protects and guards the females. They groom each other. They are playful and easy to tame. In captivity the chimpanzee can become bad tempered and unpredictable. At the age of six, the chimpanzees reach full maturity and can become very strong and dangerous.

A lot of research is being done to test the intelligence of chimpanzees. The investigations have revealed that a wild chimpanzee can make and use crude tools for capturing and eating such creatures as ants.

The chimpanzees are basically vegetarians. Their diet consists of leaves, shoots and roots. They may even eat bird's eggs and small mammals.

Pan paniscus, **Bonobo** is the rare pygmy species of chimpanzee which occurs in the south of Congo. It is regarded by some as a distinct species.

The life span of a chimpanzee is 30–40 years and the period of gestation is 8 months.

Gibbons :

Gibbons are the smallest and most active members of the ape family. They are also the least intelligent. They differ from other anthropoids in having much longer arms. They are the only apes to possess *ischial callosities*. Gibbons are found in Burma, Thailand, Indo-China, Malaya, Sumatra, Java and Borneo. The genus *Hyalobatus* includes *Hylobates hoolock* the **Hoolock Gibbon,** the **Lar Gibbon** (*Hylobates lar*) and the **Black Gibbon** (*Hylobates concolor*). The first two are about three feet in height and weigh above fifteen pounds.

Gibbons are slender, swift moving animals, living almost entirely on the trees. They are the only apes which can normally stand and walk upright when they are on the ground. They are incapable of swimming and afraid of water. They are quite noisy, chanting in chorus from morning till night. The species *Hylobates hoolock* is called Hoolock after the sounds they make.

The gibbons are frugivorous and herbivorous. They also eat occasionally insects, bird's eggs and small vertebrates.

The life span of Gibbons is 10–20 years and the period of gestation is 7 months.

Orangutans :

There is only one species *Pongo pygmaeus* strictly restricted to the low lying forests of Sumatra and Borneo. The word Orangutan is Malayan for '*Old man of the woods.*' The facial resemblance to man is marked. It is the only anthropoid whose head has developed upwards, producing a high arched fore-head. It possesses like man twelve thoracic vertebrae and twelve pairs of ribs.

The arms of orangutan are longer than those of the gorillas and chimpanzees. The legs are shorter and the canines more fang-like. With the exception of face, palms and hands, the orangutan is covered with long, red coloured hair. An adult male may be 5½ ft. tall and weighs upto 210 lbs. The male possesses a huge laryngeal cavity forming a sort of goitre which hangs down over the chest. There are two fatty cheek swellings.

Orangutans almost entirely live on trees. At night they build nests in the trees but during the day time they search for food which consists of fruit, grains, leaves, insects and eggs.

Orangutan's life span is 30 years and the period of gestation is 230 days.

Family Hominidae :

The family Hominidae includes only two genera, the extinct *Pithecanthropus* (= *Sianathropus*) including the *Java* and *Pekin men* and the Genus *Homo* which was first indentified in the Pleistocene, including two species *Homo neanderthalensis* and *Homo sapiens.*

The only surviving species is *Homo sapiens* which embraces all the known races of men—**Australoids, Negroids, Caucasoids** and the **Mongoloids.**

Revision questions

1. Describe the general characters of mammals.
2. What are egg laying mammals? Give in brief the primitive and specialised features of the egg laying mammals.

or

Write a brief note on (i) Platypus *(Ornithorhynchus)* and (ii) Echidna *(Tachyglossus).*

3. Describe the general characters of marsupials and their distribution.

4. Write notes on the following :
   (a) Kangaroo
   (b) Marsupial mole
   (c) Common or Virginian opossum.

5. Give the diagnostic characters of the Eutherian or Placental mammals.

6. Write what you know about :
   (a) *Erinaceus*, Hedgehog
   (b) The European Common Mole *(Talpa europea)*
   (c) Armadillo
   (d) Pangolin
   (e) Baleen or whale bone.

7. Write what you know about the group *Platyrrhina* and Apes.

PART III

Heredity

Evolution

&

General Concepts of Ecology

CHAPTER XVIII

Heredity—Principles of Mendelian Inheritance

For many centuries man was aware of the fact that '*like begets like.*' Human babies are always cast in the human mold and often resemble in particular ways their parents and siblings. Puppies always grow to be dogs and usually have the body, shape, size, colour and other characteristics of their breed. This tendency of individuals who resemble their parents or progenitors is called **Heredity.** Heredity thus is an organic (genetic) relation between successive generations. All forms of life has a capacity for reproduction and in viruses as well as men, this capacity leads to the transfer of hereditary characteristics from one generation to the next.

Resemblences between the parents and the offspring are no doubt close but are usually not exact. Thus, '*Like produces like but no two individuals are ever exactly alike.*" The offspring of a particular parent differ from each other and from their parents in many respects and to different degrees. Such differences are called **variations.**

Like heredity, variations are also characteristic of living things. Some variations are inherited i.e , they can be transmitted from the parents to their progeny and from the progenies to their succeeding generations.

The branch of life science concerned with these phenomena of heredity and variation and the study of laws governing similarities and differences between individuals related by descent is called **Genetics.**

Mendel's Principles of Heredity :

Gregor Mendel, an Austrian Abbot was for the first time able to know the exact mechanism of heredity on the basis of his experiments on the transmission of certain characteristics in the Garden

Pea plant. Mendel was successful due to the fact that he studied the inheritance of a single pair of contrasting characteristics. His theory about the mechanism of inheritance is also referred to as the *Particulate inheritance* or *Factor hypothesis*. According to this, Mendel concluded that inheritance is governed by separate *germinal units* or *particulates* which he called *factors*. The appearance of characteristics in the progeny depends on the transmission of character bearing *germinal units* or *factors* from the parents. Mendel's germinal units or factors in the light of present knowledge corresponds to the *genes*. The conclusions arrived at by Mendel are now referred to as *Mendel's law's of inheritance* or *Mendelism*.

Gregor Mendel (1822–1884), was a monk in the Augustinian monastery of Brün, Austria, now Brno (Zechoslovakia). He became a priest in 1847 and in 1851 was sent by his order to study natural sciences at the University in Vienna.



Fig 18.1 Gregor Mendel the founder of Genetics

Mendel taught natural sciences in the monastery school and as such became interested in the problems of heredity.

In 1857, Mendel began to collect many varieties of the Garden Pea (*Pisum sativum*). After seven years of experimental work in the monastery gardens he presented the results of his experiments together with the generalizations we now know as *Mendel's law's of inheritance*. He presented his results at two meetings of the Natural History Society of Brün in the spring of 1865. The results and the theories were published in the annual proceedings of the society in 1866. The importance of his findings were however not appreciated by other biologists of his time. His findings thus were neglected until 1900.

In 1900, when details of mitosis, meiosis and fertilization were known—three different investigators rediscovered the findings

which had been described by Mendel. The scientists who independently arrived at Mendel's conclusions were *de Vires* in Holland, *Correns* in Germany and *Von Tschermak* in Austria. These scientists while searching through the literature found Mendel's paper already published in 1866. The credit goes to these investigators who named their findings after Mendel.

Mendel's work thus got its recognition 16 years after his death or 34 years after his discovery in 1866. Two of the fundamental laws of inheritance i. e., the *law of segregation* and the *law of independent assortment* were named after Mendel, as *Mendel's laws of inheritance.*

Mendel in his experiments selected the garden pea plant on account of certain advantages which are as follows.

1. The garden pea plants can be self pollinated.
2. The plant can be grown easily in the kitchen gardens even.
3. There is constancy of characters in the pea plant.
4. The hybrids obtained by crosses between the pure strains are also fertile.
5. The pea plants are annuals—hence can be reproduced rapidly.

Mendel selected in the garden pea plant *seven contrasting characteristics of seven different traits.*

Traits	Contrasting characteristics
1. Form of the ripe seed.	Round or wrinkled.
2. The colour of the peas.	Yellow or bright green.
3. The colour of the seed coats.	Grey or white.

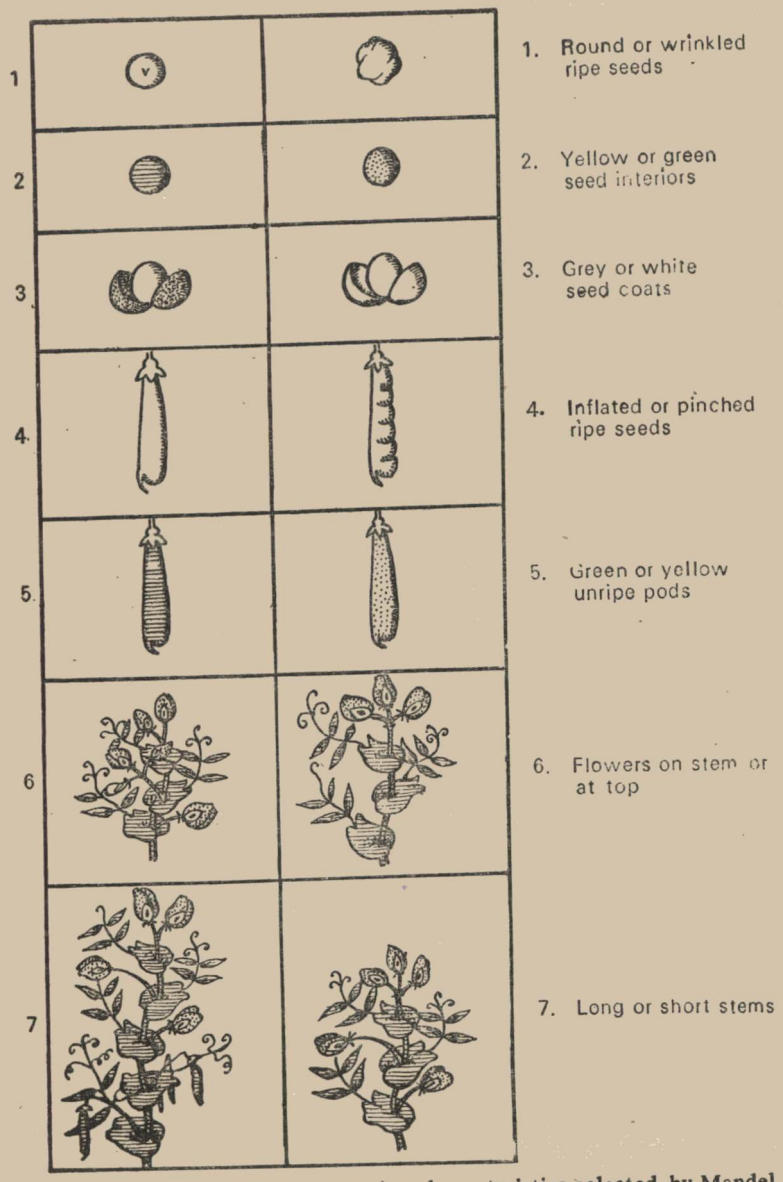


Fig 18.2 Seven pairs of contrasting characteristics selected by Mendel in his experiments on Garden pea plant *(Pisum sativum)*

Traits	Contrasting characteristics
4. The form of the ripe pods.	Inflated or pinched between the seeds.
5. The colour of the unripe pods.	Green or vivid yellow.
6. The positions of the flowers.	Distributed along the stem or bunched at the top.
7. The length of the stem.	Long (6 to 7 feet) or short (9 to 18 inches)

Mendel in his experiments avoided the complexities that had troubled the earlier investigators by simplifying the problem as far as possible. The early investigators made observations upon the plant or animal as a whole, studying at once all the traits and structures in which the hybrids differed from the parents and from each other.

Mendel confined his attention to a single character at a time—flower colour for example. When the behaviour of each single trait was established, he then studied two traits together, such as flower colour and height of the plant.

Mendel's procedure was to cross two pure strains of plants differing in a pair of contrasted characters. He then observed the characters of the first hybrid or (F_1) *filial generation.* He then crossed the first hybrid plants together or allowed them to effect self fertilization and raised a second generation of hybrid plants called *the second hybrid generation* or *a second filial* (F_2) *generation.*

Mendel maintained a regular record of the crossess made between pure strains, their F_1 progeny as well as crosses between F_1 plants and their F_2 progeny.

His results in crosses involving seven pairs of alternative characters are given in a tabular form. In F_1 as is indicated from the chart out of a contrasting pair of characters only one character

appears and is referred to as *dominant character.* The character which does not make its appearance is called a *recessive character.* When F_1 were mutually crossed, then in the plants of F_2 generation dominant and recessive characters both appeared in the ratio of 75% dominant and 25% recessives or in 3 : 1 ratio

TABLE

The synopsis of the data obtained by Mendel, as a result of crossess involving seven pairs of contrasting characters

Characters	F_1 Dominant	F_2 Number of Plants			F_2 Percent		
		Dominant	Recessive	Total	Dominant	Recessive	Ratio
1. Seeds, round × wrinkled.	All round	5474	1850	7324	74·74	25·26	3 : 1
2. Seeds, yellow ×green.	All yellow	6022	2001	3023	75·06	24·94	3 : 1
3. Flowers, red ×white.	All red	705	224	929	75·90	24·10	3 : 1
4. Flowers axial, ×terminal.	All axial	651	207	858	75·87	24·13	3 : 1
5. Pods, inflated ×constricted.	All inflated	882	299	1181	74·68	25·32	3 : 1
6. Pods, green ×yellow.	All green	428	152	580	73·79	26·21	3 : 1
7. Stem, tall ×short.	All tall	787	277	1064	73·96	26·04	3 : 1
Total		14,949	5010	19,959	74·90	25·10	3 : 1

The character which appears in the F_1 generation is dominant and the recessive character is one that reappears in smaller numbers in F_2.

Mendel's Experiments:

1. **Monohybrid inheritance:** Mendel's success in his experiments may be attributed to his good judgment in making crosses in the first instance between parents that differed in a single pair of constrasting characteristics of a particular trait. He took into consideration, for example, the height as a particular trait and observed how the alternative characteristics of this trait i.e., *tallness* and *dwarfness* in a pea plant are inherited.

The flowers of a tall strain of peas were fertilized with their own pollen; the resulting offsprings were all tall. When a dwarf variety was selfed (or self-fertilized) it produced only dwarfs.

Mendel observed that, weather, soil and conditions of moisture nodoubt affect the growth characteristics of the peas, but heredity was the main limiting factor under the conditions of his experiments.

In a given environment tall plants were 6 to 7 feet high while the dwarfs measured from 9 to 18 inches. On selfing, no true talls turn into dwarfs and no true dwarfs become talls. Now Mendel raised separately, the pure strains of tall and dwarf plants of the garden peas, *Pisum sativum*. These were referred to as **pure parental strains** indicated by the symbol *P*.

Mendel now crossed tall and dwarf parental strains of the garden peas. All of the offsprings obtained were *tall*. The offsprings of the cross between parental strains are called the **first filial generation** represented by the symbol F_1 (*Filial* from Latin meaning progeny). F_1 **plants** thus were all **tall**. The dwarf trait had disappeared in the F_1. The tall progeny of F_1 obtained by the cross between pure parental strains of plants is called the **hybrid.** In the above example, the F_1 progeny is referred to as a **monohybrid cross. Monohybrid cross** is thus a cross between parents differing in only one trait e. g., tall or dwarf or in which only one trait is being considered. The process of forming monohybrids is called *monohybridization*.

In the F_1 generation, out of two alternative characters i. e., tallness and dwarfness only one characteristic i.e., tallness appeared, the dwarfness on the other hand disappeared. The character that appeared in the F_1 was said to be a **dominant** characteristic and that which did not appear was called **recessive.**

The next step in Mendel's experiment was that tall hybrid plants of F_1 were fertilised by their own pollen (selfed) and their progeny referred to as second filial generation was obtained. In the F_2 generation, the missing trait (i.e., dwarfness) appeared again. Some progeny were tall and some were dwarfs. A number of plants of the first hybrids were selfed. From a total of 1064 F_2 'Grand Children' from the original (P) plants, 787 were tall and 277 were dwarfs. On the basis of these figures the ratio between the tall and dwarf plants in the F_2 generation was about 3 : 1 i. e., 3 talls and 1 dwarf. *This cross, as stated earlier in which the inheritance of the alternative characteristics of only one trait is considered is referred to as mono-hybrid cross.*

The experiments performed by Mendel on the inheritance of a single pair of characteristics can be explained on cytological basis.

The parental pure strains of plants are indicated for the sake of understanding by the letter (P). As for Mendel's conclusions every characteristic of the pea plant must be determined, or controlled, by a pair of **factors** or **genes** (as we call them today) located on the chromosomes. If we refer the genes, determining the charateristic of tallness by the capital letter T, then the tall plants will have a pair of genes **TT** on their chromosomes which determine the characteristic of tallness. The two letters TT for tallness are used as we have already learnt that the adult develops from a zygote having a diploid ($2n$) number of chromosomes. The zygote (being a product of fusion between the male and the female gametes), receives as such each T in this case from each gamete. The genetic constitution of a zygote as such would be TT. To indicate the character bearing units for dwarfness the same letters are used but the convention is to use small letters for all recessive characteristics

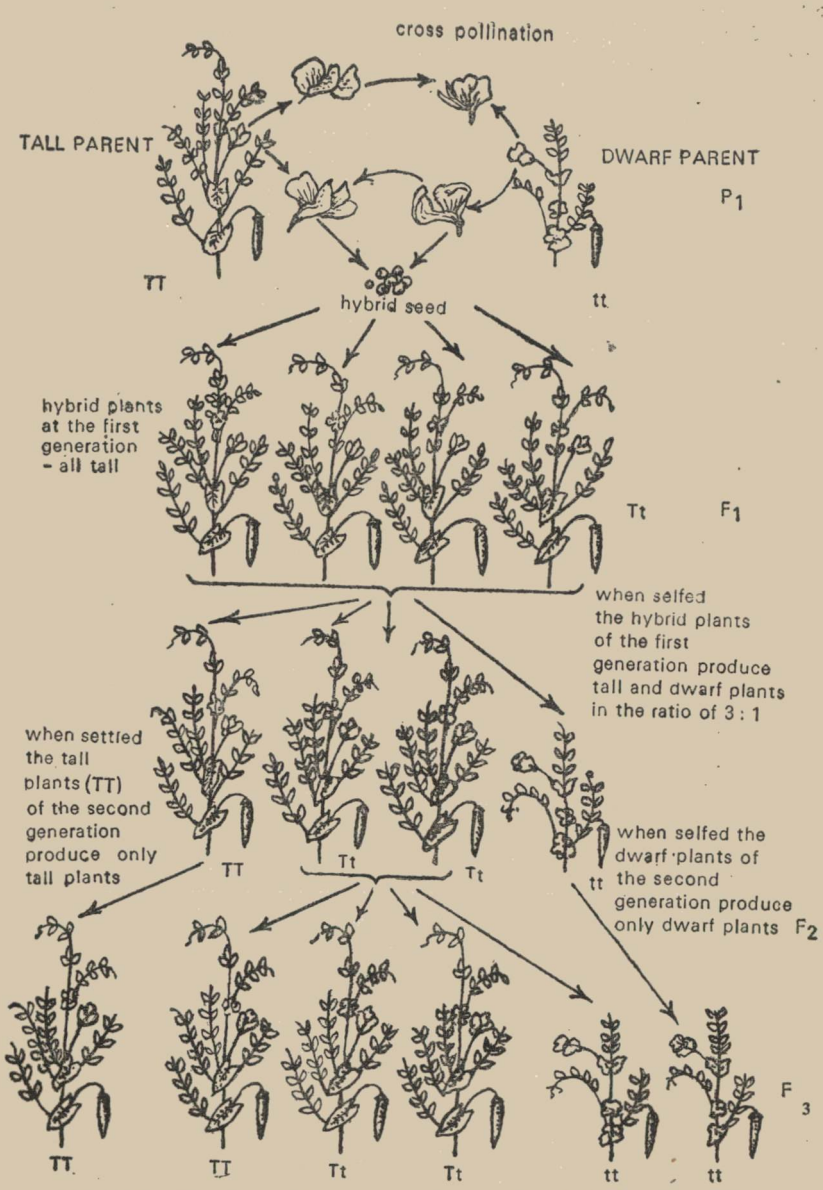


Fig 18.3 Diagrammatic representation of Mendel's experiments on monohybrid inheritance by crossing tall pea plants with dwarfs. The F_2 and F_3 progeny is also shown diagrammatically.

which apparently disappear in the F_1 generation. As the characteristics of dwarfness disappear in F_1, the dwarfness determining units of a dwarf plant will as such be represented by the small letters (tt).

