Puri Sir (Zoo)
unit IV :: mammals

8 Mammalia

Mammals are *warm blooded vertebrates with mammary glands, hair and diaphragm* (*Mamma*=breast).

Mammals *form the final product of evolution*. They form a very important group because of three reasons;

1. They occupy the top of the evolutionary tree;
2. They include man, the master of the present age
3. They include the largest and heaviest animals like whales.

Class Mammalia (*L. mamma* = breast) comprises animals having ***mammary glands***, ***hair***, ***diaphragm***, ***warm blood*** and ***viviparity***.

Mammals evolved during the ***Triassic*** period of the *Mesozoic* era from mammal-like reptiles. Several groups of mammal-like reptiles contributed to the early ancestry of mammals i.e. mammals had a ***polyphyletic origin***. After their origin they evolved in different directions and the ***coenozoic era*** is rightly called the "***age of mammals***".

General Characters

1. *Mammals* are *warm blooded vertebrates with mammary glands, hair and diaphragm* (*Mamma*=breast).
2. They give birth to youngones and give milk to youngones. The skin has ***sweat glands*** and ***sebaceous glands***.
3. In females, there are ***mammary glands*** to nourish the youngones.
4. Presence of ***fleshy pinna*** to collect air borne sound waves.
5. There are two ***occipital condyles*** (***Dicondylic***).

6. A *secondary palate* separates the nasal passage from the food passage or buccal cavity.
7. The *auditory capsule* projects outwards as a swollen structure, the *tympanic bulla*.

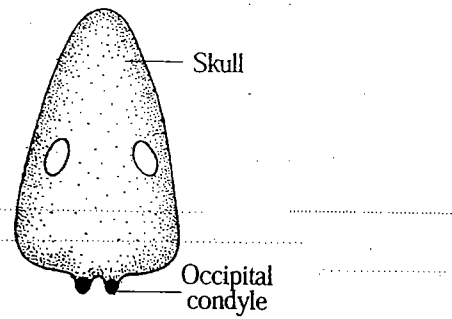

Fig.8.1: Skull of a mammal showing two occipital condyles.

8. Jaw suspension is ***craniostylic.***
9. Lower jaw is formed of a large ***dentary bone*** which articulates with the ***squamosal bone.***
10. ***Cervical vertebra*** are seven in numbers.
11. Coracoids and precoracoids of the pectoral girdle are much reduced.
12. The limbs are of the ***pentadactyl type.***
13. Teeth are ***thecodont*** (present in sockets), ***heterodont*** (different types of teeth like incisors, canines, premolars and molars) and ***diphyodont*** (presence of ***milk teeth*** in young which are replaced by ***permanent teeth***).
14. Presence of a muscular ***diaphragm*** that divides the body cavity into a ***thoracic*** and ***abdominal*** portions.

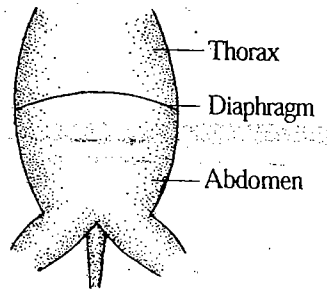

Fig.8.2: Mammalian body showing diaphragm.

15. Heart is ***four chambered.*** Only ***one aortic arch*** present on the left side.
16. RBC is ***non-nucleated.***
17. Lungs are contained in ***pleural cavity.***

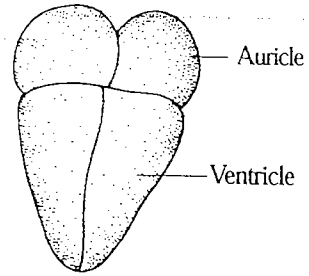

Fig.8.3: Four chambered heart of mammals.

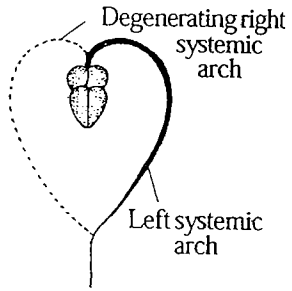

Fig.8.4: Left systemic arch of a mammal.

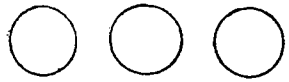

Fig.8.5: Non-nucleated RBC of mammals.

18. Presence of ***corpus callosum*** in the brain.
19. Optic lobes are four in numbers ***(corpora quadrigemina).***
20. ***Cochlea*** of the inner ear is highly coiled.
21. ***Three ear ossicles***, namely ***malleus, incus*** and ***stapes*** are present in the middle ear.

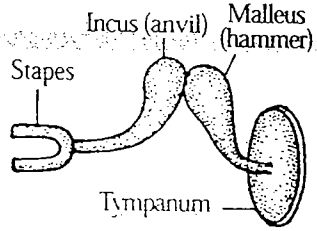

Fig.8.6: Ear ossicles of a mammals.

22. The copulatory organ is the *penis*. The testes are extra abdominal and present in the *scrotal sacs.*
23. Ovum develops in the *Graafian follicle* of the ovary.

24. All mammals except Prototheria are *viviparous*. A special structure called *placenta* develops by the union of the foetal and uterine tissues for the purposes of nutrition, respiration and excretion of the embryo.

25. Mammals show *parental care* of a high level.

Classification in Brief

Mammals are *warm blooded vertebrates with mammary glands, hair and diaphragm.*

They are included in the phylum *Chordata* because they develop a *notochord* in the embryos.

They have a vertebral column. So they are included in the subphylum *Vertebrata.*

The brain is enclosed in a cranium. So they are included in the group *Craniata.*

They have *jaws*. So they are included in the superclass *Gnathostomata.*

They have 4 limbs. So they are included in the group *Tetrapoda.*

They develop an *amnion* around the embryos. So they are called *Amniota.*

They have *mammary glands*. So they are included in the class *Mammalia.*

Class *Mammalia* is divided into three subclasses, namely

Subclass 1. Prototheria

Subclass 2. Metatheria

Subclass 3. Eutheria

Subclass 1. Prototheria

Prototheria are *egg laying mammals.*

The Mammary glands are unspeci-alized and without teats.

In the brain, there is no corpus callosum.

Pinna is absent. They are *oviparous.*

Eggs are large, yolky and shelled.

Development is *external* and there is no placenta.

Subclass 2. Metatheria (Marsupialia)

Metatheria are *pouched mammals*. They have a *marsupium* or *brood pouch. Corpus callosum* is absent.

A true placenta is absent.

The egg is small and develops in the lower portion of the oviduct.

Pinna is present.

Eg. *Didelphys* (American opossum), *Thylacinus* (Tasmanian wolf), *Myrmecobius* (Banded anteater) and *Perameles.*

Subclass 3. Eutheria

Eutheria includes *true placental mammals.*

They are perfectly warm blooded animals.

They have a true *allantoic placenta* and the embryos are kept in the uterus till an advanced stage of development.

Corpus callosum is well developed.

Mammary glands are well developed with *teats.*

Pinna or *external ear* is present.

The anus and urinogenital apertures are separate and cloaca is absent.

The testes are extra abdominal and are usually enclosed in the scrotal sacs.

Eggs are small and *alecithal* (yolkless).