When the tall plants (*TT*) as well as dwarf ones (*tt*) form their gametes, meiosis will take place. Each gamete of these parents will have a haploid number of chromosomes. In this case each gamete of a tall plant will receive a single capital *T* and that of a dwarf plant a single small *t*. When tall and dwarf plants of the parental strains are crossed, then the *T* gamete of tall plant will fuse with the *t* gamete of dwarf plant. The F_1 hybrid consequently will have the genetic constitution of Tt. Since the gene, determining tallness is dominant, the F_1 plants all appear to be tall although they have in them the gene *t* for dwarfness in a recessive form. The gene for dwarfness i.e., *t*, was neither lost nor mixed in the F_1 plant but was only unable to express itself in the presence of the factor for tallness. In other words, in the F_1, the factor or gene for tallness masked, or dominated over the factor for dwarfness.

The F_1 tall plant, possesses thus a dominant gene *T* and a recessive gene *t* This is called a hybrid plant. *We can thus define the term hybrid to be an organism (plant or animal) in which a dominant factor or gene is paired with a recessive factor or gene. The hybrid thus has a genetic combination of dissimilar genes representing alternative characters of a particular trait. e.g., (Tt) of F_1 generation.* A plant or animal in which both the factors or genes are similar, i.e., either dominant or recessive is known as *pure*, such as parental pea plants tall (*TT*) and dwarf (*tt*) selected here for the experiment.

The pair of genes representing alternative characteristics of a particular trait are called the **alleles** or the **allelomorphs** (From the Greek word meaning one form or the other). All alternative forms of a gene found at one locus are called alleles but any one chromosome bears only one allele for a given locus i. e.. *each member of an allele occurs at an identical locus in homologous chromosomes. Tt* are the alleles in the example described.

The zygote or the individual organisms (plants or animals) carrying like genes of a particular trait are called **homozygous**

organisms and those which have unlike genes are called **heterozygous** organisms. We can as well state that when both the members of a pair of alleles are identical, the individual is **homozygous** (a **homozygote**); when two different alleles are present, the individual is **heterozygous** (or **heterozygote** or **carrier**). In the example quoted here the parental strains of tall plants *TT* and dwarf plants *tt* are homozygous plants whereas a F_1 plant having unlike genes *Tt* is a heterozygous plant. Two other useful terms proposed by *Johansen* in 1911 namely *Phenotype* and *Genotype* can also be explained here.

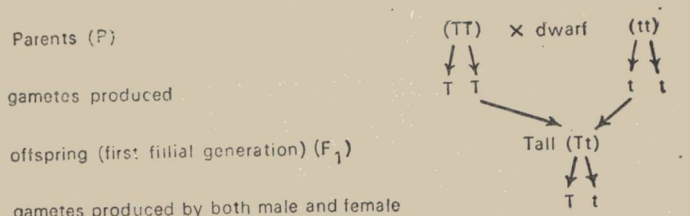
The Phenotype : (Greek *Phainen* : to show) is an organism defined as having certain observable characters. *TT* or *tt* the parental plants are observably tall and dwarf respectively. The F_1 plant (*Tt*) is phenotypically tall but it is a heterozygous plant. The individuals of a phenotype thus may appear alike but may not breed alike.

The Genotype of an individual is its full set of genes i. e., an organism with its expressed and latent genetic constitution. *Tt* of F_1 has a genetic constitution or a genotype in which *T* is expressed and (*t*) is latent. *TT* or *tt* are the examples of the same genotype where similar genes are present. The individuals of the same genotype breed alike.

Mendel's next step after obtaining the F_1 generation of all apparently tall plants (*Tt*) was to perform selfing in the F_1 plants. The results of F_1 selfing are indicated in the form of charts resembling checker boards The **checker boards** are also referred to as **Punnet squares**. The possible combination of genes in the male gametes are shown in the spaces at the top of the chart, and the gene combinations in the female gametes are indicated on the left side of the chart. The results of the selfing between F_1 hybrids are indicated in the Punnet's square showing the progeny of F_2 in the ratio of 3 talls to 1 dwarf.

The results of selfing of F_1 hybrids to get F_2 generation are now summarised on cytological grounds. When F_1 plants phenotypically tall with (*Tt*) and (*Tt*) genotypes are selfed they will produce 50% of the male and female gametes of *T* type and the other 50% of male and female gametes of (*t*) type, as a result of meiosis.

During meiosis *Tt* or allelic pairs will separate so that the gametes formed will receive either the (*T*) or (*t*) but not in any case both.



offspring second fillial generation) (F_2) when various Individuals are crossed and shown by so called chock-board (Punnett square)

female gametes \ male gametes	T	t
T	TT	Tt
t	Tt	tt

Fig. 18.4 The results of the experiments on the cross between the parental strains of pea plants and their F_1 progeny are shown with the help of a checker board.

When *T* and *t* types of male gametes will combine with *T* and *t* types of female gametes, the F_2 plants obtained will have the genotype *TT*; *Tt*; *Tt* and *tt* i.e., 3 : 1 ratio will be obtained. Three tall plants obtained are nodoubt phenotypically tall but they differ, in their genotype. One tall plant is *TT* i.e., a pure tall. The other two talls with *Tt* combination have in their genetic constitution genes for dwarfness which are not expressed on account of the presence of a dominant *T*. These two tall plants are therefore hybrid talls. The dwarf plant with '*tt*' is phenotypically as well as genotypically dwarf with *tt* constitution. It is therefore a pure dwarf. The 3 : 1 ratio therefore includes 1 pure tall, two hybrid talls and 1 pure dwarf or the actual ratio of F_2 is 1 : 2 : 1.

The pure talls of F_2 generation when selfed will produce only tall plants. The pure dwarfs of the F_2 generation likewise when selfed will give rise to dwarf plants only. The hybrid talls of F_2 on selfing will behave like the hybrid of F_1 and will give rise to the ratio of 3 talls to 1 dwarf (See figure 18·3).

Mendel carried out similar experiments on six other varieties of pea showing contrasting characters such as red and white flowers, smooth and wrinkled seed coats, etc. In every case he discovered that the basic pattern of inheritance was the same as that recorded for tall and dwarf varieties.

Mendel's First Law or Principle of Inheritance:

On the basis of the above experiments on the inheritance of a single pair of contrasting characters in the monohybrids, the first law or principle of inheritance referred to as the **Law or Principle of segregation of genes** at the formation of gametes or the *Principle of purity of gametes* was deduced. This simply means that the members of a pair of alleles separate cleanly from each other when an individual forms germ cells or gametes. The principle of segregation thus implies that the two members of a single pair of genes are never found in the same gamete, but always segregate and pass to different gametes. In the present example, the (*Tt*) alleles of F_1 hybrid, separate during the formation of gametes. In other words, the genes representing alternative characters do not blend with or contaminate each other, but segregate and pass into separate gametes. The gametes of (*Tt*) hybrid will either receive (*T*) gene or (*t*) gene but not both. The gametes as far as the genes are concerned will be pure receiving either a gene for tallness (*T*) or a gene for dwarfness i.e., (*t*).

As stated earlier, the character which appears in F_1 after a cross between the two pure strains is called a dominant one. This is also referred to as the *principle of the dominance.* This simply means that one of the members of a pair of contrasting or alternative characters exhibits itself as a dominant character while the other remains hidden or latent as a recessive character.

Prior to Mendel's time, it was believed that the characters of the parents blend in the offspring. Mendel however stated clearly that blending did not occur, but the characters of the parents, though they might not be expressed in the first generation progeny, could reappear quite unchanged in a later generation. This is often referred to as the principle of *unit inheritance.* Modern genetics however lays little stress upon this principle but in Mendel's time however it was an entirely new concept.

The Example of Monohybrid Inheritance in Animals :

The monohybrid inheritance as worked out by Mendel with peas applied to all forms of life—animals as well as plants. An experiment with *guinea pigs* may show how monohybrid inheritance takes place in animals.

We can select a male guinea pig with a black coat descended from a race which has had black coats for many generations. This can be taken as a pure strain of black coated male guinea pigs with a genotype (*BB*), where *B* represents the black coat as a dominant gene. This can be crossed with a pure strain of female guinea pig with white coat having a genotype of (*bb*) where (*b*) represents the white coat as a recessive character.

When the homozygous black coated male (*BB*) is mated with a homozygous white coated female (*bb*), each sperm will carry one gene for black i.e., '*B*' and each egg will carry one gene for white (*b*). All the F_1 offsprings of this cross will be heterozygous with genotype (*Bb*). The F_1 individuals will all be black coated as black is a dominant gene.

When the germ cells within the testes and ovaries of these heterozygous F_1 (*Bb*) individuals undergo meiosis, the two types of genes (*Bb*) are segregated. Consequent to this, one half of the gametes will receive gene for black coat i. e., *B*, while the other half receives a gene for white coat. There can be no such things as self-fertilization or selfing as we found in garden peas. We can however mate the first generation offsprings F_1 among themselves. The result will be that the F_2 offspring will show the same ratio of 3 : 1 i. e., 3 black coated guinea pigs and one with white coat. The genotypes of these F_2 offsprings will be **BB, Bb, Bb,** and **bb.** Out of 3 phenotypically black coated guinea pigs, one will be a pure one with *BB* genotype, the other two will have a genotype *Bb*. The white coated one with a genotype (*bb*) will also be a pure one. The actual ratio of F_2 thus will be 1 : 2: 1. The phenotypically and genotypically black coated guinea pigs of F_2 (*BB*) if mated with parental black strain (*BB*) will produce all black coated guinea pigs. Likewise the white coated F_2 guinea pigs (*bb*), mated with pure parental white coated strain will give rise to white coated forms only. The

phenotypically black coated guinea pigs with (*Bb*) genotype if mated amongst themselves will give a progeny having a ratio of 3 : 1 or 1 : 2 : 1.

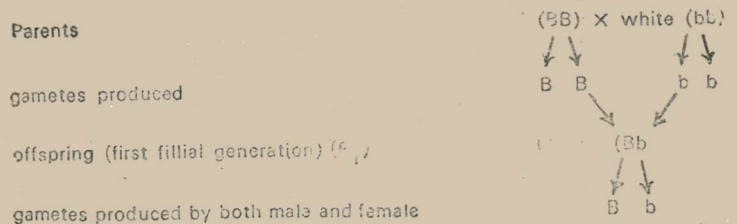


Fig. 18.5 The results of experiments on the cross between the pure strains of Guinea Pigs and between their F_1 progeny shown with the help of a checker board.

Test Cross :

The progeny that shows the dominant character in a cross are nodoubt alike phenotypically but may be either heterozygous or homozygous for that character. The identification of homozygous individuals is of utmost importance to an animal or plant breeder who is trying to establish true breeding strains of animals or plants. If the breeder is interested in establishing a strain, that is true breeding for a dominant character, he needs a test that will enable him to tell whether a given individual is homozygous dominant or heterozygous dominant. The test used for this purpose is called a **test cross**. The test cross is a Back cross to the recessive parental type or a cross between genetically unknown individuals with a fully recessive tester to determine whether the individual in question is heterozygous or homozygous for a certain allele.

For example, we want to know whether a particular tall pea plant has a genotype of TT or Tt. The most we can say about this plant from a simple observation is that it is tall and hence must have at least one *T* allele. We write about its genotype as T—; in other words half of its genotype for this character is known and half is unknown and is as such designated by a dash. We can cross this plant with a short or dwarf which can only have the genotype tt. The results of crossing should give us the information we seek.

If the plant in question has T *T* as its genotype, then the results of the cross with tt will be as follows :

T *T* × tt

Tall dwarf

Tt Tt Tt Tt

Tall Tall Tall Tall

If on the other hand, the plant in question has the other possible genotype T*t*, then the results of the cross will be as follows :

T *t* × tt

Tall dwarf

Tt Tt tt tt

Tall Tall dwarf dwarf

In other words, the unknown half of the test plant's genotype may be either *T* allele or *t* allele. In case it is *T* allele, then the full genotype of the plant is *TT* and such a plant when back crossed with a homozygous recessive *tt* plant will produce a progeny all of which are heterozygous *Tt* and show a tall phenotype. If on the other hand, the unknown is a *t* allele, then the full genotype of the plant is *Tt* and such a plant when test crossed with a homozygous recessive plant, *tt* will yield progeny, 50% of which are heterozygous and show tall phenotype and 50% of which are homozygous recessive and show a dwarf phenotype.

2. Dihybrid, and Trihybrid Inheritance: As already stated Mendel limited his experiments at first to the crosses involving a single phenotypic character.

Mendel conducted some more experiments in which he considered two or three characteristics at a time. The crosses that involved two characters are referred to as **dihybrid crosses** and those concerned with three characters are called **trihybrid crosses.**

Mendel performed a series of experiments involving two or more of the characters listed in the table given on page 480. For instance he crossed pea plants in which he considered the inheritance of two characteristics i.e., the shade and colour of the seeds of pea plant. He found that some plants produced seeds which stayed **round** after drying while others gave seeds which became **wrinkled** A monohybrid cross showed that round shape of the seed was dominant over the wrinkled shape. Some seeds turned **yellow** when dried, while others remained **green.**

In order to see, now the mechanism of inheritance of the two **traits**—*shape and colour of the seeds*, he crossed pure strains of plants producing **yellow round seeds** with others producing **green wrinkled seeds.**

Mendel obtained all **yellow round seeds** in the F_1 generation, as was expected, since he had already demonstrated that yellowness and roundness were the phenotypes displayed by two dominant genes concerned. The green wrinkled characters in F_1 were thus recessive or latent.

Mendel now crossed the F_1 hybrids amongst themselves. The resulting F_2 progeny showed four distinct types of seeds i. e., 1. Round yellow seeds, 2. Wrinkled yellow seeds, 3. Round green seeds and 4. Wrinkled green seeds. In order to ascertain the ratio in which these four distinct types of seeds have been obtained he collected some 556 seeds from F_2 generation plants. Out of 556 seeds, the number of four different phenotypes of F_2 obtained is thus given below.

315	Round yellow seeds.
101	Wrinkled yellow seeds.
108	Round green seeds.
32	Wrinkled green seeds.
Total 556	

On the basis of the above figures examined we can see that, they approximate a ratio of 9 : 3 : 3 : 1 i. e., out of the total number, 9/16 show both dominant characters, 3/16 show one dominant and one recessive, 3/16 show the other dominant and the other recessive and 1/16 show both recessives.

The above results of Mendel obtained by a crossing between the pure strain plant of round yellow seeds with a pure strain plant of wrinkled green seeds can be expressed by using the symbols as was explained in the case of monohybrid inheritance.

We can use the letter **R** representing a gene for **Round seeds** and r for the gene representing the **wrinkled seeds** Likewise **Y** can express the gene for **yellow colour** and y for the allele for **green seeds.** The genotype of the parent plant with round and yellow seeds will be **RR YY.** The genotype of the parent plant having wrinkled seeds and green colour will thus be **rr yy.**

The round yellow parent **RR YY** will produce gametes of only one genotype **RY.** The wrinkled green parent could produce only ry gametes. When *RY* gametes from the one parent were united with the *ry* gametes from the other parent in the process of fertilization, all the resulting F_1 offsprings were heterozygous for both characters *RrYy* and showed the phenotype of the dominant parent Round Yellow i.e., *RrYy* as shown in figure 18.6.

The F_1 plants or dihybrids will now form four different types of gametes i. e., *RY*, ; *Ry* ; *rY* and *ry*. When such F_1 plants are crossed, there were 16 possible combinations of gametes (4×4), as shown in the checker board. The 16 combinations of F_2 plants included nine different genotypes i. e , *RRYY*; *RRYy*; *RRyy*; *RrYY RrYy*; *Rryy*; *rrYY*; *rrYy*; and *rryy*, which determined four different phenotypes in the ratio of 9 : 3 : 3 : 1 as shown below.

S. No.	Total number of phenotypes	Genotypes
1.	9 Round, Yellow	RRYY; RRYy; RrYY; RrYy.
2.	3 Round, Green	RRyy; Rryy.
3.	3 Wrinkled, Yellow	rrYY; rrYy.
4	1 Wrinkled, Green	rryy.

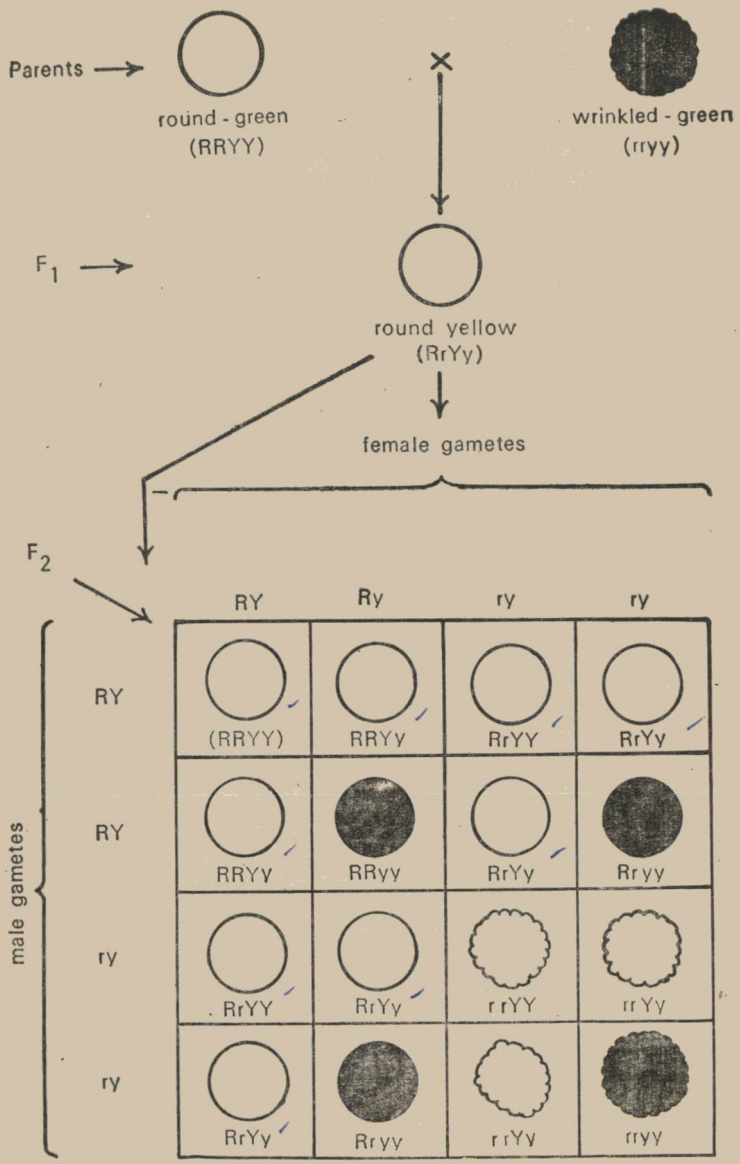


Fig 18.6 Results of a second hybrid generation of a dihybrid cross

On the basis of the results obtained in a monohybrid cross, Mendel had concluded that the members of pair of alleles separate clearly from each other when an individual forms gametes or germ cells.

On the basis of results obtained in a dihybrid cross, Mendel could draw another conclusion which involved the independent combinations of different pairs of alleles, or *independent assortment.* This concept is sometimes referred to as *Mendel's second principle.*

The second principle of *independent assortment states that the members of different pairs of alleles assort or segregate independently of each other when germ cells are formed.* The same principle can be explained as shown below by taking example of F_2 pea plants phenotypically having Round Yellow seeds but with a genotype *RrYy.*

In F_2 Plant of phenotype

$$\frac{R}{r}\quad\frac{Y}{y}$$

Since *R* separates from *r* at the formation of gametes

Half of the gametes will contain *R*	and	half of the gametes will contain *r*

Since *Y* separates from *y* independently of *R r* separation, at the formation of gametes

half of these gametes will contain *Y*	and	half of these gametes will contain *y*	While	half of these gametes will contain *Y*	and	half of these gametes will contain *y*

So the resulting gametes are

$\frac{1}{4}RY$: $\frac{1}{4}Ry$: $\frac{1}{4}rY$: $\frac{1}{4}ry$.

The separation of the *Rr* allelic pair, and of the *Y y* allelic pair, respectively, can be treated as independent events i. e., *the members of different pairs of alleles assort or segragate independently of each other when gametes are formed.*

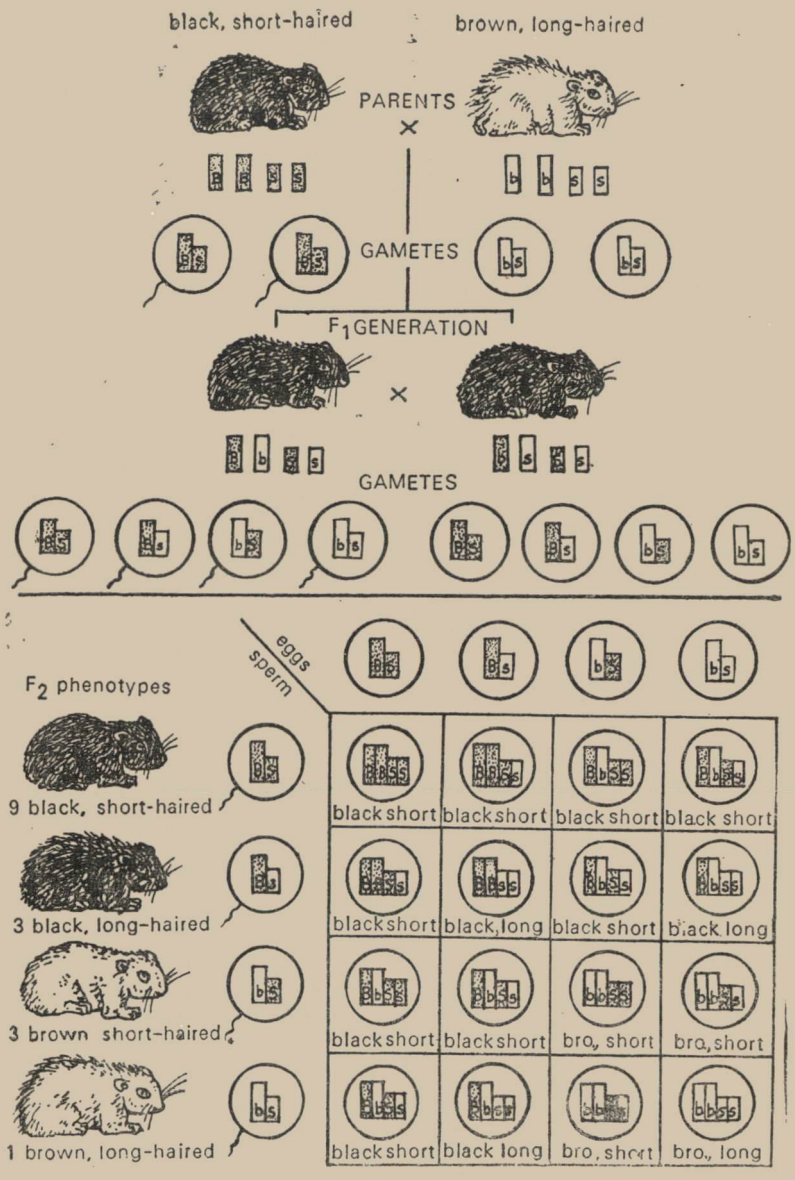


Fig. 18.7 The results of a cross between black short haired (dominant) and brown long haired (recessive) guinea pigs.

In the case of animals as well, the dihybrid inheritance following the principle of independent assortment was observed.

The results of a cross between a **black short haired guinea pig (BBSS)** and a **brown long-haired guinea pig (bbss)** are as follows.

It was observed that black was dominant over brown and short hair over long hair. This was thus a good example where one can study the dihybrid inheritance amongst the animals. The black short haired animal with **BBSS** genotype produces only **BS** gametes and the **bbss** guinea pig produces only **bs** gametes. Mating between these two pure parental strains gives rise to F_1 progeny which is phenotypically black and short haired but with a genotype (**BbSs**).

When two of the F_1 dihybrids are mated, each produces four types of gametes **BS, Bs, bS** and **bs** These four types of gametes (4×4) will give rise to F_2 progeny with 16 zygotic combinations as illustrated in a Punnet square. The sixteen zygote combinations of F_2 Guinea pigs include nine different genotypes i. e , **BBSS**; **BBSs**; **BbSS**; **BbSs**; **BBss**; **BbSs**; **bbSs**; **bbSS**; **bbss**; which determine four different phenotypes in the ratio of 9 : 3 : 3 : 1 as per the details given below.

S. No.	Total number of phenotypes	Genotypes
1.	9 Black, Short haired.	**BBSS**; **BBSs**. **BbSS**; **BbSs**
2.	3 Black, Long haired.	**BBss**; **Bbss**.
3.	3 Brown, Short haired.	**bbSs**; **bbSS**.
4.	1 Brown, Long haired.	**bbss**.

Gene Interactions — *Phenotypes not Expressed in Parents but in Progeny* :

A classical example of interaction of genes based on the results of crosses between different varieties of chickens was reported by **William Bateson** (1861—1926) and his associate **R. C. Punnet.**

It was noted that two forms of comb, the **rose comb** and the **pea comb** occurring in poultry, breed true. But when birds with

rose comb and **pea comb** are bred together, a totally different form of comb called the **walnut** appears. This is an example of incomplete dominance. In this case, two different genes influencing a particular character interact to produce single-character phenotypes that neither gene alone could produce. The production of walnut comb is the example of **collaborative interaction** between the genes.

In this example, one gene represented by **R** produces **rose comb**, while its recessive allele **r**, produces a **single comb.** Another gene **P** produces a **pea comb**, while its recessive allele **p**, also produces **a single comb.** *When R and P occur together they collaborate to produce a* **walnut comb** *a type of comb which R and P cannot produce alone. Rose comb* is characteristic of *Wyandotte chickens*, and *pea comb* is characteristic of *Brahma chickens.* A cross between a *Wyandotte chicken RRpp* and a *Brahma rrPP* could be summarized in the following way.

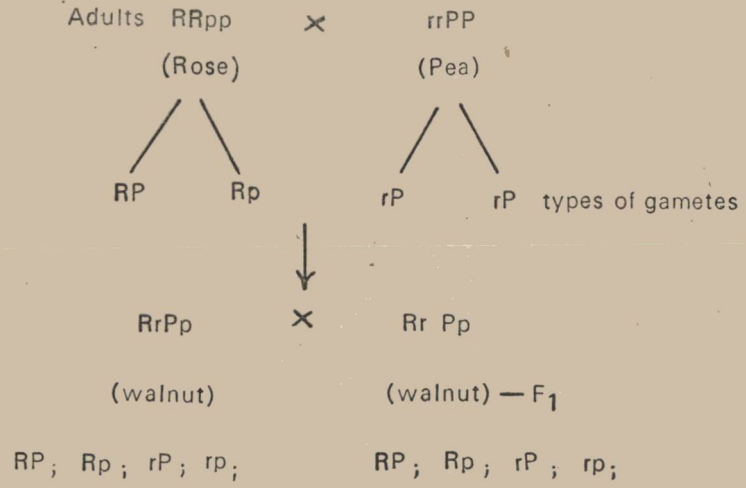


Fig. 18.8 The types of gametes produced by parental strains of Rose and Pea comb chickens and their F_1 progeny.

In the F_1, *collaboration between R and P produces a* **walnut comb.** The F_1 walnut produces four types of gametes following the principles of independent assortment. The gametes are **RP, Rp,**

rP and rp. When F_1 walnut comb varieties are mated together then their F_2 progeny with four types of gametes (4×4) will give rise to F_2 progeny with 16 zygotic combinations and the type of combs obtained in F_2 progeny will be **9 walnut, 3 rose, 3 pea and 1 single combs.** The same results are shown in the form of a checker board. (See page 499).



Single



Walnut



Pea



Rose

Fig. 18.9 The different types of combs in chickens

Trihybrid cross: In a trihybrid cross, we consider the inheritance of three pairs of alternative characteristics.

In a cross between two pure parental strains differing in three alternative characteristics, the gametes obtained from each parent, carry three genes. Each F_1 hybrid gives rise to 8 kinds of gametes. When F_1 hybrids are crossed (8×8) 64 combinations are

♀ ↓	0 → RP	Rp	rP	rp
RP	RRPP Walnut	RRPp Walnut	RrPP Walnut	RrPp Walnut
Rp	RRPp Walnut	RRpp Rose	RrPp Walnut	Rrpp Rose
rP	RrPP Walnut	RrPp Walnut	rrPP Pea	rrPp Pea
rp	RrPP Walnut	Rrpp Rose	rrPp Pea	rrpp Single

Adults 9 walnut : 3 rose : 3 pea : 1 single.

obtained in the F_2 progeny. The ratio in the F_2 progeny will be 27 : 9 : 9 : 9 : 3 : 3 : 3 : 1 = 64.

The details of the trihybrid cross between a **short, black, smooth haired guinea pig** (SSBBrr) with a **long, white rough coated** guinea pig will give the following results.

	Phenotype,	**Genotype**	×	**Phenotype,**	**Genotype**
Parent	Short Black Smooth	SSBBrr	×	Long White Rough	ssbbRR
P —	Gametes	SBr	×		sbR
F_1	Short Black Rough	SsBbRr	×	Short Black Rough	SsBbRr
F_1	Gametes	1. SBR 2. SBr 3. SbR 4. Sbr 5. sBR 6. sBr 7. sbR 8. sbr	×	1. SBR 2. SBr 3. SbR 4. Sbr 5. sBR 6. sBr 7. sbR 8. sbr	

F_2 Generation of a Trihybrid Cross

Phenotypes

27	9	9	9	3	3	3	1
Short Black Rough	Short Black Smooth	Short White Rough	Long Black Rough	Short White Smooth	Long Black Smooth	Long White Rough	Long White Smooth

Genotypes

1. SSBBRR	1. SSBBrr	1. SSbbRR	1. ssBBRR	1. SSbbrr	1. ssBBrr	1. ssbbRR	1. ssbbrr
2. SSBBRr	2. SSBbrr	2. SSbbRr	2. ssBBrr	2. Ssbbrr	2. ssBbrr	2. ssbbRr	1 Long
2. SSBbRR	2. SsBBrr	2. SsbbRR	2. ssBbRR	3 Short	3 Long	3. Long	White
2. SsBBRR	4. SsBbrr	4. SsbbRr	4. ssBbRr	White	Black	White	Smooth
4. SSBbRr	9 Short	9 Short	9 Long	Smooth	Smooth	Rough	
4. SsBBRr	Black	White	Black				
4. SsBbRR	Smooth	Rough	Rough				
8. SsBbRr							
27 Short							
Black							
Rough							

Sex and Heredity :

The various examples mentioned in connection with the mechanism of monohybrid, dihybrid or trihybrid inheritance have no relation to the determination of the sex of the individual. We will now see in what way the sex of the individual is determined. It has been observed that somatic and early germ cells of many male animals have a pair of homologous chromosomes in which one member is smaller than the other and sometimes of a different shape. This pair of homologous chromosomes is called the **sex chromosomes.** The larger one is called the **X chromosome** and the smaller one the **Y chromosome.** In some species there is no *Y* chromosome and the males have thus only *X* chromosome. In females a pair of *X* chromosomes is present. The male as such can be designated as *XY* or *XO* and a

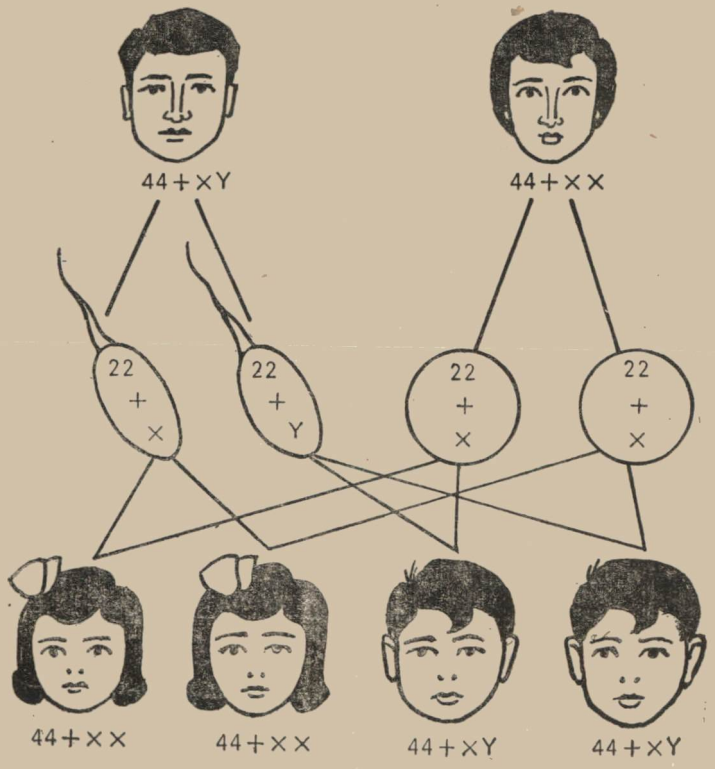


Fig. 18.10 The mechanism of sex determination in man.

female as *XX*. The chromosomes other than the sex chromosomes are called **autosomes.**

Somatic cells in human beings have 46 chromosomes. Out of these there is a single homologous pair of **sex chromosomes** and 22 homologous pairs of **autosomes.** During the maturation of gametes, the sex chromosomes segregate freely like other chromosomes, so that an ovum or egg contains 22 autosomes and an *X* chromosome. A sperm has 22 autosomes and either an *X* chromosome or a *Y* chromosome. Thus, the sperms will be of two kinds—*X* bearing or *Y* bearing whereas all ova are *X* bearing. *X* and *Y* bearing sperms are formed in equal numbers.

The sex is determined by the type of sperm that fertilizes an egg. If *X* bearing sperm fertilizes an egg, the zygote will develop into a female XX. If *Y* bearing sperm fertilizes an ovum, the zygote will develop into a male XY. In birds and moths the situation is reversed. The males are homozygous XX or ZZ and the females are heterozygous XY or ZW.

We have learnt that characteristics are inherited from genes. The studies on *Drosophila* have revealed that besides sex chromosomes, autosomes are also involved in sex expression. The deciding factor in sex expression is the ratio between the number of *X* chromosomes and of sets of autosomes in the fertilized egg.

Revision questions

1. What is meant by the term heredity? Define 'particulate inheritance.'

2. Describe in detail Mendel's first law or principle of inheritance with suitable examples of plants and animals.

3. Define the principle of independent assortment. Explain the same with suitable examples.

4. Explain the phenomenon of the collaborative interaction between the genes with the example of comb types in poultry.

5. Write what you know about the following:
   (a) Dominant and recessive characters.
   (b) Homozygous and Heterozygous states.
   (c) Alleles or Allelomorphs.
   (d) Phenotype and Genotype.
   (e) Hybrid.
   (f) Monohybrid, dihybrid and tribybrids.
   (g) Test cross.

CHAPTER XIX

ORGANIC EVOLUTION

The literal meaning of the word *Evolution* (L. *Evolvo*: unroll) means unrolling or unfolding or a gradual development. The word has a very wide application as there is hardly a thing that is not subject to a process of change. The *Universe* in which we live is in fact the product of a series of changes referred to as *Cosmic Evolution*. Our planet earth as we know today is the result of a series of geological changes or *Geologic Evolution*. Likewise the historical events leading to the development of human civilizations may be referred to as *Cultural Evolution*.

You have studied in the previous chapters of this volume and volume I various types of animals—their structure and functions. Our method of presentation of the structure and functions of the various animals was to proceed from the simplest animals like *Amoeba* to the more complex forms like the frog. This arrangement followed in the study of various types of animals, is, in fact an expression of a point of view, *that in the living world also there is in operation a process called 'Evolution.'*

The evolution in the realm of organic or living things is called **Organic evolution** The organic evolution refers to the changes undergone by living things i.e., plants and animals. The principle of organic evolution implies, *the development of an entity in the course of time through a gradual sequence of changes from a simple to a more complex state*.

The doctrine of organic evolution teaches that the present day diverse forms of living things which exist on the earth are the result of a process of gradual development or change from more simple or lowly organised forms of life which existed in the past. The millions of forms of animal and plant life, simple or complex have all descended from pre-existing forms and are mostly different from them in their organisation. These changes according to the

theory of organic evolution have taken an incredibly long period of time, extending into several geological ages which are perhaps to be computed in millions of years.

We can thus summarise that all living organisms including man are the *modified descendants* of one or a few simple living things. All organisms have undergone evolution from common ancestors as a result of which members of the various lines of descent share not only structural, mental and genetical characters but also physiological and biochemical mechanisms and immunological reactions.

Early Concepts About the Origin of Diversity in the Living Forms :

According to some it was thought that the Universe is unchangeable and so also the organisms inhabiting the universe. It was believed that all the diverse forms of organisms have been existing without any change and will continue to exist in the same state throughout eternity. This idea is referred to *as the concept of enternity of present conditions.*

The theory of *Special Creation* postulates that present day forms were created by some outside influence when life came into existence on earth, and have continued with little alteration ever since.