Eg. *Rat, Rabbit, Cow, Elephant, Hedgehog, Monkey, Man.*

Detailed Classification

The class Mammalia is broadly classified into three subclasses, namely

Subclass 1. *Prototheria (Mono-tremata)*

It includes 2 families, they are

Family 1. Ornithorhynchidae

Family 2. Echidnidae or Tachygl-ossidae

Subclass 2. *Metatheria (Marsupialia)*

The subclass *Metatheria* include 3 orders

Order 1. Polyprotodontia

Order 2. Diprotodontia

Order 3. Coenolestidae

Subclass 3. *Eutheria*

The subclass *Eutheria* includes 16 orders, namely

Order 1. Insectivora

Order 2. Dermaptera

Order 3. Chiroptera

Order 4. Edentata (Xenarthra)

Order 5. Pholidota

Order 6. Perissodactyla

Order 7. Artiodactyla

Order 8. Hyracoidea

Order 9. Rodentia

Order 10. Lagomorpha

Order 11. Proboscida

Order 12. Tubulidentata

Order 13. Cetacea

Order 14. Sirenia

Order 15. Carnivora and

Order 16. Primates

Subclass 1. Prototheria

1. Primitive *egg laying mammals* found in Australia and neighbouring islands of Tasmania and New Guinea.

2. The mammary glands are unspecialized and without teats.

3. In the brain, there is no corpus callosum.

4. The pectoral girdle has well developed coracoid and precoracoid bones.

5. The epipubic bone is present in the pelvic girdle.

6. Pinna is absent and the cochlea is very simple, not spirally coiled.
7. The vertebrae are without epiphyses.
8. Testes are ***abdominal.***
9. Eggs are large, yolky and shelled.
10. There is no uterine gestation.
11. They are imperfectly warm blooded.

Eg. *Echidna* (Tachyglossus), *Ornithorhynchus* (Duck-billed platypus).

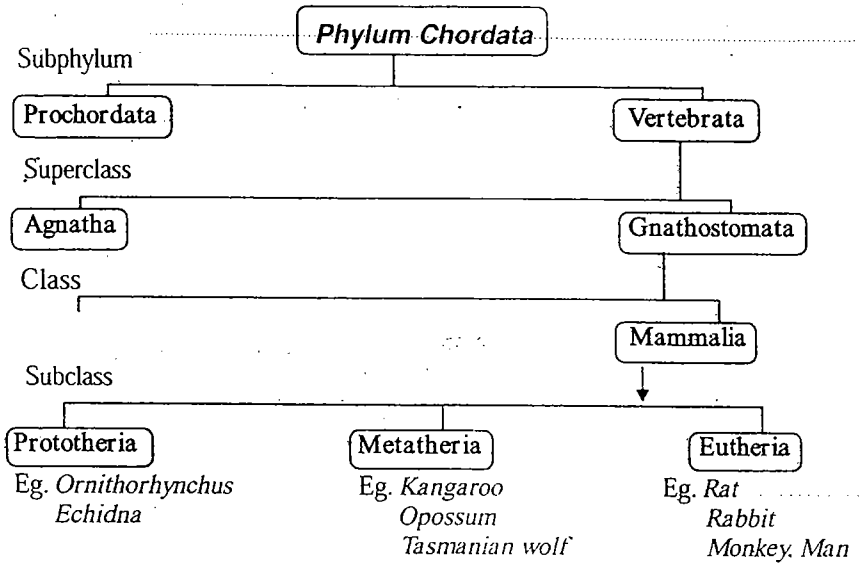

Fig.8.7: Classification of mammalia.

Subclass 2. Metatheria (Marsupialia)

1. They have a ***marsupium*** or ***brood pouch*** in which the young born in an immature state are kept and fed with milk by the mother.
2. Distinct ***teats*** are present.
3. The ***brood pouch*** is supported by the epipubic bone.
4. The number of teeth is 44. They are the only mammals to have more than three incisors on each side.
5. A true placenta is absent.
6. The egg is small and develops in the lower portion of the oviduct.
7. Pinna is present and cochlea is much coiled.

The subclass Marsupialia is divided into 3 orders on the basis of the character of the teeth.

Order 1. Polyprotodontia

In these marsupials, the incisors are numerous about four or five in the upper jaw and one or two in the lower jaw. The canines are large and the molars are furnished with sharp cusp.

They are ***insectivorous*** or ***carnivorous***. The caecum is absent or very small. The common examples are:

1. *Didelphys* (American opossum)
2. *Thylacinus* (Tasmanian wolf)
3. *Myrmecobius* (Banded anteater)
4. *Perameles*

Order 2. Diprotodontia

They are ***herbivorous marsupials*** in which the incisors are adapted for ***gnawing***. There are three pairs of incisors in the upper jaw and one pair in the lower jaw. The canines are usually small or absent. The molars are furnished with blunt tubercles. The common examples are:

Petaurus (Flying phalanger), *Macropus* (Kangaroo).

Order 3. Coenolestidae

This order includes three species belonging to the genus *Coenolestes*. They have the upper jaw resembling the polyprotodont and the lower jaw is typically diprotodont. They are ***nocturnal, terrestrial*** animals represented only in South America.

Subclass 3. Eutheria

1. They are perfectly ***warm blooded*** animals.
2. They have a true ***allantoic*** placenta and the embryos are kept in the uterus till an advanced stage of development.
3. ***Corpus callosum*** is well developed.
4. ***Mammary glands*** are well developed with teats.
5. ***Pinna*** or ***external*** ear is present.
6. There is no epipubic bone.
7. The anus and urinogenital apertures are separate and cloaca is absent.
8. The testes are extra abdominal and are usually enclosed in the scrotal sacs.
9. The ***vagina*** is single.
10. Eggs are small and ***alecithal*** (yolkless).

Order 1. Insectivora

1. The most primitive eutherians from which all other placental mammals have evolved.
2. There is a long flexible snout projecting beyond the lower jaw.
3. Teeth show the full complement.

i 3/3, c 1/1, p 4/4, m 3/3 = 3, 1, 4, 3 = 11x2 = 22x2 = 44.

4. The tympanic bulla and zygomatic arch are absent.
5. There are ***five clawed digits*** and the gait is plantigrade.
6. The ***mammae*** are arranged all along the ventral surface.
7. The placenta is ***discoidal.***
8. They are ***nocturnal*** animals either ***arboreal*** or ***burrowing.***

The common examples are:

1. *Suncus caeruleus* (musk shrew)
2. *Talpa* (mole)
3. *Paraechinus* (Hedgehog)

Order 2. Dermaptera

1. It includes *herbivorous arboreal* mammals like *Galeopithecus* (flying lemur).

2. They have a *parachute*-like fold of skin between the neck, limbs and tail. The parachute is used for gliding movements from tree to tree.

3. The dental formula is $\frac{2,1,2,3}{3,1,2,3} = 34$

4. They rest like bats suspended by the hind limbs and are *nocturnal* in habit.

Eg. *Galeopithecus* (Flying lemur).

Order 3. Chiroptera

1. This order includes *true flying mammals* like bats.

2. The wings are just folds of skin extending between the second digit of the fore limb and tail.

3. The second, third, fourth and fifth digits of the hand are elongated and support the wings. The thumb (first digit) is clawed and does not support the wing.

4. The sternum has a keel for attachment of powerful flight muscles.

5. The hind limbs are weak with five clawed digits and the knee is directed backwards.

6. The external ear or *pinna* is large and the sense of hearing is very acute.

7. Eyes are small and the sense of sight is very weak.

8. Bats possess *echo-location* apparatus which helps them to locate objects during flight.

9. The placenta is *discoidal* and *haemochorial.*

10. Bats are *nocturnal* in habit. During day time they are seen suspended by their feet, head downwards in dark *places.*

Examples: *Rhinolophus* (Horse-shoe bat), *Indian Vampire* (Megaderma)., *Pteropus* (Flying fox), *Cynopterus* (short-nosed fruit eating bat of India).

Order 4. Edentata (Xenarthra)

1. It includes *anteaters, armadillos* and *sloths* of South and Central America.

2. They are *solitary, nocturnal* and *arboreal mammals.*

3. Milk teeth are absent and the dentition is *monophyodont.*

4. Anteaters are *toothless.* In sloth and armadillos, incisors and canines are absent but the molars though present are without enamel.

5. The lumbar vertebrae have extra-articulating surface.

6. The coracoid of the pectoral girdle is fused with the acromion.

The representative types of this order are:

1. Choelepus (Sloth)

2. Dasypus (Armadillo)

3. Myrmecophaga (American anteater)

Order 5. Pholidota

1. It includes the *pangolins* or scaly anteaters of Africa and Asia.

2. The body is covered dorsally with overlapping *horny scales.* The scales are formed by the fusion of hairs. *Hair* is present inbetween the scales.

3. They are *terrestrial, burrowing* forms.

4. The snout is long and teeth are absent.

5. The tongue is long sticky and protrusible and used for catching insects.

6. The limbs are short and have five digits.

Eg: *Manis crassicaudata* (Pangolin or scaly anteater).

Order 6. Perissodactyla

1. This order includes *hoofed* mammals-like the *horse, tapir, rhinoceros, zebra*, etc.

2. They show unguligrade foot posture and the hoof is formed of uneven number of toes (odd toed ungulates).

3. Horns are absent.

4. They are herbivorous mammals in which the premolars and molars form a continuous series with broad transversely ridged crowns.

5. The stomach is simple, the caecum is large and sacculated.

6. The placenta is diffuse and epitheliochorial.

This order includes three families.

Eg. *Tapirus* (Malayan Tapir).

Egs. *Equus equus* (horse), *Equus asinus* (donkey).

Eg. *Rhinoceros indicus* (the great one horned rhinoceros).

Order 7. Artiodactyla

1. This order includes the even-toed ungulates like the *sheep, oxen, pigs* and *hippopotami.*

2. They are *herbivorous* having bunodont or selenodont molar teeth.

3. The stomach is complicated and the caecum is small.

4. Mammae are few and inguinal or many and abdominal.

Eg. *Hippopotamus, Camelus dromedarius* (single-humped camel), *Lama pacos* (Lama) (Lamas have wolly hair and are smaller in size compared to camels), *Axis axis* (Chital or spotted deer), *Cervis unicolar* (Sambur), *Bos gaurus* (Indian bison), *Bos bubalis* (Wild buffalo), *Nilgiri tahr.*

Order 8. Hyracoidea

1. It includes small rodent-like animals with a split snout.

2. The upper incisors are curved and *chisel* like. The lower incisors are *comb*-like.

3. The molars are *lophodont.*

4. A *diastema* is present.

5. The gait is *plantigrade.*

6. The stomach has two divisions.

7. The brain resembles the ungulates.

8. The placenta is *zonary.*

9. They show affinities both with the rodents and ungulates.

Eg. *Dendro hyrax.*

Order 9. Rodentia

1. It includes *gnawing* mammals like the *squirrels, beavers, rats, mice, porcupine* and *guinea pigs.*

2. Most of them are small and terrestrial.

its burrow for rest, shelter and as a nursery for the young. Originally rat was a herbivorous animal. Its food was various kinds of seeds and grains. This can be noted by examining its teeth. By practice rat has become omnivorous. It can eat practically anything that contains nourishment and is within its easy reach.

Rat is a very prolific animal. Its average life is hardly three years but its fecundity or the rate of reproduction is quite high. It becomes mature when it is 3-6 months old. It produces 4-5 litters a year; each litter contains 4-10 young. On an average a female rat produces about 30 young ones in a year.

Rats harbour rat-fleas, *Xenopsylla cheopsis*. This flea transmits the bubonic plague. The rat flea does not normally attack human beings. When the rat dies of plague, the fleas leave off the rat. Then the rat flea may seek man as an alternative host. In doing so, the fleas transmit plague. Both the species of rat (field rat and house rat) are subject to bubonic plague. Rats also carry two of the many forms of Typhus germs. *Scrub-typhus* is transmitted by blood sucking larval stages of certain mites. The Endemic or *Murine typhus* is transmitted from rat to rat by fleas, lice and mites, and from rat to man by fleas or by contamination of food.

Weil's disease is common among sewer workers. It is a form of infective jaundice; it is caused by *Spirochaete* found in the urine of rats. It is usually transmitted through a contact of skin abrasion with rats urine.

A rat-bite or a scratch from an infected rat may result in a rat-bite fever.

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2. EXTERNAL CHARACTERS—RAT

The rat has a cylindrical and soft body, gradually tapering towards both the ends. This type of body is well suited for running in narrow burrows or squeezing through small holes and crevices. Its body has a typical mammalian form. It is divisible into head, neck, trunk and tail.

The head— More or less conical in shape, the head is slightly compressed laterally. It tapers towards the anterior end, forming a pointed snout. At its front end, the head bears a pair of oblique slits, the external nostrils, and a narrow mouth, bounded by soft upper and lower lips. The upper lip is cleft in the middle, so that the front teeth are exposed even when the mouth is closed. On either side of the nostrils, the snout bears long and stiff hair called vibrissae or whiskers (Fig. 2.1). These are sensitive hair grouped into four types according to their position :

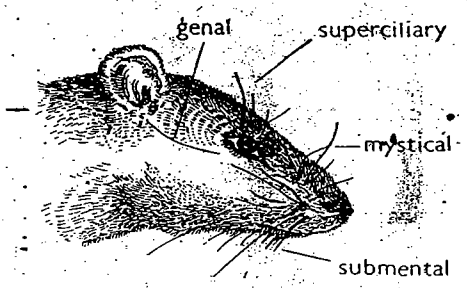


Fig. 2.1. Head of a rat—lateral view

(1) **Mystical**— located on the upper lip; the anterior ones are short but they gradually increase in length posteriorly.

(2) **Superciliary**— short vibrissae placed above the eye.

(3) **Genal**— a single vibrassa lying below the eye.

(4) **Submental**—these are are numerous vibrissae located on the chin.

The eyes are situated one on either side of the head in such a manner that they look diagonally forward and on the sides. Each eye (Fig. 2.2) is protected by the upper and lower eyelids. Both of them are bordered with eyelashes. At the inner angle of each eye, there is a transparent membrane often called the *nictitating membrane*; it forms the

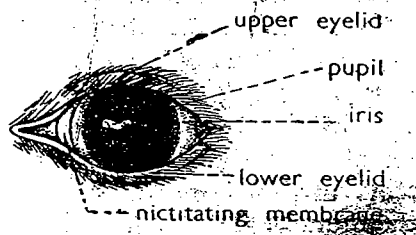


Fig. 2.2. Eye of a rat

third eyelid. As compared to the birds and frogs, it is extremely reduced to a *plica semilunaris*. The colour of the eye is due to the pigmented membrane that lies below the transparent cornea. This coloured portion is the iris. It has a central opening, the pupil, through which light enters the eye. Behind the eyes are a pair of rounded external ears or pinnae, located at the posterior end of the head. Each pinna is a large movable flap meant to catch, concentrate and direct the sound waves into the *external auditory meatus*, a passage leading to the middle ear. This meatus lies at the base of the pinna.