The concept of *Spontaneous generation* states that living organisms appear suddenly. **Pasteur** (1822–95), however showed conclusively that *today* no organism arises except as the offspring of pre-existing organisms. We should however remember that some simple forms of life certainly *must* have arisen spontaneously, although perhaps under very different conditions, early in the Palaeozoic.

Cuvier (1769–1832), examined the fossils of animals quite unlike those found living today. Cuvier therefore suggested that there had been in the history of the world *several creations* and that each, at the end of its period, had been wiped out by some *cataclysmic upheaval* and a fresh set of organisms were created on different lines. This theory of Cuvier is termed as *Catastrophism.*

The *theory of evolution* only is however accepted regarding the origin of the various forms of life (with unity and diversity) *descended with modifications from the ancestral types.*

The fact of organic evolution can be proved by evidences from different disciplines of biology such as morphology, palaeontology, physiology, biochemistry, genetics, bio-geography and taxonomy.

Evidences of Organic Evolution

Anatomical Evidences :

1. Evidences from classification : The purpose of classification as already stated (See Vol. I pages 251 & 252) is to arrange animals into groups so as to show their *presumed relationships.* The very fact that we are able to classify the animals on the basis of their resemblances and differences into major and minor groups like phyla, classes, orders, families, genera and species is a strong evidence in favour of evolution.

The classification of animals into related groups, explains fundamental similarities based upon inheritance from common ancestry. Further the differences between the species or a sub-species indicate that the groups are in the process of divergence from common ancestry. The sub-species in the course of time becoming distinct species is a clear-cut evidence of the fact that the process of evolution is in operation.

2. Connecting links : We are able to arrange existing forms of animals in progressive series. In this arrangement we have certain examples of individual animals or animal groups which show characters of two groups and thus represent a transitional stage from one group to another group. Such animals or animal groups which show transitional features are often referred to as '*Connecting links*' as they connect, so to say, two groups. The group of monotremata or egg laying mammals as you have studied can be regarded as a connecting link which fills the gap between reptiles and mammals. *Peripatus* is an arthropod which connects the arthropods with the annelids. The existence of such connecting

links is a strong evidence that the animals that exist today have become modified during their long descent from those that existed in the past.

3. Homologous and Analogous Organs : The comparative study of the form and structure of animals shows *homologous* and *analogous* structures. The structures having the same embryonic origin but may have different functions. Such structures or organs are called *homologous structures* or *organs*. The limb of a rabbit, dog, and man, the wings of a bird and bat and likewise the paddles of a whale, have a common foundation in the pentadactyl limb skeleton. It can, therefore, be reasonably assumed that they are homologous organs derived from a common ancestral type but have adapted for different functions. The presence of homologous organs is a clear evidence that they have arisen as a result of a process of modification of basic type. In the example quoted, the basic structure of the pentadactyl limb skeleton has been modified to form the *legs* in rabbits and dogs, *arms* and *legs* in man, *wings* in birds and bats and the *paddle* in a whale. The recognition of homologous structures is a good evidence for a fundamental similarity of design and the groups possessing these structures may be thought to have originated from a common stock.

As against homologous structures, we also find certain structures or organs serving the same function but have different origins. Such organs which perform similar functions but totally differ in their origin are called *Analogous structures* or *organs*. The good examples of such organs are the wings of a bird or bat and those of an insect serving the function of flight. The wings of a bird or bat and the wings of an insect however differ totally in their structure and development.

The functional resemblances in the analogous structures like the *fins* of fishes, *paddles* of whales, *wings* of birds or bats, and *wings* of insects are due to the common habitat but not common ancestry. It should be remembered that analogous similarities are on the whole rather superficial in nature. However, the discovery and analysis of homologous structures are the most powerful tools used in tracing the evolutionary histories and relationships of animals.

4. Vestigeal organs : Further proof of evolution comes from the *vestigeal organs.* Vestigeal or rudimentary organs are the parts of the body which are relatively small in size and have little, if any, ascertainable function. Their presence in certain animals appears to represent remnants of structures or organs which are functional in some animals.

The most familiar rudimentary organ in man is the *vermiform appendix.* The vermiform appendix is small and apparently a functionless structure in man but is well developed in herbivorous mammals like the rabbit. This suggests that man has inherited the appendix from some remote ancestor living on a diet which necessitated its presence. When the descendants of this ancestor changed their food habits, the large caecum and the vermiform appendix, being no more useful, decreased in size. The semi lunar fold of skin (*Plica semilunaris*) in the corner of the eye of man is the vestige of the nictitating membrane. The remnants of the tail in man is represented by the *coccyx.* We cannot move the pinna of our ear or twitch the skin as other mammals can do. However, we have muscles associated with these structures in the form of *vestiges.*

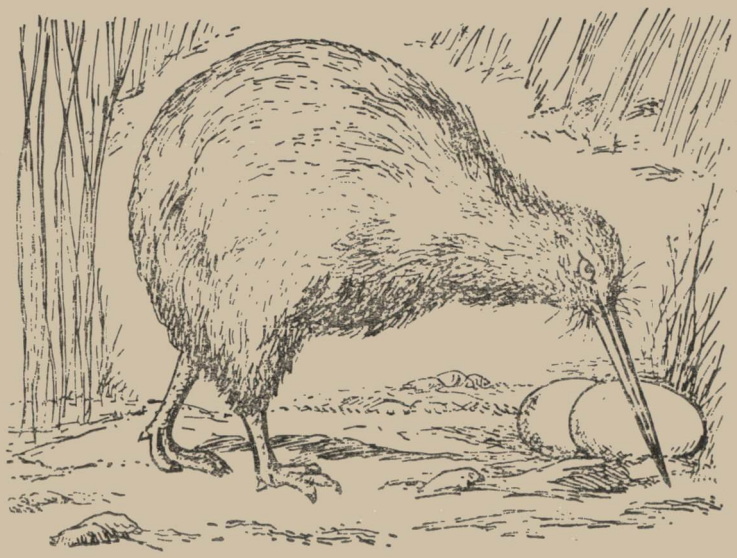


Fig. 19.1 The Kiwi, *Apteryx* with vestigeal wings and wing muscles.

Snakes as we have studied do not possess the limbs but python has the vestiges of the pelvic girdle and hind limbs. Whales possess the rudimentary pelvic girdle and the hind limbs embedded in the flesh. The presence of these vestiges indicates that snakes and whales have all descended from ancestors that possessed functional limbs and limb girdles.

Flying birds as we know possess wings and associated muscles that move the wings. The flightless birds like the 'Kiwi', for example, possesses wings and associated muscles in the form of vestiges.

5. *Atavistic organs* : In addition to the vestigeal organs *atavisms* or *reversions* are sometimes encountered in man and animals. Atavisms or reversions are *abnormal structures* which are reminiscent of normal structures possessed by other usually 'lower' animals. Atavistic organs are not present in every individual of a species but appear only in exceptional cases. Just like the vestigeal organs, the atavistic organs give an important clue in establishing genetic ties between separate groups of living forms. A few examples of atavistic organs are quoted below.

As mentioned, a rudimentary tail, coccyx is present in all people but occasionally a human baby is born with a short fleshy tail protruding from the base of the spine. As the vertebral column usually does not extend into the atavistic tail, it can easily be removed by a surgeon. In certain cases, the tail had rudimentary vertebrae. A boy was born in Germany in 1848 with a ten centimetre long tail.

Human beings in common with other primates are provided with a pair of mammary glands in the pectoral region on the chest. The other mammals like pigs, dogs, etc., have a row of mammary glands extending along both the sides of the chest and the abdomen. Occasionally human beings are born with an extra pair of nipples or mammary glands reminiscent of the condition which is normal in lower mammals.

Another example of the famous freak was the '*Lion boy*,' *Stefan Bobrovsky*, whose entire face and body were covered with

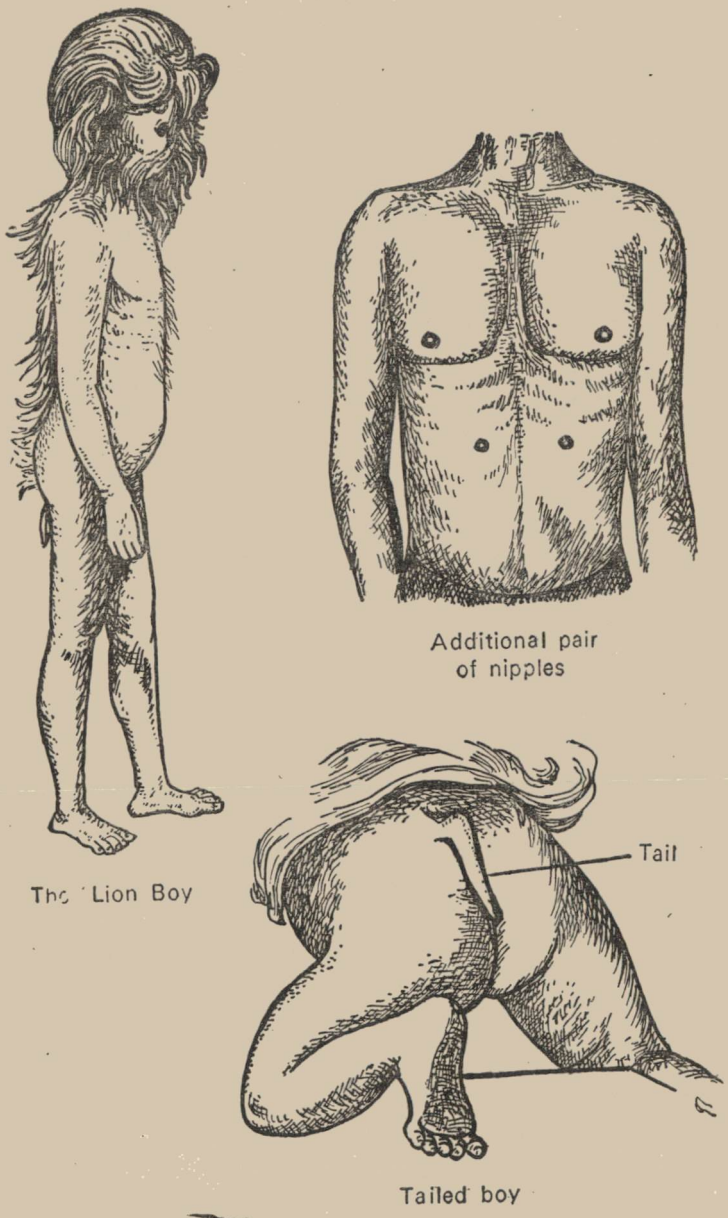


Fig. 19.2 A few examples of atavistic structures in human beings.

long thin golden hair. The human foetus, as we know, is covered by the primary downy hair (lanugo). In exceptional cases, the primary downy hair are not replaced by secondary coat of hairs which persist throughout the life. The '*Lion boy*' is thus a case of the retention of the downy hairy (lanugo) covering.

Embryological Evidences :

With the point of view of an embryologist, evolution consists of changes in the pattern of development in successive generations. The development of an individual from a fertilized egg to adult is called its *Ontogeny* and the racial history of an adult, its *Phylogeny*.

We find a remarkable resemblance in the embryos of various groups of animals. The resemblances between the Ontogenies of different animals led **Von Baer** (1792–1867), and later **Ernst Haeckel** (1843–1919), to formulate the famous *Recapitulation hypothesis* (Biogenetic law). According to this hypothesis, an individual during its development (i.e., Ontogeny) goes through a series of forms resembling its *adult ancestors*. Haeckel thought that in some way the adult condition of an ancestor is pushed back into embryonic development so that the embryos of the descendants pass through that ancestral adult stage. This has been expressed in a phrase, *that each animal during its development climbs up its family tree* i.e., ontogeny recapitulates or repeats in a condensed and even modified form the development of the race (Phylogeny). Ernst Haeckel expressed this in the terse dictum : *Ontogeny repeats phylogeny*.

The task of describing precisely the ontogenies of animals was effectively stated by *Von Baer*. Based on these studies, Von Baer drew certain conclusions. He noted particularly that young stages (embryonic phases) of different animals often resembled one another more closely than did the respective adults. *He observed that the embryos of higher animals repeat embryonic stages of their ancestors but not the adult stages*. On the basis of further investigations embryologists confirmed that Von Baer was right in suggesting that in the ontogeny of an animal, the embryonic stages do not resemble the adult ancestors but the young stages of those ancestors. In support of the above view it was noted that gill pouches of a mammalian embryo are much more like the gill pouches of a fish embryo than they are like the gill slits of an adult fish.

We have further to distinguish two kinds of characteristics in recapitulation, which are as follows.

1. The primitive or universal and generalised characteristics called *Palingenetic* characters.

The *Palingenetic characters* were more or less common to all the embryos. In human embryo, for example, the gill clefts, the two chambered heart, the metameric musculature, the tail, etc., could be considered as palingenetic characters.

2. The characteristics which the embryo itself develops as new adaptive changes that are necessary for its survival as an embryo. These are called *Cenogenetic* characters. The appearance during the embryonic life of a new structure which in later phylogeny remains an embryonic structure is called *Cenogenesis*.

A clear example of Cenogenesis is afforded by the evolution of extra embryonic membranes.

In the final analysis, one should remember that many palingenetic features must have been cenogenetic at some time in the early history of the evolution of the race.

There are also certain examples in ontongenies where organs do not develop in the *proper chronological order* as they were evolved in the species. This reversal of the order in the appearance of embryonic structures is called *Heterochrony*. For example, in phylogeny, teeth appear in the earliest type of fishes prior to the development of the tongue. In mammals, the tongue appears first during the embryonic development followed later by the development of teeth. In certain ontogenies *tachygenesis* or shortening of parts of the life history occurs.

Some examples of the constancy of developmental plans could as well be cited.

In certain parasitic cirripedes, where adults have lost almost all their crustacean characters, the constant appearance of characteristic larval forms—*nauplius*, *cypris*, etc., enables us to place the organism in its correct phylogenetic position.

The fact that similarities persist between the larvae of different phyla such as Annelida and Mollusca or Hemichordata and Echinodermata gives us a clear evidence for affinities between these phyla.

One should however bear in mind the fact that 'similarity in Ontogeny between certain animals is nodoubt a proof of their affinity but it does not give any clue to the adult structure of the ancestor.

We will now consider the various ways in which ontogenetic changes can alter the adult structure. de Beer has worked out various possibilities of ontogenetic changes resulting in altering the adult structure. Some of these ontogenetic changes are discussed below.

1. Deviation and reduction : Deviation and reduction are in fact the processes which could be regarded as two sides of the same coin. In amphioxus and in the *'ammocoetes' larvae* of lampreys and probably the adult ancestors of the vertebrates, water is taken in, at the mouth and expelled through a numerous series of ciliated gill slits, which sieve out minute food particles. The most important part of this feeding mechanism is the *endostyle* which is a mucus secreting organ on the floor of the pharynx between the gill slits. At metamorphosis in lampreys this feeding mechanism is lost and the endostyle is transformed into an organ – the *thyroid gland* which is characteristic of all higher vertebrates. Thus, the process which led to the *reduction* of the endostyle also led by *deviation* to the appearance of thyroid. A similar process of deviation between successive ontogenies led to the reduction of the numerous ciliated gill slits (mainly used in feeding) to a smaller number of gill slits in higher aquatic vertebrates, used in respiration. Eventually in the land vertebrates the gill slits have been reduced to the embryonic gill pouches, although an anterior gill slit, modified as a *spiracle* in fish, remains in adult land vertebrates as the *eustachian tube* connecting the cavity of the throat with the middle ear. In terrestrial animals, *the lateral line system* can serve no useful purpose. In fishes, it helps in detecting pressure changes in the surrounding water. The canals of the inner ear present both in aquatic and terrestrial vertebrates, have evolved

as specialized derivatives of lateral line system. In amphibia, the lateral line system is present in the aquatic larvae but is usually lost at metamorphosis and has thus been reduced to an embryonic structure. Reptiles, birds and mammals do not develop lateral line organs at any stage of development.

2. *Neoteny and Paedogenesis*: The process of neoteny is the retention in the sexually mature adult, the structures which were confined to the embryos of its ancestors. This can be achieved by the acceleration of the developmental processes leading to sexual maturity relative to other processes, so that maturity is reached in an individual which in other respects retains the characteristics of a larva. This is referred so as *Paedogenesis.*

Alternatively, the rate of development of one or a few characteristics may be slowed down, so that the larval condition, in the adult is retained. This is referred to as *neoteny.* There cannot be drawn any sharp line of demarcation between *paedogenesis* and *neoteny* and often the term *neoteny* is applied to cover both.

Neoteny has played a significant role in the evolution of man as at least some specifically human characteristics have been evolved by retaining the embryonic characters in the adult.

Evidences from Geology and Palaentology :

The crust of the earth is formed by the rocks. Most of the rocks forming the crust of the earth are arranged in layers of strata one above the other. It is known that the crust has taken millions of years to form and generally speaking, the deeper the crust the more ancient it is. The strata of rocks can be arranged in a series in which the oldest lie at the base and most recently formed, at the top.

From the above account, one can follow that if animals and plants or their remains became buried and preserved in the strata of rocks during the stage of deposition some record of the animal and plant populations of the past would be available.

The remains of plants and animals formed in various strata of the earth's crust are called *fossils.* Literally the word fossil means, 'anything dug out of the earth.' The fossils of animals and plants were found in the rocky strata of the earth.

Fossils discovered from the strata of the earth provide nodoubt a good account of the life in the past. But it should however be remembered that the geological record available is still incomplete. *Darwin* has aptly compared the geological record or the record of rocks *to a book from which many pages have been torn and upon those that remain, only a few words are legible.*

In certain cases, however, the fossils available have enabled us to trace more or less completely, the evolutionary history of certain forms e.g., horse, elephant, camel or even man. We have been able to devise certain methods to calculate the age of the rocks as well. This helps us mainly in establishing the date of the fossils.

The stratified rocks containing fossils and specifying millions of years of earth's history have been divided into *Eras* and *Epochs.* A much simplified *geological time table* is thus given on pages, 516 and 517 and this indicates the major groups of animals that are believed to have existed during each epoch.

From the table it is revealed that various periods of the history of life covered millions of years. We can better understand the significance of these events if they are presented in another perspective. We have to imagine for the sake of comprehension, as if, these events might have occured in just *24 hours.* Under this analogy, the starting point, representing the beginning of life some two billion years ago can arbitrarily be fixed at *mid-night* i.e., zero hour. On this scale upto 1 p.m. (afternoon) first fossils were recorded. At about 6 p.m. all major groups of invertebrares first made their appearance but they did not leave many fossils. At 8 p.m land plants appeared and at 8–30 p.m. insects and amphibians joined the land plants in the panorama of life.

The reptiles made their appearance at about 9–30 p.m. and flourished till 11 p.m., when the mammals gradually started superseding them. *Man, as we know him, would have strutted on the stage at about 11–59 p.m. or less than a minute before mid night.* His age of written history would have occupied a little more than the last one-fourth of a second on the clock. *The calendar of*

The Geological Time Table Showing the History of Life on Earth

Time in millions of year since beginning of epoch	Eras	Epochs	Major evolutionary events			Time (on a 24 hour scale since origin of life)
			Type of evolution	First appearance	Peak of radiation	
1	2	3	4	5	6	7
1		Pleistocene	Cultural	Man	Flowering plants.	11·59 p.m.
10		Pliocene				
30	Cenozonic	Miocene			Insects.	
40		Oligocene			Bony fishes.	
60		Eocene			Mammals.	
75		Plaeocene				11·00 p.m.
135		Cretaceous		Mammals.		
165	Mesozoic	Jurassic		Flowering plants.	Reptiles	
205		Triassic		Birds.		9·30 p.m.