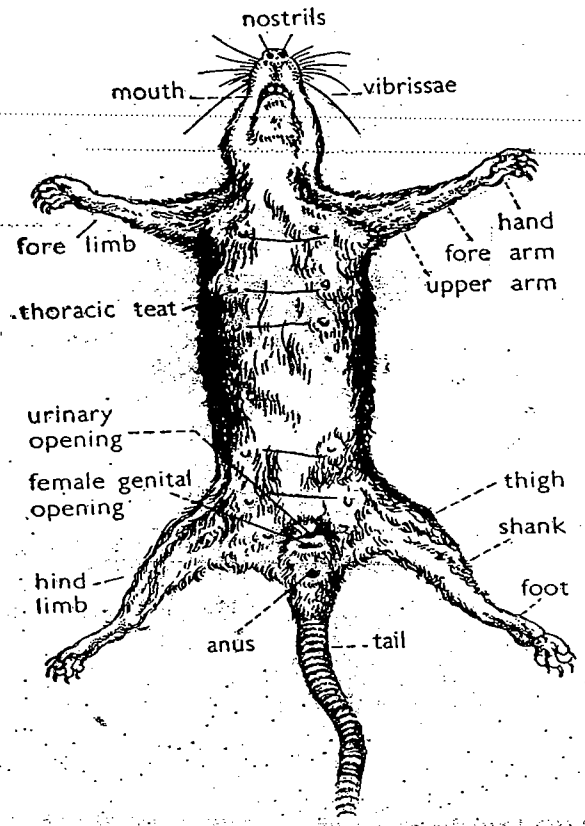


Fig. 2.3. Female rat—ventral view.

The Neck—The *neck* is short; it joins the head to the trunk. It allows free movement to the head, so that it can be turned in any direction to see the surroundings.

The Trunk—The *trunk* is elongated; it is divisible into the anterior thorax and the posterior abdomen. The thorax is supported by ribs and a breast bone; the abdomen is however soft. In the female rat (Fig. 2.3) the ventral surface bears 10-12 nipples or teats arranged on two unevenly spaced rows. Three pairs are on the thoracic region and the other three pairs on the abdominal (niguinal) one. These teats bear the external openings of the milk or mammary glands. The teats in the male are very small and often undeveloped.

The Tail—At the posterior end of the trunk is a tail; it is as long as or longer than the trunk. The cylindrical tail gradually tapers towards the hind end. It is covered over by overlapping epidermal scales arranged in rings. The rat has about 210 such rings on the tail. From below the edges of these scales, the hairs on the tail project out. The tail is much used as a balancing organ.

The anus is situated at the base of the tail on the ventral side in both the sexes. In the male, however, the anus is somewhat obscured from view by a pair of scrotal sacs (Fig. 2.4). The presence of the scrotal sacs is peculiar to mammals only. The testes or male reproductive organs are lodged inside these sacs. In front of these sacs a common urinogenital aperture can be marked at the tip of the retractile penis. The latter is enclosed in a loose sheath of skin called *prepuce*. In the female, the urinary and genital openings are separate. They lie anterior to the anus. A transverse slit-like female genital opening called vulva is situated in front of the anus. A smaller urethral or urinary opening lies in front of it.

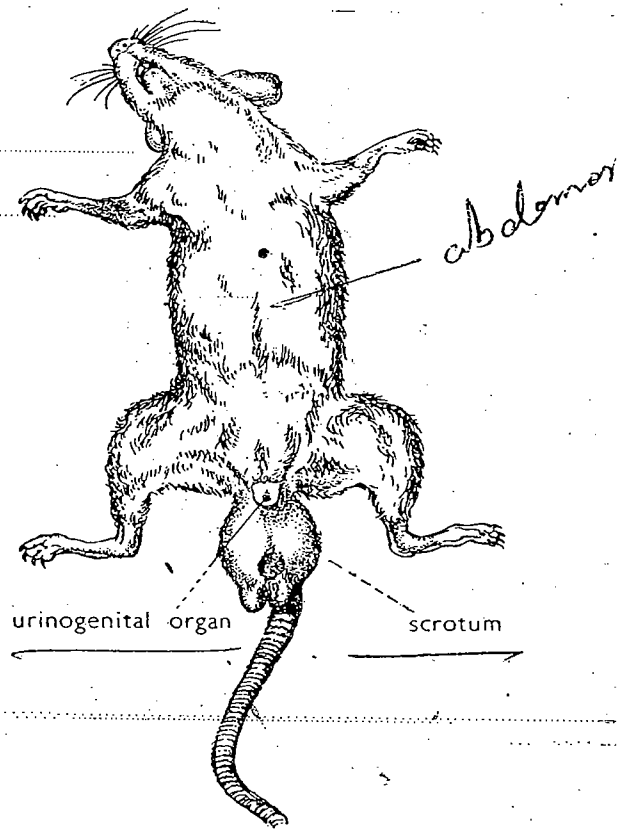


Fig. 2.4. Male rat showing the scrotal sacs

Epidermis. The outer part of the skin consists of many layers of cells only; it is formed by stratified epithelium. Some of the outer layers consist of cells that have become cornified or horny. These are dead cells. The layers together form a *stratum corneum*. Below this the epidermis shows the *stratum lucidum*. If consists of layers of clear cells. The *stratum granulosum* lies below this. The cells in this layer appear to be granular due to the deposition of a horny substance, a keratohyalin. The innermost stratum in the epidermis is the *stratum Malpighii*. It consists of a number of layers of soft and protoplasmic cells. The deepest cells are columnar in form and are set on the dermis. They are capable of active multiplication so as to produce new flat cells by division. These replace the worn out cells from the horny layers. The malpighian layer sinks deep down into the dermis at intervals, producing pitlike invaginations called the hair follicles. There is a slight hollow at the base of the follicle which is plugged as it were by the basal hair papilla, dermal in origin. Certain parts e. g. the palms and soles have a very thick epidermis; these are not covered with hair.

The dermis. It shows a complicated arrangement of connective tissue, blood vessels, muscles, nerves and a fatty tissue. The latter layer of subcutaneous fat or paniculus adipose is the deepest part of the dermis. It separates the skin from the muscular layer below it. The superficial layer of the dermis is a vascular layer; it bears numerous papillae projecting into the epidermis. Many of the papillae contain looped blood capillaries. Some of them, especially those on the palms, soles and fingers are sensory papillae. Nerve fibres end in these papillae forming the tactile corpuscles.

Epidermal derivatives. Many structures are produced from the epidermis. Hairs, claws, nails, and the integumentary glands are the chief amongst them.

Hair. The hair is a characteristic feature found in mammals only. Structures commonly called hair amongst invertebrates, especially in Arthropoda and Annelida, are really bristles and setae. They are not true hairs.

The hair is an epidermal structure developed in deep pits, the hair follicles. The hair grows from the bottom of the follicle.

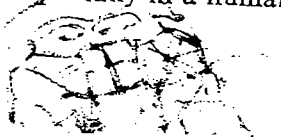
The part of the hair lying within the follicle is called its root. At the base of the hair, there is an outpushing of the dermis, the papilla. It is very rich in blood capillaries and nerves. The slender and cylindrical shaft of the hair is embeded in the hair follicle. The shaft projects beyond the surface of the skin. The hair is made up of an outer cornified layer, the cortex and the inner soft medulla. The outer surface of the cortex is modified to form a thin cuticle. The cortex contains pigmented cells that give a characteristic colour to the hair. The medulla on pith is made up of a large number of flattened, cornified and dead cells. This part frequently shows a darker appearance due to the presence of air bubbles. Into the hair follicles, sebaceous glands open. They secrete an oily substance which keeps the hair supple and water-proof.

Nails and claws. In mammals, the nails and claws are developed at the tips of the digits; in some of them hooves are formed instead. These are all derived from the stratum corneum.

Integumentary glands. Three types of glands are associated with the mammalian skin. These are sweat or sudoriferous glands, sebaceous glands and other modified cutaneous glands. Some of the latter have a double origin; they are partly sebaceous and partly sudoriferous.

(1) **Sweat glands.** Tubular inpushings are noticeable in the dermis; they are known as sweat glands or sudoriferous glands. Each one is a long, slender tubule forming a coiled knot, deep down into the dermis. The coiled part is the gland itself, while the rest of the tubule forms its duct which opens at the surface of the skin as a sweat pore. Blood capillaries from the skin supply blood to the gland. Sweat glands produce a watery secretion which contains small amounts of salt and nitrogenous waste materials. This is known as the sweat. The water from the sweat drop evaporates on the surface of the skin. In doing so it utilizes heat from the body. This has a cooling effect. This brings down the temperature of the body. On warm days a large amount of heat from the body will be utilized to evaporate it. This is helpful to maintain a constant temperature of the body.

Sweat glands are present in the skin of a large number of mammals; especially in a human being their number is greatest



Limbs (Fig. 2, 3, 5, 6). There are two pairs of limbs attached to the trunk. They are set well apart. The anterior pair, or the forelimbs, are shorter while the posterior pair, or the hind limbs, are longer. Both the pairs are so flexed that the body is slightly raised above the ground. The fore-limb shows three parts—(1) the upper arm or brachium, (2) the fore-arm or ante-brachium and (3) the hand or manus. The hand bears four digits, each ending in a curved claw. The fifth or the innermost digit, the pollex (thumb), is greatly reduced. It is represented by a small nodule; it bears a flattened nail-like claw. The hind limb is likewise divisible into the thigh, shank and the foot including the ankle. The foot bears five toes ending in curved claws. The hallux or the first digit is much shorter than the others.

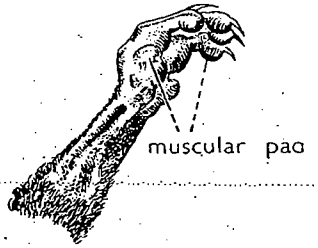


Fig. 2.5. Fore-limb of a rat showing four digits with curved claws

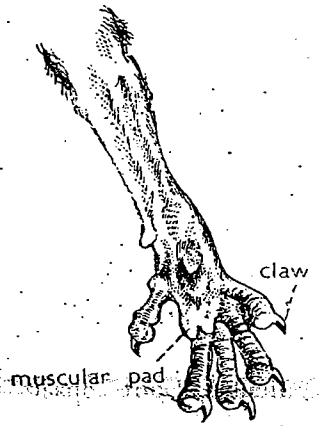


Fig. 2.6. Hind limb of a rat—note the muscular pads

The head, neck, trunk and limbs have a uniform covering of short hairs of definite pigmentation. The colour of the rat depends upon the colour of the hair. The pinnae and feet are without hair. Naturally the palms of the hands and the soles of the feet are without hairs; but they bear muscular, scaly pads called *tori* or *friction areas*. These are situated on the tips of the digits and on the palms and soles. With the help of these pads, the rat can move about without making any noise.

3 : GENERAL INTERNAL STRUCTURE

The rat is a bilaterally symmetrical, coelomate animal. The body is covered with skin; this forms a bacteria-proof and water-proof covering; it separates the internal structures from the external surroundings. Internally the body is supported by a bony framework or skeleton (Fig. 4.1). Muscles are attached to many bones from this skeleton. The animal moves with the help of these muscles. Some parts of the skeleton, e. g. backbone, the skull and the ribs can be easily felt through the skin. The movements become possible not only because of the presence of muscles, but also the joints which allow certain free movements.

Joints. As in all other vertebrates, three kinds of joints can be marked in rat.

(1) Fixed or immovable joints. In such joints the bones are joined together by a tough fibrous tissue. This may become bony in course of time. Sutures of the skull show such immovable joints.

(2) Slightly movable joints. In such joints a pad of cartilage lies between the opposing bone surfaces. The bones are bound together by a capsule of tough fibrous tissue around the cartilage. The movement with the help of such joints becomes much restricted. Majority of the joints between centres of the vertebrae, the pubic symphisis, etc. are the examples of such joints.

(3) Freely movable or synovial joints. The shoulder, hip, elbow and knee joints are of this type. In such joints the articular surfaces are covered with cartilage and the bones are held together by a capsule of elastic fibrous tissue, the ligament. The capsule is lined with a synovial membrane. It produces small quantities of synovial fluid. The fluid lubricates the movements between the opposing surfaces of the joint.

The skin. The skin of a rat, as in all mammals, is formed of two main layers the epidermis, derived from the ectoderm and dermis or cutis vera, derived from the mesoderm of the embryo. The epidermis is cornified so that it becomes tough while the dermis is fibrous and contains numerous blood vessels, nerves and small masses of fat.

Secretory organ :—

(6) It also serves as an organ of secretion. The sebaceous glands secrete oil; this oil makes the hair supple and water-resisting. The mammary glands secrete milk for the nourishment of the young ones.

(7) It helps to store the food. Reserve food is stored below the dermis as subcutaneous fat. Whenever needed food can be drawn from this stored fat.

Coelom. While dissecting the animal, the skin is found to be attached to the muscular body-wall underlying it. When this body-wall is cut open from the ventral side, a large space, the body cavity or coelom is exposed in the trunk region only. It does not extend into the head, or the limbs. It contains the coelomic fluid that bathes all the organs.

The coelom in rat is divided by a muscular, dome-shaped partition, the diaphragm, into the thoracic cavity in front and the abdominal cavity behind. The thoracic cavity is subdivided by non-muscular membranes so that the heart and lungs lie in separate chambers. These are known as pericardial and pleural cavities respectively.

The entire coelom is lined by a serous membrane which also covers all the organs in the cavities. The serous membrane consists of an outer layer of parietal epithelium and an inner layer of visceral epithelium. The parietal epithelium lies in contact with the parietles or the body-wall while the visceral layer lies in contact with the viscera or different organs in the coelom. The epithelial linings of the pleural cavities containing the lungs are known as pleura. Thus each pleural cavity has an outer parietal pleura ond an inner visceral pleura.

The two pleural cavities are separated from each other by a median space, known as mediastinum or mediastinal space; it encloses a pericardial cavity and lodges the oesophagus and blood vessels.

The pericardial cavity containing the heart is also lined by a *double membrane*. The outer membrane which lines the pericardial cavity is the *pericardium*. The inner membrane lies closely applied to the heart; it is called the epicardium. A little pericardial space lies between the two; it is filled by the pericardial fluid. This fluid is lymph-like; it serves as a water cushion for the heart.

The peritoneum forms a sheath round a number of organs forming the viscera. It also forms the suspensory folds. These are known as *mesenteries* when they support the parts of the alimentary canal. Similar folds when they support oviducts in the female are known as *mesovaria*, and mesometria respectively. Those supporting the testes in the male are called mesorchi. A transverse section through the thorax of a rat would

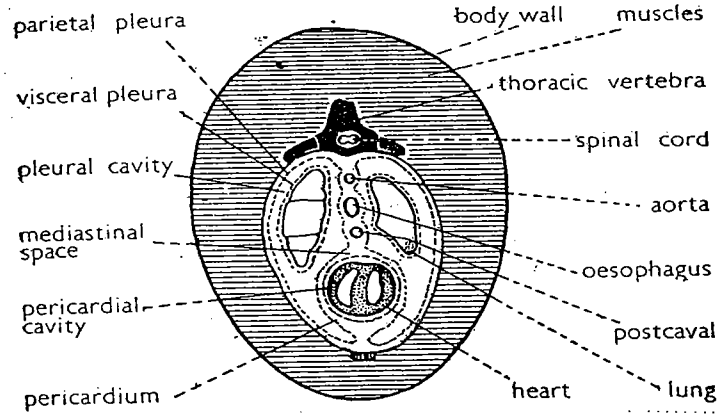


Fig. 3.3. Transverse Section of thorax (diagrammatic)

show many of these layers. The section (Fig. 3.3) shows two distinct regions : a smaller dorsal region occupied by the backbone and a ventral region with a large thoracic cavity. The backbone encloses the spinal cord and gives attachment to a considerable mass of muscles. In the ventral region the body-cavity is enclosed by comparatively a thin mass of muscles. The body-wall is lined by pleura in this region. The median reflected portion of this membrane extends right upto the ventral side so as to separate the two pleural cavities in which the two lungs lie. The heart is surrounded by the pericardial chamber that lies between the inner and outer folds of a similar membrane called the pericardium. The oesophagus being a straight tube is cut transversely and is surrounded by the visceral peritoneum. The section also shows the aorta and the caval vein cut across.