1	2	3	4	5	6	7
230		Permian		Gymnosperms reptiles.	Amphibians	
250		Pennsylvanian		Amphibians insects.	tree ferns	8·30 p.m.
280		Mississipian		Land plants.		8·00 p.m.
325	Paleozoic	Devonian	Organic	Fishes.		
360		Silurian		Algae.		
425		Ordovician				
500		Cambrian		All major groups of invertebrates		6·00 p.m.
3000	Pre-Cambrian	Pretorozoic		First fossils.		1·00 p.m.
10000		Archeozoic	Chemical nuclear	First life origin of earth.		12·00 mid-night.

Earth's history, thus, like the immensity of astronomical space, gives us a valuable lesson in humility. Our civilizations and cultures however old and ancient we may regard, are, indeed very recent on the evolutionary time scale.

Evidences from Geographical Distribution :

The branch of study which deals with the study of geographic distribution of animals in space and the factors controlling it is called *Zoogeography*. All the animals living in a particular area whether large or small are collectively called the *Fauna*.

The animals on the earth are not evenly distributed. Certain zones of the earth, determined by latitude, elevation, temperature etc., have their characteristic faunas. There are also the places with the same climatic conditions in different regions of the world where similar animal forms are not always found. Elephants for instance, occur in Africa and India but not in Brazil. The familiar animals of the British Islands and Newzealand are very different although the climatic conditions of both the islands are alike. Likewise the climatic and other conditions of the land near the north and south poles are nearly the same yet each has its own totally different fauna. *Penguins* for example are restricted to the south polar region and *Polar bears* to the north pole.

There are also examples where the representatives of particular groups of animals may inhabit widely separated places but not in the regions in between them. This type of distribution is called '*discontinuous distribution.*' A good example of such distribution is of *Lung fishes*, certain species of which are found in the rivers of South America (e.g., *Lepidosiren paradoxa*), West Africa (e.g., *Protopterus aethiopicus*) and South Australia (e.g , *Neoceratodus forsteri*). As a rule, animals with a discontinuous distribution are the members of groups of primitive animals known from the geological record to have had a much wider range of distribution in past times.

The present day distribution of any group of animals depends partly on its centre of origin and also partly the extent to which the group undertook migrations or its migrations hindered

in the past by the *barriers* or obstacles. The *barriers* or obstacles limit the distribution of animals. The obstacles of physical nature or *physical barriers* are the mountains, rivers, lakes and seas for land fauna, land and land masses for aquatic animals. Amongst the *climatic barriers* we may mention the unfavourable temperature, light and humidity which cause hindrances to land and fresh water fauna. Salinity, light, temperature, currents and tides are the obstacles for marine fauna. In the *biological barriers*, one can mention the effective competitors, dangerous enemies and also the disease and the scarcity of appropriate food in the new area.

The present day distribution of plants and animals can only be explained on the basis of organic evolution. When Darwin visited Galapago islands in 1835, the peculiarity of the fauna of these islands exerted a strong influence on his mind in shaping the concept of evolution.

The Galapago islands are a group of isolated islands in the Pacific Ocean about 600 miles west of Ecuador, the coast of South America. The Galapagos islands first arose above the surface of the sea as the result of some subterranean volcanic disturbance. They had no indigenous land animals then. Those that are found there now must have come from the mainland either by flying, swimming, being carried by wind, ocean currents or on drift wood or floating vegetation. Some might have even been introduced by man on his rare visits.

The examination of fauna of these islands reveals that although the animals found here bear some resemblances to those on the mainland, they clearly differ from them. Darwin's attention was attracted towards the several species of birds found here which did not occur anywhere else. These birds are familiarly referred to as *Darwins finches* (*Geospiza*). Darwin's studies of these isolated species greatly influenced his historic theory of evolution. Darwin discovered some 13 species of finches on the islands. Each finch displayed differences in sizes, plumage and kinds of beak. They were however basically alike. Darwin as such did not believe that these finches could have been created separately and still have so much in common. On the basis of this study, he reasoned, evolution working over millions of years had developed the different species from

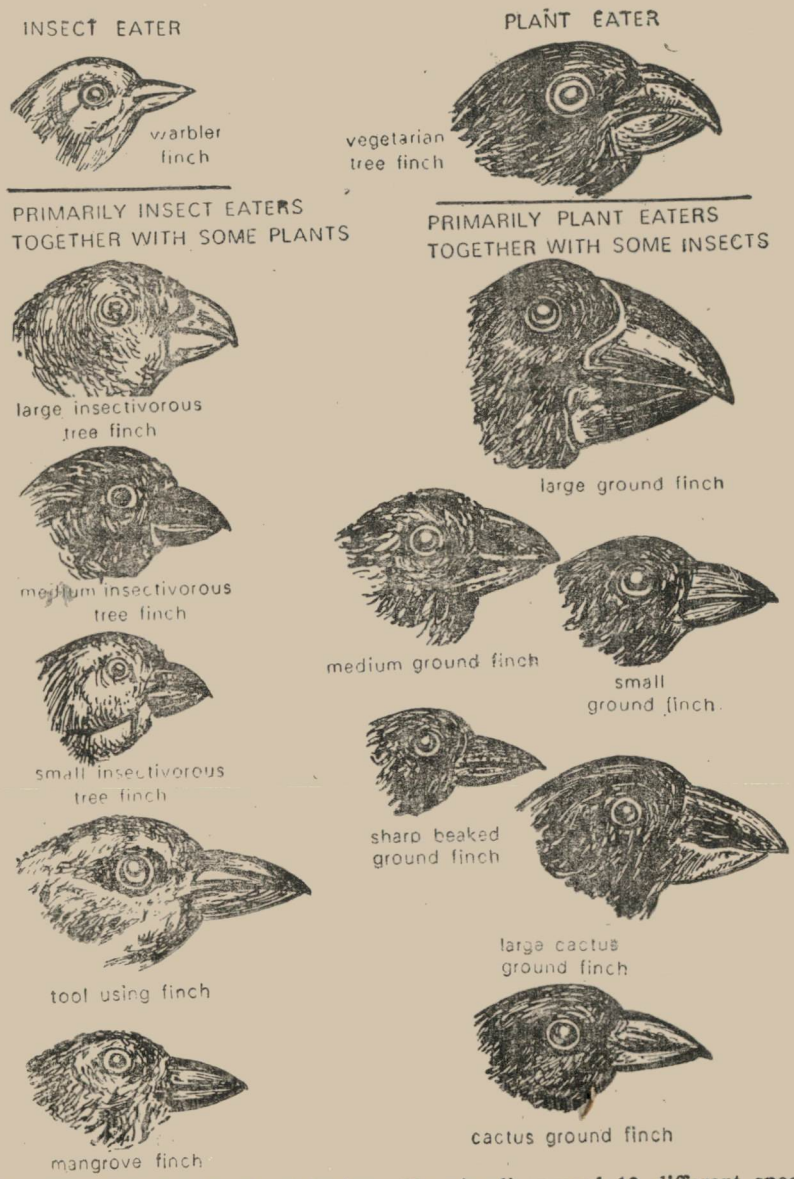


Fig. 19.3 Darwin's family of finches. Darwin discovered 13 different species of finches on Galapagos islands, each showing differences in size, plumage and kinds of beaks. They were however basically alike.

a single common ancestor. According to this, we can say that the remote ancestors of these finches were accidentally transported to these islands. The barrier of the sea was a hindrance to these finches to spread to other places. In response to the conditions of life prevailing on these islands the ancestral birds gradually evolved into the present day forms.

The zoogeographical distribution thus provides a strong evidence in favour of organic evolution. The present day distribution of animals is only understandable if we accept the following two conditions. 1. All existing animals are the descendants of extinct populations which were of a more generalised type. These wandered out from their places of origin and became modified to meet the new conditions they faced. Intermediate populations possibly died out. 2. The changes in configuration of the land during geological time resulted in the isolation of certain groups due to the erection of barriers of one sort or the other. These isolated groups later were free to evolve along different lines but were prevented from interbreeding with other populations, ultimately becoming so different that they could not inter-breed even if brought together again.

Evidences from Comparative Physiology and Biochemistry:

The evidences in favour of organic evolution discussed so far have mainly dealt with structural features. It should however be remembered that changes in structure must have been accompanied by corresponding physiological changes. The investigations performed in the field of physiology reveal that various physiological processes in the organisms and the various chemicals present in their body give a definite clue to the place of an organism in the evolutionary scale.

It has been observed that the physiology of the structurally simpler organisms is usually less complex than that of the higher animals. Further, the animals that are said to be related to one another on structural grounds show physiological similarities as well.

The primitive members of most of the main phyla and classes lived in the Palaeozoic seas or estuaries. Later, in the course of

evolution the descendants of the Palaeozoic forms resorted to land living and became adapted to their new environment. The most fully adapted terrestrial vertebrates retain even now unmistakable traces of their descent from aquatic ancestors. This is revealed by the analysis of the body fluids of both aquatic and terrestrial animals. The body fluids are fundamentally similar in composition and, further, the body fluids in their ionic composition resemble sea water.

In all living organisms various chemical processes take place. In certain processes construction or synthesis of molecules occurs. These are called anabolic processes. Along with this, organisms also perform catabolic processes which involve breaking down of molecules into simpler fragments.

The catabolism of proteins, nucleoproteins and carbohydrates helps a lot in the study of evolutionary changes that occured in the organisms in the disposal of the products of nitrogenous wastes. The metabolic reactions of amino acids mostly occur in the liver. The *ammonia* is produced in amino acid metabolism. Ammonia is highly toxic to the living organisms. It has to be disposed of from the body as any mixing of it with the blood will be fatal to the life of the organism.

In aquatic animals like fish which lives in water, ammonia, as and when produced, being highly water soluble, is soon washed out of the body. There is as such no mixing of ammonia with blood The organisms in which the end product of protein metabolism is ammonia, are called '*ammonotelics*.'

In the case of insects, reptiles and birds, ammonia cannot be washed out from the body as in aquatic animals. The bulk of the excess of nitrogen in these animals is thus excreted in the form of *uric acids* or *urates*. These are practically insoluble substances. This property of the substances favours reabsorption of water from the contents of the excretory tubules with the result that the urine is so concentrated as to be semi-solid. By the excretion of semi-solid urine considerable economy in water is also effected. The animals excreting uric acid as the end product of protein catabolism are referred to as *Uricotelic animals*.

In amphibians and mammals including man the end product of protein metabolism is urea. The elaboration of innocuous substance, urea, from ammonia released during deamination is a necessary complication of the excretory processes of land animals where the intake of water is restricted. Animals in which urea is the end product of protein catabolism are called *ureotelics*.

The energy reservoir in the muscles of all vertebrates is creative phosphate whereas muscles of the invertebrates contain arginine phosphate.

Man's haemoglobin has been intensively studied. About 100 variants of haemoglobin have been described. These variants of haemoglobin differ from the normal by the substitution of only a single abnormal amino acid. Human haemoglobin variants were useful in anthropology as '*racial markers*.' The haemoglobin of animals however is not identical with the human haemoglobin. The protein components of the haemoglobin differ and endows the pigment with different properties which are infact the adaptations to the respiratory needs of the body. It is quite probable that haemoglobin has been evolved many times quite independently. In the haemoglobin of carp and man there are multiple amino acid differences between the polypeptide chains. There are 20 polypeptide chain differences between the haemoglobin of horse and man and only 3 polypeptide chain differences between the gorilla and the man.

The chemicals and the chemical processes in the body of organisms thus provide an authentic information regarding their place in the evolutionary scale. *Chemotaxonomy* has provided valid information to the systematists to confirm or clarify the relationships of organisms that have been traced out by other means like the study of anatomy and embryology, etc.

Innumerable examples of obvious similarities between the physiology of structurally related animals strongly favours the view point that animals took origin in common stock.

Mechanism of Organic Evolution :

It is now established beyond all doubt that evolutionary changes have been going on in living organisms.

We shall now discuss the theories that have been put forward to explain how evolution takes place. Three theories about the mechanism of organic evolution were put forward. They are as follows:

1. Lamarck's theory of inheritance of acquired characters also referred to as *Lamarckism.*
2. Darwan's theory of natural selection referred to as *Darwinism.*
3. The theory of mutation by Hugo De Vries.

1. Lamarck's Theory of Inheritance of Acquired Characters:

The first clear recognition and demonstration of the fact of evolution was made by the French naturalist *Jean Baptiste Lamarck* (1774—1829). His theory was explained in his famous treatise *Philosophic Zoologique* published in 1809. Lamarck's theory introduces two basic ideas. (i) *The use and disuse of organs* which lead to structural change and (ii) *The inheritance of acquired characters* which at the same time endows the organism with an inherent capacity or 'inner want' to increase in size and complexity.



Fig. 19.4 Jean-Baptiste Lamarck (1744-1829).

Lamarck postulated that in order to meet the needs of the environment, organisms used certain structures of their body continuously. Such structures in constant use became modified. These modifications in structures acquired due to constant use, according to Lamarck, are inherited in the succeeding generations. Similarly, Lamarck mentioned that the structures which were not used tended to be less developed and this condition also was equally heritable. In order to support the above concepts Lamarck quoted the classic example of the *giraffe* which is mentioned below.

Lamarck suggested that the ancestors of the giraffe had a short neck and used to feed on small herbs. When the herbs

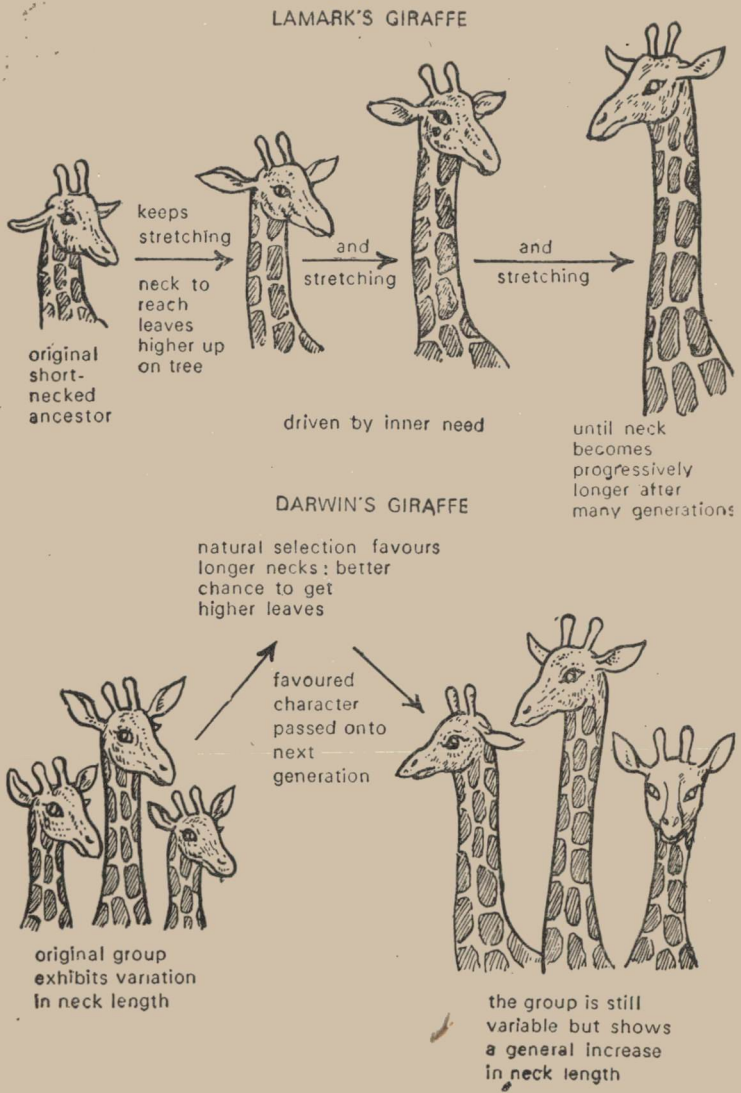


Fig. 19.5 Above : Lamarck's interpretation regarding the evolution of long necked giraffe. Below : Darwin's interpretation regarding the evolution of long necked giraffe.

became scare the ancestral forms had to browse on the leaves of trees. In an attempt to reach them they made a *conscious effort* to stretch their necks. After sometime when the lower branches had been eaten away, the giraffes were forced to stretch their necks still further. The acquired character of the increase in the length of the neck due to constant use was passed on to the succeeding generations. The offsprings continued their conscious efforts by further stretching of their necks to reach the vegetation. This acquired character thus became substantial resulting in an extraordinarily long neck as seen in present day forms of the giraffe.



Fig. 19.6 The existing forms of long necked giraffes.

The wings of the present day flightless birds according to this concept have attained their present ill-developed condition on account of their constant disuse for flight since generations.

August Weismann (1834–1914), a German biologist however opposed the assumption of the inheritance of acquired characters in the light of his theory of *the continuity of the germ plasm*. According to this theory, the inheritance is the sole concern of the germ cells (gametes) and the somatic or body cells have nothing to do with it. The use and disuse of organs in response to environmental needs effect only the somatic cells and not the germ cells. The variations or changes thus produced or acquired by the somatic cells cannot be inherited.

Lamarck's concept regarding the inheritance of acquired characters did not stand to the experimental proof. It is therefore difficult for us to conceive Lamarck's theory as a perfect answer to the mechanism of evolution. It should however be remembered that Lamarck understood well the role of environmental needs in producing changes which was so strongly stressed by Darwin.

2. Darwin's Theory of Natural Selection :

It was through the work of **Charles Darwin** and **Alfred Russel Wallace** that the *theory of evolution* finally won acceptance.



Fig.19.7 Charles Darwin (1809-1882), a methodical painstaking English naturalist. He was 66 when this photograph was taken, four years after the publication of his controversial book. 'The Decent of Man'; Darwin put creation firmly on scientific basis

Darwin's early life and his contributions : **Charles Darwin** (1809–1882) was born on the 2nd February, 1809 in the year when his predecessor, *Lamarck* as mentioned, postulated the theory of the *inheritance of acquired characters*. Darwin was the son of *Dr. Robert Waring Darwin*, a physician and the grandson of *Dr. Erasmus Darwin*, who was well known as a physician, naturalist and poet.

In 1831, soon after the completion of his university education Darwin at the age of 22, undertook a long journey for five years in the capacity of a naturalist, on a British warship *H M S. Beagle*. On December 27, 1831, the Beagle

sailed from Devonport. The purpose of the voyage was to survey the South American coastline and the islands of the Pacific. This vessel explored South America, the Galapagos islands and other regions. Darwin as a naturalist collected animal and plant specimens seen on the voyage and kept a written record of his observations.