Mammary gland → milk

per square inch. The rat does not have any sweat glands because its hairs are set very close together. Some of them however, do occur in the skin of palms and soles.

(2) **Sebaceous glands.** These glands are attached to the hair follicles. They secrete oil that makes the hair supple.

(3) **Ceruminous glands.** These are found in the external auditory meatus (canal) of the ear. They are in fact modified sweat glands closely associated with large sebaceous glands. They secrete a waxy cerumen. This substance makes the auditory meatus water-proof. It also becomes useful to trap dust particles and small insects or foreign bodies entering into the canal.

(4) **Meibomian glands.** These are modified sebaceous glands located on the margins of the eyelids. They form a row of long meibomian glands with their ducts opening at the edge of the eyelids. They secrete an oily substanc on the exposed surface of the eyeball.

(5) **Lacrimal (lachrymal) glands.** These are compound, racemose glands associated with the eye. Their secretion is more or less aqueous and is called ' tear '. The lacrimal (lachrymal) or tear ducts open at the upper fold of the conjunctiva. The tear is spread over the eyeball by the movements of the eyelids. The excess of it, however, is drained into nasal cavity.

(6) **Harderian gland:** This gland lies anterior to the eyeball. It is well developed in amphibians, reptiles and birds; but it is absent in some mammals. In rat it is present. Its secretion is slightly oily; it lubricates the eyelids.

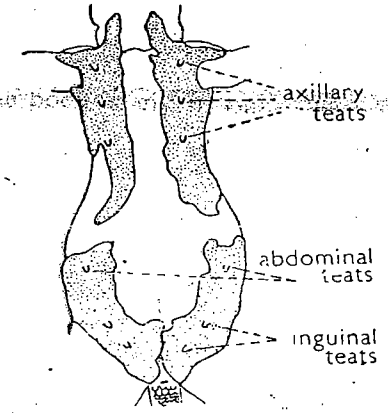


Fig. 3.2. Mammary glands—female rat.

(7) **Perineal glands.** These glands are in the perineum, close to the anus. In rat, as in rabbit, the secretion of these glands gives out a strong, characteristic smell. The smell becomes useful to attract the members of the opposite sex.

(8) **The mammary glands.** The presence of these glands is characteristic of the mammals. These glands lie under the skin of the ventral region. In the male they occur in a very imperfect and functionless condition. But they are well developed in a mature female. They undergo a considerable enlargement in the pregnant and lactate females. They secrete milk for the nourishment of the young. The young are thus fed on milk by the mothers.

Each gland consists of a branching system of ducts and alveoli. The ducts open on raised elevations called teats or nipples. The two are different. A rat usually has six pairs of teats: three pairs are in the axiliary region, one pair is abdominal and two pairs lie in the groin i. e. inguinal region. Each teat bears the opening of a single mammary gland to start with. However, during development the glands extend and coalesce into four large masses (Fig. 3.2).

Functions of the skin. (1) The skin acts as a protective covering over all the internal organs. It protects them from :

(a) The mechanical injuries and other external forces.

(b) It protects the inner tissues from drying. Because of the activity of the oil glands, it becomes almost water-proof, so that the water is neither absorbed nor given out from the body, of course excepting through the sweat pores.

(c) It prevents the entry of harmful and unwanted germs.

(d) It checks the loss of water from the body by evaporation.

(2) The sweat glands present in the skin of a mammal (not in the case of a rat) help in removing the waste products. Through the sweat the excess of water in the body is given out. This sweat may contain a little amount of waste matter dissolved in it.

(3) The non-conducting felt on the skin provides a mammal an effective insulation against excessive heat in warm weather and for conservation of heat in cold weather.

(4) Evaporation of sweat from the surface of skin regulates the temperature of the body.

(5) It acts as an organ of sense. Due to the presence of the nerve endings in the form of touch corpuscles, it acts as a tactile organ. It receives stimuli due to pressure, pain and temperature.

stratified epithelium with cornified superficial layers. The muscles of the tongue are of two types : (1) extrinsic muscles that originate from the bones of the skull and (2) intrinsic muscles that lie entirely within the tongue. The former move the whole tongue while the latter are responsible for altering its shape. The tongue is used to move the food in the buccal cavity while it is being chewed. It helps in mixing the food with the saliva from the salivary glands. It also helps swallowing the morsel of food by pushing it into the gullet. On the dorsal surface of the tongue except for a small part, small elevations, the papillae are marked. These are of three types : *filiform, fungiform* and *circumvallate* papillae. The cone-shaped filiform papillae are very numerous. They are formed entirely of epithelial cells. The overlapping cornified cells form the projecting parts. The fungiform papillae are slightly elevated above the surface. Each such papilla is formed from the underlying lamina covered over 3 or 4 rows of epithelial cells. Each papilla has a single taste bud at its centre. A singie circumvallate papilla is situated at the base of the tongue in the middle line. It does not project above the surface and is surrounded by a circular groove. Both the walls of the groove contain stratified squamous epithelium, however, their superficial cells are not cornified. The groove contains numerous taste buds. These are sensitive to certain stimuli. With their help rat can know the taste of its food, however, the majority of flavours are simply smelt.

Each taste bud contains two types of cells : the tall peripheral supporting cells and the slender, neuro-epithelial cells that end in hairlike processes. The peripheral cells enclose a small central space; this is the taste pore. The processes of the sensory neuro-epithelial cells project into the taste pore.

At the base of the tongue numerous serous glands are present near the circumvallate papilla. Their short ducts open at the base of the groove. Small lobules of mucous glands are present laterally and dorsally; their ducts open directly on the surface of the tongue.

Teeth—The teeth of a rat, like those of other mammals, are *thecodont*. They are set in sockets of the jaw bones. They are also *heterodont*, i. e. all of them are not alike. They are divisible

into groups : incisors and molars. In some mammals e. g. cat, dog, etc., there are canines, the pointed teeth. They are lacking in the group Rodentia to which rat belongs. Similarly most of the mammals are *diphyodont* i. e. they have two sets of teeth : milk set and permanent set. The milk set consists of incisors, canines and milk molars called premolars. These fall off soon and are replaced by the adult incisors, canines, premolars and molars.

Structure of a typical mammalian tooth—The thecodont tooth of a mammal is fixed in a socket. The exposed part of each tooth is known as the *crown*; the part embedded in the alveolus (socket) of the jaw bone is the *root*. The part in between the two is slightly narrow; it forms the *neck*. Each tooth thus has got a root, a neck and the crown, The crown is covered over by a hard and shining white substance called the enamel. This is the hardest substance in the body. The neck and root of a tooth are covered by a bone-like cement.

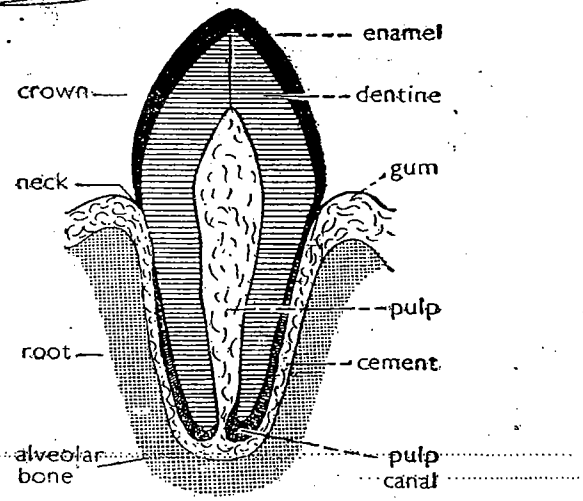


Fig. 5.3. Structure of typical mammalian tooth

The bulk of the tooth is formed by a hard substance called *dentine* or ivory. It is produced by a special layer of cells called odontoblasts. These form a layer inside the dentine and enclosing the central pulp. The pulp fills up the core of the tooth and contains a soft or loose connective tissue, blood vessels and nerves. Normally the growth of a tooth is limited to a certain period. After that it ceases to grow and its root becomes constricted. Such a tooth is often called a rooted or closed tooth. In some teeth e. g. the incisors of a rat, the growth continues throughout the life of the animal. Their roots do not get constricted. Such teeth are spoken of as the rootless or open teeth.

5. THE DIGESTIVE SYSTEM

The digestive system of a rat consists of its alimentary canal with its associated mesenteries and glands (Fig. 5.1). The alimentary canal is a continuous tube that starts anteriorly at the mouth and ends posteriorly at the anus. The following regions can be recognised in it: mouth, buccal cavity, pharynx, oesophagus, stomach, small intestine, large intestine ending in the anus. The glands associated with the canal are the salivary glands, liver and pancreas.

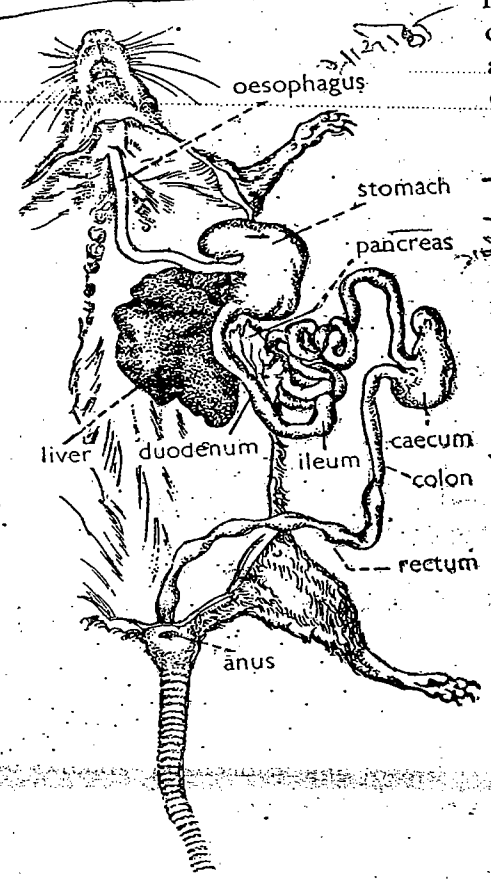


Fig. 5.1. The alimentary canal of a rat

Mouth—The head shows more or less a pointed snout. The mouth is the opening at this narrow end bounded by the upper and lower lips with the corresponding upper and lower jaws. When the mouth is opened, the mouth or the buccal cavity is seen.

The buccal cavity—(Fig. 5.2). This cavity lies between the mouth and the pharynx. It is supported by the jaws. The upper jaw is fixed while the lower jaw is movably articulated with the skull. Both the jaws bear teeth. The jaws and teeth separate the buccal cavity into a median oral cavity and a peripheral *vestibule*. The latter is bounded by jaws internally and by lips and cheeks externally. There is a large toothless space in between the *incisors* (cutting teeth) and the *molars* (grinding teeth). This space

usually occupied by tissues of the lips and cheeks; hence the vestibule becomes discontinuous. The oral cavity is widest in the region of the molars. Posteriorly it narrows and leads to the pharynx. The oral cavity is bounded on sides by the jaws; on its floor there is a muscular tongue and its roof is formed by the palate.

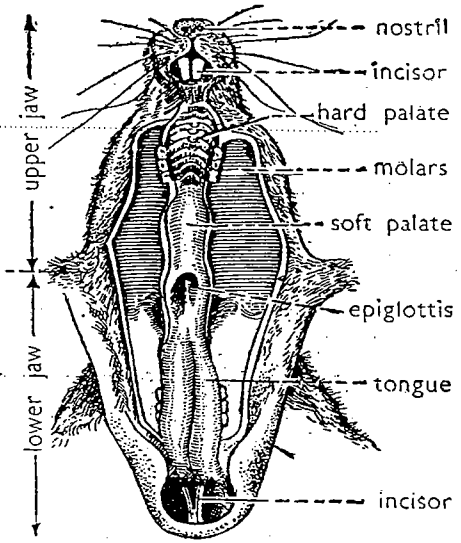


Fig. 5.2. Buccal cavity of rat as seen from front

The *palate* separates the oral cavity from the nasal one. It is hard in front and soft behind. The front part of the palate supported by the bones is known as the *hard palate*. The posterior part, however, consists of striated muscle fibres covered over by fibrous connective tissue and the mucous membrane; it is called *soft palate*. Prominent transverse *palatal ridges* formerly called rugae are present on the roof of the oral cavity. Of these, the first three on the anterior side are very prominent. They are situated anterior to the molars. The rest lying posterior to the molars are W-shaped. Minute spines are present on these ridges. The soft palate is very flexible. It extends posteriorly and forms the roof of the *oropharynx*. Above the soft palate there lies a part of the pharynx described as nasopharynx. Both these parts—oropharynx and nasopharynx—become continuous or communicate with the *laryngo-pharynx*.

The tongue—The tongue is very muscular; it has a ridged and rough surface. It shows one prominent median groove on the dorsal surface. The ridges and grooves on the tongue fit into the grooves and ridges of the palate. In resting position of the tongue, this condition almost fills the buccal cavity. This prevents the inhalation of dust while gnawing. The tongue is covered over by

below the soft palate, and the (3) laryngopharynx, the region between the soft palate and the oesophagus. From the laryngo-

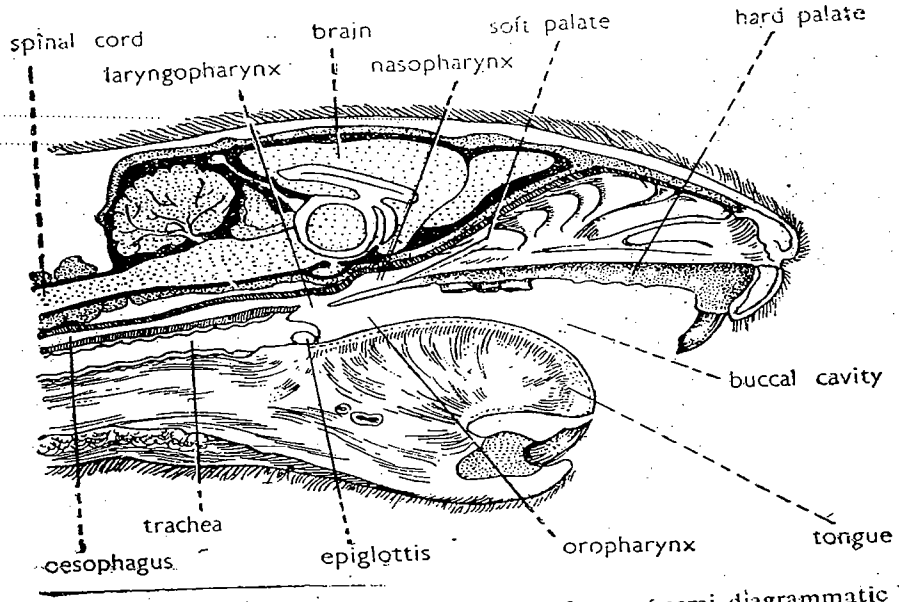


Fig. 5.5. Vertical section through the head of a rat (semi-diagrammatic)

pharynx lead two tubes, oesophagus and trachea. The opening of the trachea lies on the ventral side of the pharynx; it is known as the glottis; this prevents the swallowing food from entering the trachea. In rat the epiglottis exiends to the edge of the soft palate. Thus in swallowing, the food passes through the oropharynx and laryngo-pharynx, while the air taken through the nostrils passes through the nasopharynx and the laryngopharynx.