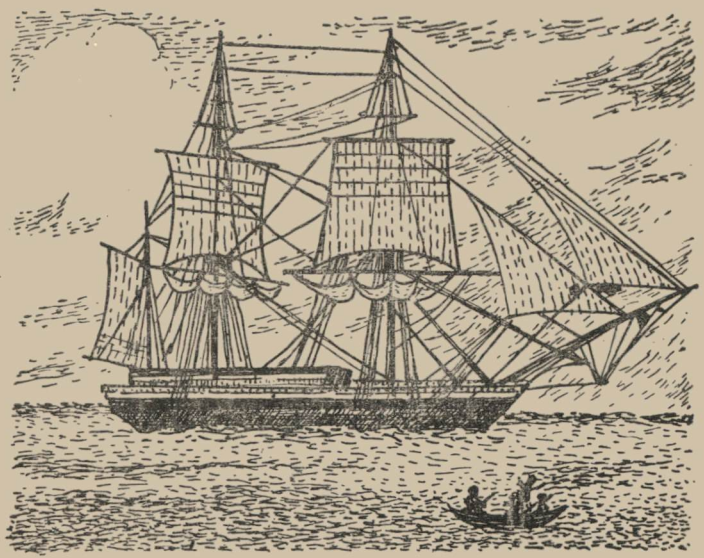


Fig. 19.8 The H.M.S Beagle—the 100 foot vessel on which Darwin spent nearly five years during his exploratory trip around the world.

On October 2, 1836, when Beagle reached the shores of England after 5 years of voyage, Darwin worked on his field notes and collections for another 20 years and arrived at certain generalisations. Darwin was convinced that all members of a species are not identical but exhibit variation in size, strength, health, fertility, longevity, instincts, habits, mental attributes and countless other characters. He was aware of the fact that desirable characters in plants and animals were obtained by man in the course of '*selective breeding*' practised in the production of cultivated plants and domestic animals since the Neolithic Age. Darwin however was puzzled over the question about the way of selection that operates on wild plants and animals in nature since the beginning of life on earth without man or a conscious being to direct it. The solution of this

puzzle occured to Darwin accidentally, when in October 1838 he happened to read **Thomas Malthus'** already famous publication, '*An Essay on the Principle of Population.*' Malthus argued *that the human race would overrun the earth if not held in check by war, famine and disease, and that there was a constant struggle to stay alive.* Darwin thus realised that under the conditions of competition in which plants and animals live, any variations would be preserved which increased the *organism's ability to leave fertile offsprings.* On the other hand, those variations which decreased the ability of organisms to leave fertile offsprings would be eliminated. In a state of nature, Darwin stated that selection works automatically and that is why called it **Natural selection.** Darwin thus was able to formulate a complete theory of evolution by **natural selection** This provides a rational explanation of the causes as well as of the fact of evolution in plants and animals.

After reading Malthus' essay, Darwin nodoubt could have announced his theory of evolution but he was so cautious and modest that he did not put it into writing until 1842 when he prepared a 35 page report on the theory. Two years later he enlarged it to a 230 page essay and showed it to a few friends. For the next fifteen years he continued to collect facts to support his ideas in an attempt to produce a thoroughly convincing work. By June 1858, 11 chapters of his book were drafted. He might have absorbed himself in his vast subject for another ten years or more but for an incredible turn of event that occured on the 18th of June 1858. On this date Darwin received an essay by **Alfred Russel Wallace,** a naturalist who lived at that time in Malaya. In the essay which ran in few pages Wallace had summarised the main points of the theory of evolution on which Darwin had spent over two decades. In this essay Darwin saw that *Wallace too has clearly outlined the hypothesis of natural selection.* Darwin nearly at one stage yielded to Wallace the honour of being the first man to announce the hypothesis. Darwin stated, "*I would far rather burn my whole book than that he (i. e. Wallace) or any other man should think I had behaved in a paltry spirit.*" His friends **Sir Joseph Dalton Hooker,** Director of the Kew Botanical Gardens and **Charles Lyell** the geologist who were informed of this crisis, acted fast. They suggested that Wallace's paper and Darwin's 1844 essay both be read to a

group of scientists who belonged to the *Linnean Society*. The papers were presented to the Linnean Society of London on July, 1, 1858 under the joint authorship of Darwin and Wallace using a single title, "*On the tendency of Species to form varieties; and on the perpetuation of varieties and Species by Natural means of Selection*."

After the presentation of the paper Darwin with a feeling of urgency completed his task of writing his book entitled "*The Origin of Species by means of Natural selection or preservation of Favoured Races in the struggle for life.*" This book was published *on November 24th, 1859. The first edition of 1,250 copies were all sold in a single day and changed man's thinking for ever.*

Theory of Evolution by Natural Selection : Darwinism :

Darwin and Wallace thus suggested a theory about the mechanism of evolution which became known as the **Theory of Natural Selection or Darwinism**. Evolution as conceived by Darwin can be summarised in the following manner.

All the plants and animals are reproduced in excess of the numbers which can actually survive. The adult populations however remain relatively constant. Consequent to this, there must be a *struggle for existence*. Members of any species vary one from the other. Some of the variations may be neutral. Other variations help or hinder the organism in its struggle for survival. This results in *the survival of the fittest—(Herbert Spencer)*. Less fit variants will be destroyed either by their physical or biotic environments (natural selection). The species thus will be gradually modified in the direction of the most advantageous variants. *The evolution as such can be defined as 'descent with modification'*—(Darwin).

The theory as suggested by Darwin and Wallace can now be expressed briefly as a logical sequence based on certain observed facts with inferences drawn from them.

1. All organisms have a tendency to multiply and produce offsprings in a *geometric ratio*. The birth rate calculated for the entire population of any area is very large whether the young ones are produced sexually or asexually. Organisms produce a far

greater number of reproductive cells than ever give rise to mature individuals (the North Atlantic female cod lays 85,000,000 eggs atonce). This phenomenon is also referred to as **prodigality of production.** The increase of species in geometric ratio from generations to generations is similar to the assumption, Malthus applied to human populations. The term *increase* in geometric ratio can be explained by quoting the example of *amoeba.* If a parent amoeba divides, it produces 2 amoebae. The next generation will produce 4 and the following generations 8, 16, 32, 64, 128 and so on. A *geometric ratio is produced by multiplying by a factor, not by addition.* Some examples of prodigality of production will now be quoted for the purpose of understanding.

Paramoecium for instance, undergoes division three times in 48 hours. If all the descendants were to live and multiply for five years *unchecked*, they will produce a volume of living substance amounting to about ten thousand times the volume of the earth !

Elephant is the slowest breeder among mammals. Darwin calculated that a single pair beginning to breed at the age of 30 and continue to do so until 100 years would produce on an average six young ones. At this slow rate even, in 750 years, nineteen millions of the descendants of elephants will be produced if all were to be alive.

An oyster may have as many as 60,000,000 eggs. If a progeny of a single oyster survived and multiplied for a number of years and the succeeding generations also continue to multiply, their number would be 66,000,000,000,000,000 000,000,000,000,000,000. The heap of shells so produced would be eight times the size of the earth !

Darwin assumed that although organisms have a tendency to increase in numbers, the number of individuals of a particular species actually remains over a resonable period relatively constant. This implies that there must be a high rate of mortality.

These two assumptions i. e., the *prodigality of production* but *relative constancy in total* number of individuals of a particular species led Darwin and Wallace to conclude that there must be a *struggle for existence* or *survival* among all species of living creatures.

The constancy in number inspite of over production, suggests that there is always a competition for food, water, light and other factors in the environment. Some organisms survive this competition and some do not.

All organisms exhibit variability (one can look around any classroom to note variability in classmates). The individuals in a species are not all identical but show variation in all characters. Even the progeny of the same parent may exhibit variability.

On the basis of this, Darwin concluded that some variations would help members of a species to survive in a particular environment whereas other variations would not be helpful. Organisms with favourable variations will have a greater chance of survival and consequently of *procreation* resulting in the *survival of the fittest*. This phrase was first coined by **Herbert Spencer**. Some variants will succeed better and others less well in the competition to stay alive. In other words, the characteristics thus favoured by selection are passed on to the next generation. The parents of the next generation will be naturally selected from among those members of the species that show variation in the direction of more effective adaptation to the conditions of the environment. (See figure 19·5 which represents the mechanism of natural selection which resulted in the selection of long necked and better adapted giraffes to survive).

Darwin's theory of evolution by *natural selection* is thus based on four propositions which he already knew to be true, and the three deductions which are now also known to be true. They are summarised below.

1. Organisms always produce a far greater number of gametes than ever give rise to mature individuals.

2. The numbers of individuals in a species over a reasonable period remain more or less constant.

3. In view of the above fact, there must be a very high rate of mortality.

4. The individuals in a species are not all identical but exhibit variations in all characters.

Due to the above facts, some variants will succeed better and others less well in the competition for survival. The parents of the next generation consequently will be naturally selected from among those members of the species which show variation in the direction of more effective adaptation to the conditions of their environment.

The resemblances between the parent and the offspring due to heredity is a fact.

7. The subsequent generations therefore will maintain and improve on the degree of adaptation realised by their parents by gradual change.

When Darwin formulated his theory, many areas of biological science were not well developed and as such Darwin could not take help from these findings in working out his hypothesis. The basic findings of Gregor Mendel (Cf. p. 475–502) in the study of inheritance were not known to Darwin and most scientists of his days. It was not known how cells divide and palaeontology then was but a young science. Inspite of all these handicaps the development of the theory of evolution by means of natural selection by Darwin was a more remarkable achievement of the 19th century.

A reference can now be made about the real meaning of the phrases like '*struggle for existence*' and the '*survival of the fittest*' used in connection with Darwin's theory of evolution by Natural Selection. Certain misunderstandings have crept in, in the interpretation of these phrases in strict biological sense. For instance, the meaning of the word *struggle* in common sense is some form of combat between the animals of the same and different species. Struggles do occur, but whether or not they have any profound influence on rates of reproduction is quite a different matter. The destruction of herbivores by carnivores is often exaggerated. As a matter of fact the indiscriminate killing of herbivores by the carnivores may deprive the carnivores of their food supplies. Likewise many forms of parasites rarely do much harm to their hosts. A balance is often arrived, in which state the parasites survive and the

host shows little or no symptoms of disease. Many groups of animals are known which have developed social and other devices to minimise struggles. The animals infact try to avoid struggle and pursue life as inconspicuously as possible. For instance, they eat when they can, reproduce when they can and further, plants have never been seen to engage in struggle at all. Thus, the phrase '*Nature red in tooth and claw*' is a myth. The term *struggle for existence merely signifies that a portion of each generation is bound to die before it can reproduce itself.*

The phrase the *survival of the fittest* or the elimination of the unfit gave rise to the feeling of '*Jungle law*,' i. e., '*might is right*' and "*Everyman for himself.*" Only in these contexts the term survival of the fittest was understood. Even today unfortunately the process of natural selection is often summed up by the phrase '*the fittest survive.*' Now of course the word *survive* means really *survive into next generation by transmitting their hereditary potentialities.* Fitness in strict biological sense and in the sense Darwin used it, is *the success in producing offspring to continue the species.* The fittest may be the mightiest and the grandest organisms in the population but it might happen to be sterile. The mule, for example, is sturdier than either of its parents—mare and donkey. Its role however in evolution is nil as it is sterile and can leave no offspring. The unfit on the other hand could be sickly, weakling, yet have numerous offspring. From an evolutionary point of view what matters is not the survival nor even the existence of individual animals, but the rate at which a particular group reproduces and multiples. The health, fitness and even actual physical struggles may affect indirectly the reproductive success of organisms. To that extent such factors may have evolutionary consequences. *The whole of natural selection, directly or indirectly is undoubtedly differential survival and reproduction of variants, and its effects in each generation.* Differential reproduction simply means that some individuals of a population have more offspring than others. If differential reproduction continues over many generations, the abundant reproducers will constitute a progressively larger number of individuals to the whole population. As a result, their genes will become preponderant in the *gene pool* of the population.

Some criticisms on Darwin's Theory of Natural Selection :

Darwin's theory of natural selection has been subjected to various criticisms. Some of the objections are discussed below :

1. One objection to Darwinism, concerned natural selection itself. *It was said that natural selection simply explains the survival of the fittest but not the arrival of the fittest.* It was argued that *if this process simply preserves or weeds out what already exists, then, how can natural selection ever create anything new ?*

Darwin unfortunately emphasized the negative aspects of selection and created the notion that it is a ruthless force, eliminating some individuals while favouring others. The idea of Darwinian selection was based upon differential mortalities which may result in differential reproduction. This type of selection is only one part of the total force of selection. Natural selection to be more precise, is any environmental feature producing a relative change in the reproduction of certain genes. Natural selection brings about evolutionary change by favouring differential reproduction of genes. Differential reproduction of genes produces changes in gene frequency from one generation to the next. Natural selection thus is a creative force in evolution since it favours and encourages efficient gene combinations. Natural selection in any event creates new adaptive relations between population and environment, by favouring some gene combinations, rejecting others, and constantly moulding and modifying the *gene pool.* Innumerable laboratory studies give support to the active and positive role of selection in the modification and evolution of populations.

2. The theory of evolution as formulated by Darwin is said to be incapable of explaining the origin of highly adaptable and complex organs which are only useful in a perfect state. The vertebrate eye or the electric organs of the electric ray, are of apparent advantage only in the perfect state. The same holds good for the numerous examples of protective resemblances and mimicry. It is doubtful if a slight variation in the wings of the ancestor of *Kallima*, the leaf butter-fly, could protect it from the enemies and thus confer any advantage on it for selection.

The above objection however is based on the idea that natural selection operates only on small variations. If we, however, take into account the selection operating also on large mutations or discontinuous variations then the objection may be clarified.

3. Natural selection theory does not account for the occurrence of vestigeal and useless organs since according to this theory only useful variations are favoured and perpetuated.

4. On the basis of natural selection it is also difficult to account for the origin of *complex coordinated structures*. In the evolution of the wings of a bird for instance we have to suppose that all the component parts of a wing—such as the integument, muscles, bones, ligaments, blood vessels and nerves simultaneously varied in the same direction. The chances of such an event happening, seem to be remote.

5. On the basis of natural selection we cannot as well satisfactorily explain the power to regenerate the lost parts. Many lizards as we know can regenerate their lost tails. A little power of regeneration in the beginning would not confer any special advantage to the creature. On the contrary, if it is presumed, that the tails are at all involved in the struggle for existence, then all the lizards without tails would have been eliminated before any regeneration took place.

6. Over-specialised structures such as the huge antlers of the extinct *Irish deer* could not be interpreted on the basis of natural selection. It is inconceivable that natural selection would operate beyond the limit of greatest usefulness so as to make an over specialised organ like the antler to become a hindrance rather than a help. We know of many examples of the animals in the past such as the giant reptiles which became extinct on account of over specialization.

On account of his ignorance about the mechanism of inheritance Darwin failed to distinguish between inheritable and non-heritable variations. The variations involving the genetic substance can only be transmitted to the succeeding generations. Certain

variations however are merely direct environmental modifications of somatic or body cells and as such cannot be transmitted to the succeeding generations.

Neo-Darwinism:

In the light of the knowledge gained in genetics, a satisfactory theory of evolution based on the interaction of heredity and natural selection has emerged which is also referred to as **Neo-Darwinism.**

The dominant school of evolutionary thinking today is based upon the Darwinian principles of the prodigality of nature, variation and natural selection. To this is further added the interpretation of variation in terms of the theory of the gene, and the study of populations and changes in gene frequency with the help of statistics. The Neo-Darwinian school is exemplified by most of the outstanding students of evolution today like *Sewall Wright*, *Th. Dobzhansky*, *G. L. Stebbins* and *Julian Huxley*.

According to the Neo-Darwinian theory, the basic phenomenon of evolution is the slow accumulation of small mutations. Mutation is an event that gives rise to heritable alteration in genotype. Mutation thus is a phenomenon by which new alleles (new genotypes) appear through spontaneous change. The mutations are of two major types (i) those involving a change in a gene and (ii) those involving a change in the structure or number of chromosomes. Mutations may occur naturally or can even be artificially induced. The combinations of the mutations are screened out by ecological factors which comprise natural selection to form subspecies, and this change is assisted by isolating mechanisms. Such isolations prevent the sub species (incipient species) from merging with the general population from which it came. Most of the subspecies ultimately give rise to new species.

According to the Neo-Darwinian theory, we can thus describe evolution as a progressive change in gene frequencies The proportion of some genes in the population increases and the proportion of others decreases. The mutations may at first be represented by a single gene. If by natural selection this mutation spreads to more and more individuals, then its frequency increases whereas the frequency of the original unmutated gene decreases. *The rates at*

which gene frequencies change is in fact a measure of the speed of evolution. The changes in gene frequency are thus due to mutations. The changes due to mutations are distributed and preserved in a population by chance. Natural selection tends to preserve those mutations which are definitely beneficial but many changes of indifferent value (i. e., neither harmful nor beneficial) are also preserved. Isolation, one shou'd remember is a major factor in the preservation of all genetic changes. The isolation of populations leading to speciation may be brought about by a geographical, ecological or genetic barriers.

Natural Selection in Action:

In the natural world, Darwin clearly noted *the force of selection* as a prime evolutionary force. He quoted innumerable adaptations through selection and thousands of new cases are recorded each year.

An interesting example to show the importance of natural selection as a prime evolutionary force is furnished by the *common peppered moth.*

In the early part of the 19th century (1830s), only the light coloured speckled peppered moth *Biston betularia* was present in Great Britain. These light forms were seen on tree trunks covered with lichens. They matched so well with the tree trunks covered with lichens that they easily escaped the sight of their predators — the birds. Upto 1845, all known specimens of moths collected were light in colour. In the same year, however, near Manchester, (England), an earlier rarely recorded, *melanic form* of the peppered moth was captured and preserved as a specimen. This melanic form was given the name *Carbonaria.* In subsequent years, this melanic form became exceedingly common near Manchester and in other parts of Great Britain. The reasons for the abundance in number of the melanic forms are as follows.

When industries developed in Britain in the vicinity of cities, the lichens were mostly killed and the tree trunks became black due to the deposition of industrial *soot.* Birds that prey on moths could now easily detect and capture the light coloured forms against the

dark back-ground of dead lichens and the soot. The melanic forms now escaped the sight of the birds and in the course of almost fifty years the dark coloured moths completely replaced the light coloured ones. Due to the industrialisation of Great Britain, by 1895, the black form of the Peppered Moth comprised 99 percent of the moth populations in Manchester. The industrial areas of Britain thus support populations of the mutant melanic forms of moths homozygous for the black phenotype. This change in gene and genotype

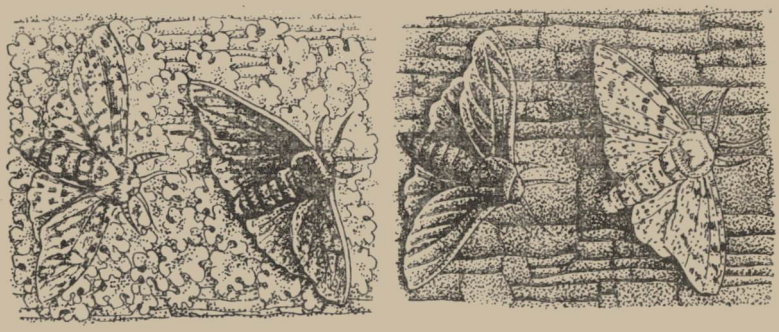


Fig. 19.9 Right: The melanic form of the moth *Carbonaria* has the advantage of being escaped from their predators—the birds, on account of the matching of their colour with the tree trunks covered with industrial soot. The light coloured moth on the other hand can easily be detected against the dark background. Left: The light coloured moths in a countryside were perfectly camouflaged to match the light coloured spotted lichens on tree trunks where it rested during the day. Against the background of light coloured spotted lichens on tree trunks the mutant black moth was quickly spotted and eaten by birds.

frequencies corresponds with the spread of industries in England during the past 120 years. *The survival of these melanic forms in the industrial areas is due to their colour pattern merging beautifully with the soot covered surroundings of the industrial cities.* This phenomenon of the survival of the melanic forms consequent to the industrialization is also referred to as *Industrial melanism. Industrial melanism was thus the name given to the phenomenon in which moths were changing their complicated patterns from light to all black colouration.* As a result of industrialization the non-melanic or the light coloured moths on the other hand became fewer in number in the industrial areas as they became an easy prey to their enemies. The increase in the number of the melanic forms to light coloured forms in the

sooty, dirty, coal-dust covered areas of England is an excellent example of natural selection. Natural selection in this case has favoured an inconspicuous colour pattern i. e., the melanic forms matching the darkened vegetation. The phenomenon of industrial melanism is also known for European industrial areas. Likewise about 100 species of moths in Pittisburgh region of the United States exhibit a similar evolutionary change, with black forms, originally rare, becoming abundant, in conjunction with the march of industry.

In quite recent years an interesting case of the appearance of light coloured moths again has been reported from Great Britain. England's landscape has begun to emerge from its layers of soots since the strict implementation of smoke control laws from 1950. Due to these laws, the trees are much cleaner and thus provided a safer resting place for any surviving light coloured speckled wing moths. With this changing phase of England's landscape, moths were collected intermittently from 1966 to 1969 in the same area where the previous survey had been made. This collection work was performed by zoologists *Lawrence Cook* and *Richard Askew* of Manchester University and *James Bishop* of Liverpool University. The results of their collections are highly significant. Of the 972 specimens collected, 25 were light coloured speckled moths. This is a clear indication of the fact that smoke control laws have made the tree trunks quite clean giving thereby now the light coloured moths better survival value than the melanic forms.

Artificial Selection :

By artificial selection, we mean a deliberate breeding by man from certain variants of the domestic plants and animals with the object of obtaining the characters he wants. Selective breeding has been practised by man since the Neolithic Age. As mentioned, it was by noticing the effects of variation and selection in domestic plants and animals that Darwin was led to think for an analogous kind of selection in nature.

Selective breeding only has produced the difference between the cabbage and cauliflower, the cart horse and the shetland pony, the Newfoundland dog and the Pekingese. Artificial selection has

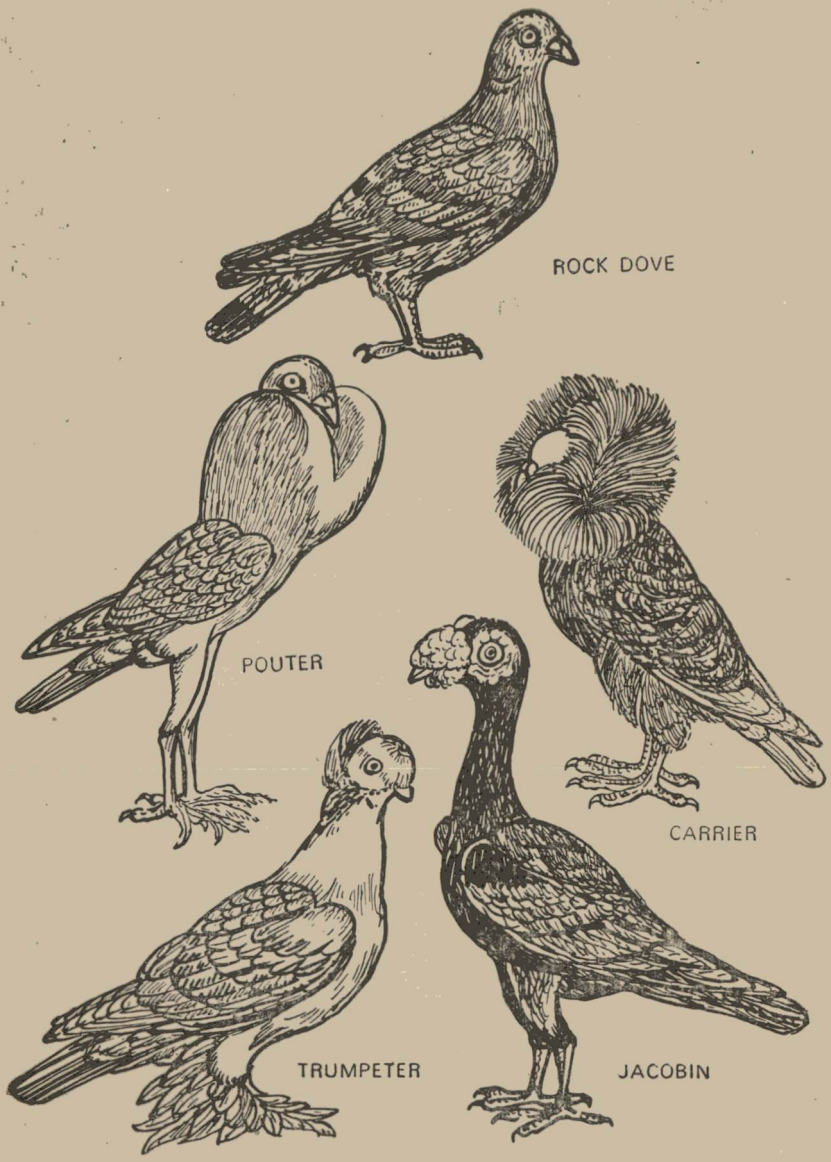


Fig 19.10 Various breeds all descended from common rock pigeon-*Columba livia* were obtained by artificial selection.

helped man in raising high yielding crops as well as milk giving capacity in the cattle. This has thus brought about *Green* and *White revolutions* (meaning the increased food and milk production respectively).

The wild Rock-Pigeon *Columba livia* is the main stock from which a large number of distinct breeds of the domestic pigeons have been obtained by man as a result of artificial selection. The variations which breeders wanted to maintain or whose features they sought to exaggerate, involve structure and behaviour. The various breeds of the pigeons such as the *pouters*, *fantails*, *carriers*, *tumblers* and so on have all descended from the wild Rock Pigeon—*Columba livia*. The Carrier and Racing-Homer have been selected for speed of flight and ability to return home; the *Tumbler* for ability to make aerial somersaults; the *Pouter* and *Fantail* for their interesting courtship activities; the Russian *Trumpeter* for its voice.

Sexual Selection:

Darwin also formulated the theory of **sexual selection** in order to explain the origin of striking colours, structures, behaviour, etc., found only in one sex of some animals, invariably the males. These structures, colours and behaviours were used by animals in fighting for mates and in the courtship.

Darwin thought that the general theory of natural selection could not account for the colour differences which so commonly characterize the sexes, nor for other types of ornamentation differentiating the sexes. The theory of sexual selection states that the female selects her mate and therefore any male which is specially attractive will have improved chances of obtaining a mate and leaving the descendants. This leads to development in the male, of brilliant colours, elaborate combs, ornamentative hooks, and in fact any secondary sex character which might be regarded as potentially attractive. Darwin included also antlers, tusks, and spurs; the evolution of which could also be accounted for by the general theory of natural selection. The idea of sexual selection requires either that males be more numerous than females, or that polygamy be the rule. Further, the ornamentation of the males should be attractive to the females. Generally speaking, the number of males

and females seem to be equal. There are also some outstanding examples of polygamous societies amongst animals. Some examples of sexual selection benefiting one sex can now be quoted.

The male Ruff, a *sand piper* has frills of conspicuous feathers which it can erect. At the breeding season the males stake out their claims of territory, fight male intruders, and court females with elaborate display. The more attractive and brilliantly coloured males are more successful in acquiring mates. Many examples of birds with brilliant plumage in males can be given which also display remarkable courtship behaviours and are thus successful in acquiring their mates. *Phalaropes* are characterized by brilliant plumage in the female and dull plumage in the male. The female in this case does the courting, while the male builds the nest and incubates the eggs.

Male elephant seals fight for breeding territories and for possession of the females which are smaller than the males. Size seems to be a considerable advantage to males of this species in their violent competitions on the beach. Larger males seem to be more successful than smaller individuals. Fighting for territory is common amongst males of polygamous species.

The antlers of male Red deer are shed and regrown annually. This causes a heavy drain on the resources of the body. The antlers are used for fighting other males. The deers being polygamous, it is deduced that the possession of antlers bestow reproductive advantage.

There is however much doubt regarding the influence of ornamentation upon actual selection of mates. The male seals referred to above have powerful tusks. The females however do not appear to have any choice of males. The females simply accept the males which is at hand when they arrive on the breeding grounds. In some cases the secondary sexual characters excite sexual activity without actually influencing the choice of mates. The courtship of males however hastens the receptiveness of the females without influencing her choice of mates. The courtship behaviour in general has more to do with sexual excitement than with choice of mates. To be more precise, simple proximity has more influence on choice of mates than does any other factor for most animals.

As the problem of sexual selection stands, few biologists would care to state categorically that it plays no role in evolution, but equally few would care to ascribe it a really important role.

3. De Vries Theory of Mutation:

The Dutch Botanist *Hugo De Vries* (1848–1935), who was also one of the re-discoverers of Mendel's laws propounded the *mutation theory* for the evolution of new species. De Vries stated that new species arise by the abrupt and more distinct inheritable variations called *mutations*. He mentioned that once a sudden change occurs in an organism then it breeds true. De Vries noted the occurrence of mutations when he was engaged in genetical studies of a species of the Evening Primrose *(Oenothera lamarckiana)*. He grew many generations of these plants and sometimes noted the appearance of certain aberrant types along with the typical forms. These aberrant types of plants were called mutants and differed from the normal type in flowers, leaves and general appearance. Two of such mutants obtained from *Oenothera lamarckiana* were named as *Oenothera brevistyles* and *Oenothera laevifolia*. *Oenothera brevistyles* had flowers with short styles and *Oenothera laevifolia* was characterised by smooth leaves These mutant plants were found to breed true to type De Vries called these mutant types as *elementary species*. Mutations observed by De Vries were found to be due to chromosomal aberrations. Darwin had also referred in his work to a number of such sudden changes to which he coined the terms *saltations* or *sports*. Darwin however had mentioned that such sudden changes have no evolutionary significance.

Many more breeding experiments on animals and plants revealed the occurrence of mutations.

In America (Massachusetts) the birth of a ram from normal parents was reported with extremely short, stumpy legs. The body of the ram was proportionately long with a saggy back and short stumpy legs. This new species of sheep was called *ancon sheep*. From this breed of sheep superior quality of wool was obtained. This new breed of sheep bred true.

Many more examples of mutations can be quoted. In animals many types of mutations occur in natural populations e.g., alibinism

in birds, rabbits, rats, mice, guinea pigs, man, etc. Other examples of mutations are polydactyly, hare-lip, cleft palate in men, white eyed condition in Drosophila, silky feathers in poultry, multi-nippled condition in sheep, double eared and hornless conditions in cattle, etc.

On the basis of occurrence of mutations De Vries suggested that new species arose as a result of large, sudden discontinuous variations or mutations and not by the accumulation in particular directions of small fluctuating variations as suggested by Darwin.

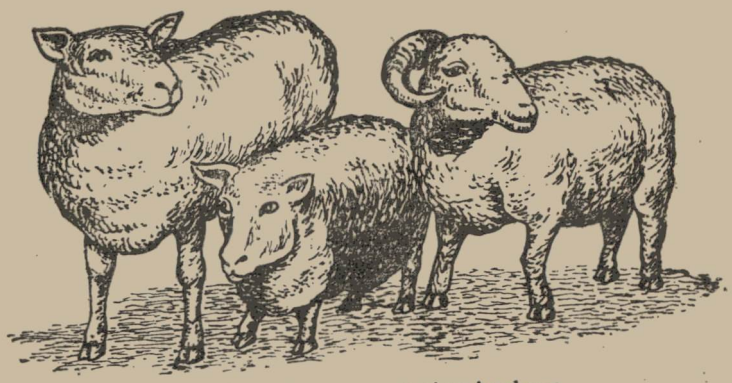


Fig. 19.11 Ancona mutation in sheep.
Left: Sheep with normal extremities. Centre: Ewe (Yoo Dial. Yo) i.e., an adult female sheep. Right: Ram i. e., male sheep with shortened extremities.

Mutations, it should be remembered are not of universal occurrence. They cannot as such furnish the complete answer to the general mechanism of evolution. Mutation merely provides the raw material of evolution; it is a random affair and takes place in all directions. Most basically natural selection, converts accidents into apparent design, randomness into organized pattern. We can put this whole matter in a nut-shell. '*The capacity of living substance for reproduction is the expansive driving force of evolution; mutation provides its raw material; but natural selection determines its direction.*' Both mutation and natural selection as such might together be considered as the contributing factors controlling the course of evolution.

Isolation—Its Role in Evolution :

Isolation is another factor in evolution. Evolution takes place when, due to various reasons, populations cease to breed with the neighbouring populations. Later under different conditions of selection these populations accumulate heritable variations in different directions. A necessary condition for the divergence in the animal groups is **biological isolation.** The divergence eventually leads to the formation of new species and higher groups. Isolation may be of three types i. e., (i) *Geographical isolation*, (ii) *Ecological isolation* and (iii) *Genetic isolation.*

1. Geographical isolation: The geographical isolation involves physical barriers such as oceans, mountain ranges or deserts which isolate the whole populations. Geographical races are the chief raw materials from which new species are formed.

The examples of Darwin's finches seen by him at the Galapagos islands in 1835 can again be referred. Charles Darwin was immediately struck by two facts. (i) All the finches showed a general resemblance to those found on the mainland of South America. (ii) Some of the islands had their own peculiar species of finch. Darwin after seeing these finches concluded that all the species of finches have descended from a common stock, and under *conditions of isolation* on different islands, have become modified by local factors of selection.

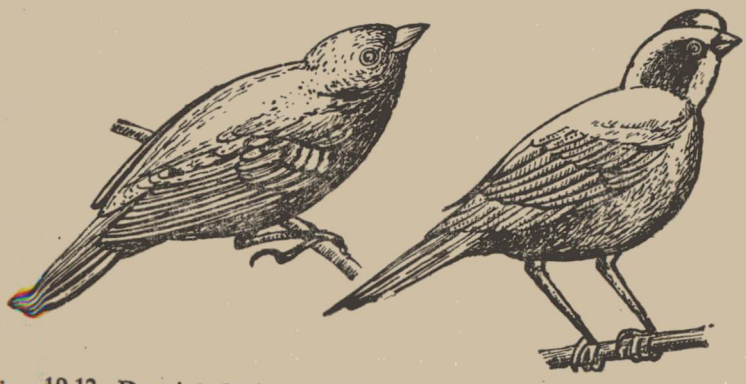


Fig. 19.12 Darwin's finches : Left : *Geospiza* sp. Right : *Camarhynchus.*

Darwin saw the species called *Geospiza pallida* which was a ground finch chiefly feeding on seeds on Albermarle island. Another species of finch named *Camarhynchus habelli* was seen on Abingdon island. It was a tree finch feeding on insects. These species of finches led Darwin to conclude that *species are not immutable* but had arisen by evolution. In this case, the geographical isolation assisted in the origin of a number of species.

Another example of the origin of species due to geographical isolation are the three distinct species of *Rhinoceros* referred to as *Rhinoceros sondaicus*, *Didermocerus sumatrensis* and *Didermoceros sumatrensis lasiotis*. These three species separately inhabit Java, Sumatra and the neighbouring mainland of Malacca. In isolated populations mutations may occur which under the influence of natural selection may lead to the formation of the sub-species and finally the new species. New species so produced in each isolated region thus became incapable of inter-breeding with the species of the neighbouring isolated regions due to genetic differences and prolonged effects of natural selection on the population of each isolated region.

2. *Ecological isolation*: Ecological isolations are those when portions of populations are separated or seggregated under different ecological conditions. Such differences of ecological conditions may be due to different modes of life e.g., feeding, breeding and nesting habits or adaptations to different temperatures, or degrees of salinity, etc.

One of the female butterfly of the species *Colias philodice* is distinguished by white colour instead of yellow. This fly is adjusted to live at a lower temperature than its white normal counterpart. It is on account of this adjustability to low temperature that the white form is more frequently found in the early morning and in the evening. These differences are controlled by a simple genetic mechanism. The yellow and white forms live in the same areas. There is neither a geographical isolation nor any sterility barrier. *There is however a partial separation in yellow and white forms based on genetic control adjusted to different environmental conditions.* In this case the environmental condition i.e., temperature has led to the production

of two distinct forms. Ecological isolation also thus plays an important part in separating the populations which become out of touch with each other and eventually evolve into new species.

3. Genetic isolation: Genetic isolation occurs when sterility between groups of individuals results from sudden changes in the gene and chromosome mechanism due to mutation or polyploidy.

Owing to actual structural differences, mating may be a physical impossibility. Sometimes the gametes may not combine, or even if they do, the resulting individual may not develop or may be sterile and unable to procreate. Mules, for example are the hybrids obtained by a cross between a mare and a donkey. They are sterile and have lost the power of procreation. It is thus a good example of genetic isolation.

As regards certain related plants it was noted that even if they live side by side they are genetically isolated due to their inability to breed and produce fertile offsprings. This inhability may be due to incompatibility between the genes and chromosome mechanisms of two plants. There are some examples where a hybrid is isolated from both its parent species by a genetic process called *polyploidy* (A plant or animal that has more than two haploid sets of chromosomes is called a polyploid). Many examples of polyploidy occuring in the plants are known. There is however scarcity of polyploids among the animals. The formation of new species of animals as such by means of polyploidy must be rare. However, one example of polyploidy in mammals is known. This is the *golden hamster*, *Mesocricetus auratus* which has twice the number of chromosomes of both the European hamster *Cricetus cricetus* and the Chinese hamster *Cricetulus griseus*. *Mesocricetus auratus* was possibly produced from the European and Chinese hamsters in the Caucasian region where their ranges over-lap.

Revision questions

1. What do you mean by the term *organic evolution*? Describe in brief the early concepts about the origin of diversity in the living forms.
2. Give an account of the various evidences with suitable examples in favour of organic evolution.

3. Describe Lamarck's theory of the inheritance of acquired characters. What are the valid grounds on the basis of which this theory about the mechanism of evolution is not acceptable ?

4. What is *Natural Selection* ? Explain this with appropriate examples. What are those solid grounds which account for the wide acceptance of Darwin's theory of evolution by natural selection ?

5. Can you give any good example of natural selection in action ?

6. Write notes on the following :
   (a) Homology and analogy,
   (b) Connecting links,
   (c) Vestigeal organs,
   (d) Fossils,
   (e) Reversions or atavisms,
   (f) Recapitulation hypothesis.

7. Discuss in brief De Vries *theory of mutation.*

8. Write short notes on the following :
   (a) Neo-Darwinism.
   (b) Palingenetic and Cenogenetic characters.
   (c) Artificial selection.
   (d) Sexual selection.
   (e) Industrial melanism.
   (f) Isolation as an important factor in speciation.

CHAPTER XX

GENERAL CONCEPTS OF ECOLOGY

Ecology is the branch of biological sciences which deals with the relationship between living things and their environment together with all the other living organisms within it. A familiar definition of ecology is that *it is a branch of biology which deals with the mutual relations between plant and animal organisms and their environments.* The key word *mutual* stresses the fact that as a rule, the most relevant part of the organism's environment is other organisms.

Ecology is thus a special field of interest for the *'Environmental biologist.'* Environmental biology, broadly speaking, is a *scientific natural history.* Under this field of study particular attention is given to the attributes of groups of organisms ranging in scope from population of one species *(autecology)* to all the populations of diverse species *(synecology)*, within an area. Further, the relations of the populations of one species with the populations of diverse species and also their relations with environment are thoroughly studied under the field of environmental biology.

The word ecology is derived from the Greek root *'Oikos'* meaning *'house.'* The term ecology thus in its literal sense is the study of 'houses' or more broadly the *'environments.'* Ecology is specially concerned with the biology of groups of organisms and their functional processes on the lands, in the oceans and in fresh waters. We can thus define ecology as *"the study of the structure and function of nature"* –(Odum). It should however be remembered that man is a part of nature, since the word nature is being used to include the living world.

To understand the nature of life, we can visualise the *levels of organisation* in the form of a *biological spectrum of living organisations*, in the following order.

Living substance ⟶ cells ⟶ tissues ⟶ organs ⟶ organ systems ⟶ organisms ⟶ populations ⟶ communities ⟶ ecosystem and the biosphere.

TABLE

The Spectrum of Non-living and Living Organizations

(Each unit is made up of the units immediately below)

	Unit	Composition
Most complex	*Ecosystem*	Community and its non-living environment.
Increasing complexity — LIVING SYSTEMS	*Community*	Several to many interacting species.
	Species	One to several genetically similar populations.
	Populations	Several to many genetically similar individuals.
	Individual	One to many cells.
	Cell	Organized living material under regulatory control of genetic materials; complex colloidal mixture of carbohydrate, lipid and protein molecules plus other substances in water.
Simplest		Organized sub-cellular living material having a single or several large protein molecules, containing DNA or RNA. The *VIRUSES*.
NON-LIVING SYSTEMS	Molecule	Two to many atoms.
	Atom	Two to many fundamental particles (protons, neutrons, electrons) bound together by energy.

Ecology is concerned largely with the levels beyond that of the individual organisms i. e., population, community, ecosystem and biosphere.

In ecology the term **population** originally coined to denote a group of people is broadened to include *groups of individuals of any one kind of organism.* One to several genetically similar populations form the **species.**

The term **community** also designated as the **biotic community** *in the ecological sense, includes all the populations of a given area.*

The community and the non-living environment function together as an ecological system or **ecosystem.** Ecosystem to be more precise, is a more technical term for nature or the living world.

The portion of the earth in which the ecosystems can operate –that is, the biologically inhabited soil, air and water—is designated as the **biosphere.**

The ecosystem thus is the basic functional unit which includes both the organisms i.e., *living* or *biotic factor* and the *non-living environment* or *abiotic factor.* Each factor influences the properties of the other and both are necessary for the maintenance of life as we have it on the earth. The organisms and the environment are inseparably inter-related and are also interactive in their nature.

The interdependence of living organisms and the abiotic environment can be explained by the following example.

Animals as we know cannot synthesise their own food. They are *holozoic (Heterotrophs).* They depend upon plants either directly or indirectly. The plants as we know are capable of synthesizing their own food. They are *holophytic (Autotrophs).* The plants however are absolutely dependent upon the abiotic environment which procures them the raw materials like water, light, carbondioxide and mineral salts for the preparation of their food. When the animals die, their bodies are subjected to putrefaction effected by a number of microorganisms like bacteria. The ultimate products of putrefaction are the organic or micro-organic substances which are added to the soil. This process thus serves to replenish the organic contents of the soil utilized by the plants. The animal excreta is also added to the inorganic content of the soil. This example gives us an idea, how a delicate and dynamic balance exists between the biotic and the abiotic environments.

One can recognise *four constituents of an ecosystem* from a *structural stand point.* These are as follows :

1. *Abiotic substances* comprising basic elements and compounds of the environment.

2. The *producers* or *autotrophs* which are largely the green plants.

3. The *large consumers* or *macro-consumers* or *the heterotrophs.* They are chiefly animals that ingest other organisms or particulate organic matter.

4. The *decomposers* or *microconsumers*, also referred to as *saprobes* or *saprophytes* which are heterotrophic organisms. They are chiefly bacteria and fungi which breakdown the complex compounds of dead protoplasm, absorb some of the decomposition products and release simple substances usable by the producers.

The place in which each kind of organism is normally found is called the *habitat*. The word has its Latin origin which means '*it dwells.*'

Each constituent of an ecosystem will now be discussed in detail separately.

1. Abiotic substances : Abiotic substances consist of inorganic materials e.g., water, carbondioxide, oxygen, nitrogen, calcium, phosphorus etc. The nitrogen and phosphorus are more often present in the form of nitrates and phosphates. Amino acids which are the decomposition products of animals are also included in the abiotic substances.

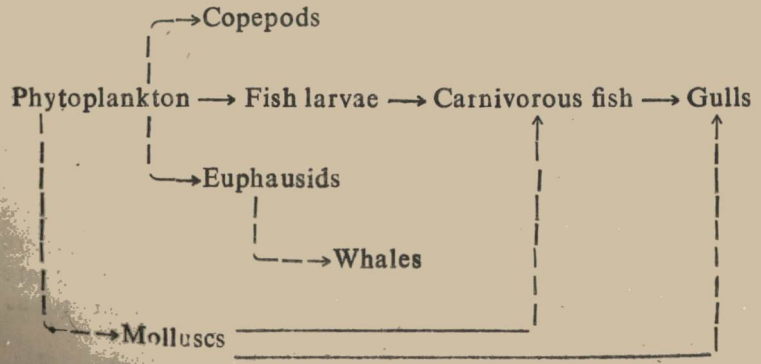
2. Producers (Autotrophs) : Producers are the living members of the ecosystem capable of synthesizing their food from inorganic or organic compounds. Photosynthetic plants are the chief members of an ecosystem. On land the autotrophs are usually large rooted plants. The grasses in the grass lands and the trees are the examples of producers in the terrestrial ecosystem. The microscopic plants and the rooted plants as well as algae are found in the aquatic ecosystem. In an aquatic ecosystem are found microscopic floating plants called the *phytoplankton (Phyto* : plant, *plankton* : floating life).

3. The Consumers (Heterotrophs) are those living members of an ecosystem which consume the food produced by the producers. Various types of animals are the consumers. The *primary consumers* in an ecosystem are *herbivores*. They graze and depend upon the plants for the sustenance of their life. A deer for example, is a primary consumer in a forest, a cow in a grass land, while a bison on a prairie. Most of the protozoans, crustaceans, rotifers, etc., are also the primary consumers in their respective habitats. These are free swimming microconsumers which are also referred to as ***Zooplanktons***.

The entire life of an ecosytsem revolves around the presence of the primary consumers or the herbivores. The primary consumers or herbivores are thus regarded by Elton as '*Key industry animals*.' The herbivores are the food of primary carnivores. The primary carnivores in their turn form the food of secondary carnivores. In order to explain this relationship, the example of a rabbit can be given. The rabbit is a herbivore and depends on plants. It is therefore a primary consumer. The rabbit in turn may be eaten by a wolf which as such, is a primary carnivore depending upon the flesh of a rabbit. The wolves form the food of a lion which is therefore a secondary carnivore. This relationship which exists between a plant, a herbivore (e.g. rabbit), a primary carnivore (e.g. wolf) and a secondary carnivore (e.g. lion) with respect to their food is known as a **simple food chain**. Besides this, a few more examples of simple food chains are thus given below.

1. Plants ⟶ Rabbit ⟶ Wolf ⟶ Lion.
2. Food grains ⟶ Rats ⟶ Cats.
3. Earthen matter ⟶ Earthworm ⟶ Bird.
   (Organic matter)
4. Oak tree ⟶ Aphids ⟶ Spiders ⟶ Small bird ⟶ Hawk.
5. Cloves ⟶ Bees (honey) ⟶ Mice ⟶ Cats or owls.
6. Phytoplanktons ⟶ Copepods (Zooplankton) ⟶ Small fishes ⟶ Dogfish.

The above are simple food chains in the form of isolated series. The food chains are also often cross linked to form a *food web* as can be illustrated diagrammatically by the following example.



4. Decomposers : Decomposers are the microorganisms which also form the living components of an ecosystem. The bacteria, for example, are the microorganisms which act on the dead bodies of organisms and break-up complex materials into simple substances. These substances are released into the environments and are thus utilized by the producers.

The last three i.e., the producers, consumers and decomposers as stated are the living organisms of an ecosystem. Of these, plants are the chief producers, animals the consumers and the micro-organisms are the essential decomposers.

All the above mentioned components are not always found in an ecosystem. One or another of the components may be absent. For instance, in the depth of the oceans the producers are not found. Their place is however taken by the dead and the decaying substance that sinks from the surface.

Pond as an Ecosystem :

A pond is a good example of a small ecosystem that exhibits a recognizable unity both in function and in structure. A general account of a pond as an ecosystem will thus be given.

In a fresh water pond, all the four basic components of an ecosystem are well represented

In the abiotic substance of a pond may be included the water, carbondioxide, oxygen, calcium, nitrogen, phosphorus, aminoacids etc.

Amongst the producers in a pond one can see the macroscopic plants (rooted plants) and the phytoplankton. In most of the ponds the phytoplanktons are the chief producers.

As regards the consumers one can see both the primary and the secondary consumers in a pond. The zooplanktons and the bottom dwellers e.g. molluscs are the examples of primary consumers. In the secondary consumers met with in ponds may be mentioned fishes and insects feeding on the primary consumers.

The decomposers in a pond ecosystem are the bacteria and the fungi.

The structure of an ecosystem may be considered from various angles.

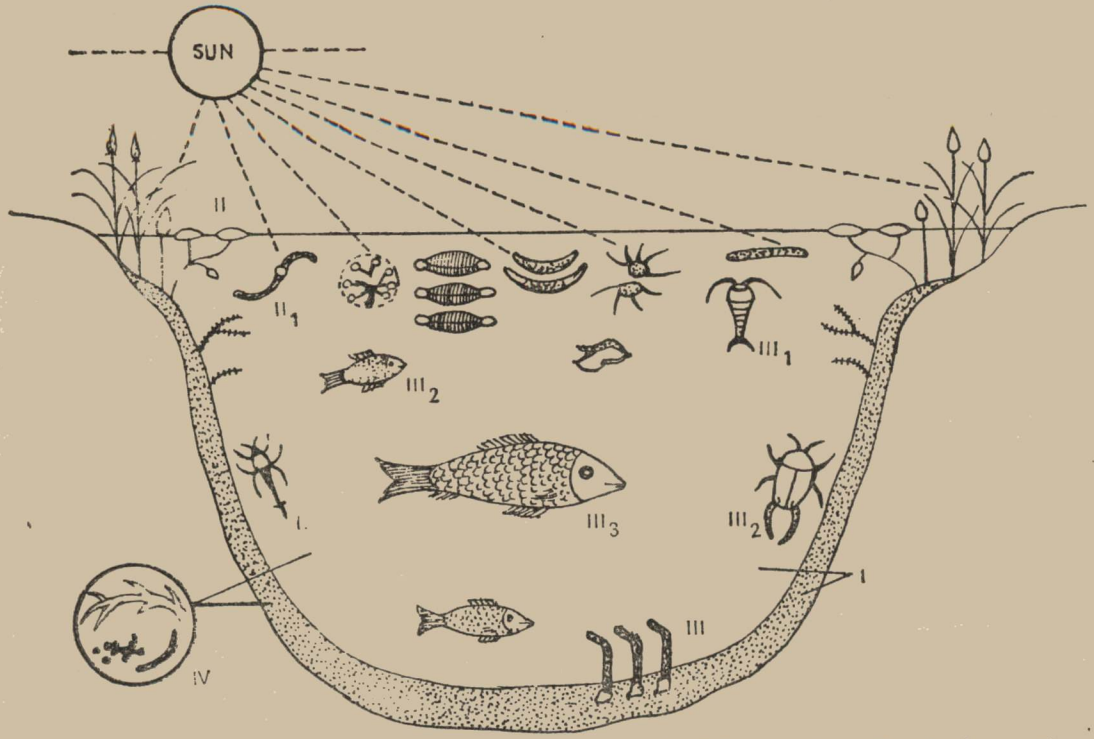


Fig. 20.1 Diagrammatic representation of a pond as an example of the ecosystem Four basic constituents of an ecosystem may be recognized. I *Abiotic substances :* Organic and inorganic matter. II *Producers :* Macroscopic plants (rooted plants) : II_1 Producers, phytoplankton III *Heterotrophs :* Primary consumers (herbivores.)—bottom forms. III_1 Primary consumers-herbivores, Zooplankton III_2 Secondary consumers (carnivores) , III_3 Tertiary consumers (Fishes) carnivores; IV *Decomposers :* Bacteria and fungi

The *producer-consumer* arrangement is one kind of structure called *Trophic structure* (trophic=food) and each 'food level' is referred to as *trophic level*. The first trophic level is an ecosystem consisting of plants or producers. The second trophic level is of herbivores and the third, the primary carnivores. If the food chain in an ecosystem has a number of cross links and many side chains, the additional trophic levels can be recognised in such an ecosystem.

The amount of living material in the different trophic levels or in a component population is referred to as the *standing crop*. This term is equally applied to plants or animals both. The standing crop can be expressed in terms of the number per unit area or terms of *biomass* i. e., organism mass. The standing crop represents the potential energy of an ecosystem. The standing crop may also be important as a buffer against physical oscillations and as a habitat or living space for organisms. The trees in a forest for example not only represent energy which provides food or fuel but they also modify climate and provide shelter for birds or human beings.

The amount of abiotic materials such as phosphorus, nitrogen etc., present at any given time can be considered as the *standing state* or the *standing quantity*. It is always important to distinguish between quantities of materials and organisms present at any one time or the average over a period of time and also the rate of change in the standing states and the standing crops per unit time.

The amount and distribution of inorganic chemicals and of organic materials present either in the biomass or in the environment are also important factors in any ecosystem. This aspect of an ecosystem may be referred to as *biochemical structure*. For instance the quantity of dissolved organic matter in water and the quantity of chlorophyll per unit area of land or water are two items of great ecological interest.

The *species structure* of an ecosystem is also of great importance. Under species structure we not only include the number and kinds of species present but also the diversity of species—that is, the relationship between the species and numbers of individuals or biomass-and the dispersion (spatial arrangement) of individuals of each species which are present in the community.

The ecosystem may be studied and conceived in rivaous sizes A small pond, a large lake, a tract of forest, or even a small aquarium can offer a convenient unit of study. Any one of the above mentioned entities may be considered as an ecosystem provided the major components of an ecosystem are present and operate together o achieve some sort of functional stability.

Revision questions

1. Define the term 'ecology' and the scope of its study.
2. What do you understand by the term *biological levels of organization*? What are those levels of organization with which ecology is concerned ?
3. Define the term 'ecosystem.' What are the chief constituents of an ecosystem ?
4. Describe the pond as an example of ecosytem.
5. Write notes on the following :
   (a) Food chains and food web.
   (b) Trophic levels.
   (c) Standing crop and standing state.
   (d) Biomass.
   (e) Biochemical structure of an ecosystem.

Two-Year Intermediate Examination

October, 1975

Part III—Sciences

BIOLOGICAL SCIENCES—Paper II

(Zoology)

I. (a) Give an account of the process of locomotion and feeding in Amoeba

Or

Describe the general characters of Annelida.

(b) Write short notes on *any Two* of the following:

1. Mantle cavity of Pila.
2. Urostyle.
3. Striated muscle.

II. (a) Write an account of the structure of the animal cell.

Or

Give a detailed account of the structure of Taenia solium.

(b) Write short notes on *any Two* of the following:

1. Cocoon.
2. T. S. of Hydra.
3. Cloaca of frog.

III (a) Briefly indicate the evidences for organic evolution.

Or

Give a detailed account of locomotion in Hydra.

(b) Write short notes on *any Two* of the following :

1. Malpighian tubules.
2. Septal nephridium.
3. Eustachian tube.

IV. (a) Give an account of the general characters of Pisces.

Or

Briefly describe the circulatory system of Earthworm.

(b) Write short notes on *any Two* of the following :

1. Mouth parts of Cockroach.
2. Hyoid apparatus.
3. Cytopharynx.

V. (a) Give a brief account of the principles of classification.

Or

What is metamorphosis? Give an account of metamorphosis in frog.

(b) Write short notes on *any Three* of the following :

1. Metatheria.
2. Histology of intestine.
3. Cytoplasm.
4. Cartilage.

VI. (a) Enumerate the general characters of Arthropoda.

Or

Give an account of the main poisonous snakes of India.

(b) Explain *any Two* of the following :

1. Ring stage.
2. Mitotic spindle.
3. Ecosystem.

VII. (a) Describe in detail the female reproductive system of Cockroach.

Or

Give an account of the structure of heart in frog.

(b) Write short notes on *any Two* of the following :

1. T. S. of Earthworm.
2. Multiple fission of Amoeba.
3. Analogous organs.

Two-Year Intermediate Examination

March, 1976

Part III—Sciences

BIOLOGICAL SCIENCES—Paper II

(Zoology)

I. (a) Describe in detail the life-cycle of plasmodium in mosquito.

Or

Give a detailed account of reproductive system of Taenia solium.

(b) Write short notes on *any Three* of the following :

1. Flame cell.
2. Multiple fission.
3. Ornithorhynchus.
4. T. S. of Vein.

II. (a) What do you understand by the term 'binomial nomenclature'? Explain the same by suitable examples.

Or

Describe in detail the respiratory system in frog.

(b) Explain *any Two* of the following :

1. T. S. of Earthworm.
2. Mitosis.
3. Metatheria.

III. (a) Describe in detail the internal structure of the heart of frog and circulation of blood in it.

Or

Give a detailed account of digestive system of Cockroach.

(b) Describe *any Two* of the following :

1. Urostyle.
2. Mouth parts of housefly.
3. T. S. of Spinal cord.

IV. (a) What is nephridium ? Describe various types of nephridia found in Earthworm.

Or

Give a detailed account of a structure of any diploblastic animal you have studied.

(b) Write short notes on *any Two* of the following :

1. Kidney of frog.
2. Bladderworm.
3. T. S. of Bone.

V. (a) Give an account of general characters of fishes.

Or

What are Mendel's laws of Heredity ?

(b) Write short notes on *any Two* of the following :

1. Non-poisonous snakes.
2. Locomotion in Amoeba.
3. Buccal cavity of frog.

VI. (a) Write a brief account of the life history of Ascaris.

Or

What is metamorphosis? How metamorphosis occurs in frog?

(b) Write short notes on *any Two* of the following :

1. Animal cell.
2. Dorsal view of frog's brain.
3. Endomixis.

VII. (a) Write an account of the role of mosquitoes and flies in spreading of human diseases.

Or

Describe external characters of leech.

(b) Write short notes on *any Two* of the following :

1. Blood of frog
2. Castings of Earthworm.
3. Squamous epithelium.

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