Most of the surface of the pharynx is lined by the stratified squamous epithelium. Its superficial layers are cornified. The submucous layer is composed of a dense connective tissue. The muscular layer consists of straited muscles. Between the muscles are mucous glands whose ducts open to the surface.

Oesophagus—It is a narrow but dilatable, straight part of the alimentary tract. It connects the pharynx with the stomach. It runs back through the neck and chest. Anteriorly the oesophagus lies dorsal to the larynx or voice box; in the neck region,

it lies parallel to the trachea. In the thoracic region it lies dorsal to the heart and in between the lungs. It perforates the diaphragm and on reaching the abdominal cavity, joins on to the stomach.

The wall af the oesophagus is muscular. The mucous membrane consists of stratified squamous epithelium. The superficial cornified cells form a very thick layer. This membrane is thrown into longitudinal folds. The muscular layer contains striated fibres throughout. There is a longitudinal layer of muscles on the outer side and a circular layer of muscles on the inner side. These act alternately and antagonistically. Their actions produce undulating movements called peristaltic movement. The movement starts at the anterior end of the oesophagus and is gradually passed on like a wave towards its posterior end, i. e. towards the stomach. This phenomenon is known as *peristalsis*. It helps the food bolus to be driven to the stomach. In its mucous membrane there are no special glands but a large number of goblet cells secrete mucus.

The stomach—The stomach lies on the left side of the abdominal cavity, close below the diaphragm. It is a large sac showing externally a division into two distinct portions—a thin-walled translucent portion on the left side, the cardiac portion and a muscular opaque portion, on the right side, the pyloric one.

Stomach of rat—Regions show distribution of spestric glands (diagrammatic). These two regions differ internally too. The cardiac portion is smooth and free of folds whereas the lining of the pyloric region is folded. Internally the stomach shows two distinct regions : (1) the non-glandular region near the entrance of the oesophagus and a part of the cardiac region and (2) the glandular part including the lower part of the cardiac region called *fundus* and the pyloric region.

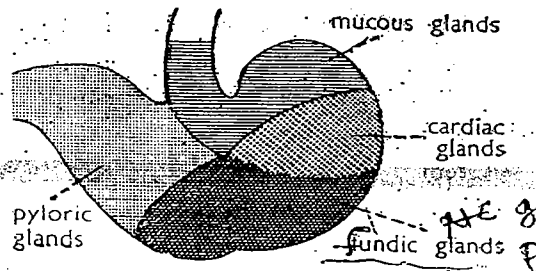


Fig. 5.6. Stomach of a rat—region showing the distribution of gastric glands (diagrammatic)

The dental formula—The number of different teeth is definite and fixed in any given mammal. Since the arrangement is fixed, it is possible to express the dentition in a fractional form : the number of teeth on the half of the upper jaw and the corresponding teeth on the half of the lower jaw are indicated as numerator and denominator respectively. This fractional representation of the teeth is called the dental formula. The names of teeth are written in short form. Thus the dental formula of man is

$$\frac{2123}{2123} = 32;$$ that of a dog is $$\frac{3142}{3143} = 42.$$

Rat is *monophyodont*; it has no milk teeth. This means there are no premolars; all the grinding teeth are molars. The teeth of a rat are highly specialised due to the gnawing habit of the animal. It has two incisors on the upper jaw and two on the lower one. These are open teeth; they grow continuously throughout life. In rat there are no canines and premolars. Thus there remains a large gap between the incisors and molars; it is known as *diastema*. The molars of rat have many cusps or ridges on top which grind the food. Each molar has several roots, not less than three. There are twelve molars; three on each side of each jaw. Thus the dental formula of a rat reads as follows :—

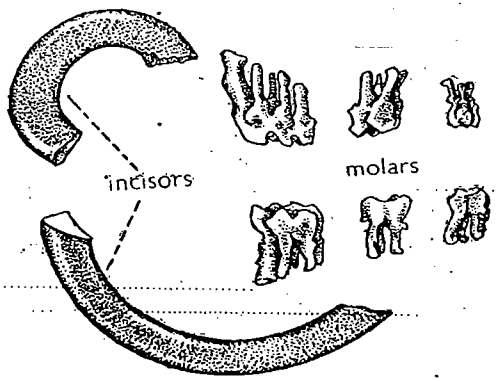


Fig. 5.4. Teeth of a rat

$$i\ \frac{1}{1},\quad c\ \frac{0}{0},\quad pm\ \frac{0}{0},\quad m\ \frac{3}{3}\quad \text{or}\quad \frac{1,0,0,3}{1,0,0,3}$$

Salivary glands. The salivary glands are associated with the buccal cavity. In rat there are four pairs of salivary glands : *parotid, submaxillary, major sublingual* and *minor sublingual*. The parotid gland is conspicuous in both lateral and ventral views. It is not a compact structure but is large and irregular. It is composed of several small elongated lobules. The alveoli of the lobules are composed of serous cells, pyramidal in shape. It runs well up behind the ear and down, to come in contact with the lymph glands of the neck. The parotid duct (Stenson's duct) is formed by the union of three principal branches; it crosses the masseter and opens opposite the molar teeth.

The two large submaxillary glands are the most prominent structures of the ventral cervical region. They lie under the chin and extend down the neck almost to the sternum. Their mid-ventral borders are continuous. They are compound, branched tubulo-alveolar glands. Each lobe is divided into several lobules which are surrounded and separated from each other by connective tissue membranes. According to Oppel the submaxillary gland of rat is a serous gland; it does not contain any mucous cells. The serous cells are pyramidal in shape with darkly staining nuclei lying at their bases. The cells rest on a basement membrane. Scattered between the membrane and the glandular cells are stellate or 'basket' cells. Closely applied to the antero-lateral surface of the submaxillary and which appears at first to be a lobe of the submaxillary is the major sublingual. This gland lies in contact with the mucous membrane of the floor of the mouth. It is small and rounded. It is composed of one large lobe divided into several smaller lobules. Their alveoli are composed of mucous cells. The ducts of the major sublingual glands run almost parallel with those of the submaxillary. Both of them open together. The minor sublinguals are irregular and flattened. They lie under the sides of the tongue. Their ducts are small and open below the tongue.

The salivary glands secrete *saliva*. It flows into the mouth cavity through the salivary ducts.

Pharynx—The buccal cavity leads posteriorly to the pharynx. It is the region between the oral cavity and the oesophagus, as well as between the nasal cavity and the trachea. In fact it is a region common to both the digestive and respiratory systems. As mentioned above the pharynx consists of three areas : (1) nasopharynx lying above the soft palate, (2) oropharynx lying

called villi. The villi of the duo-denum are tall and lear-shaped; they are wide at the base and narrow at the tip. In the ileum, they are cylindrical in shape. Bctween the bases of the villi are the openings of the tubular intestinal glands called the *krypts* of *Lieberkuhn*.

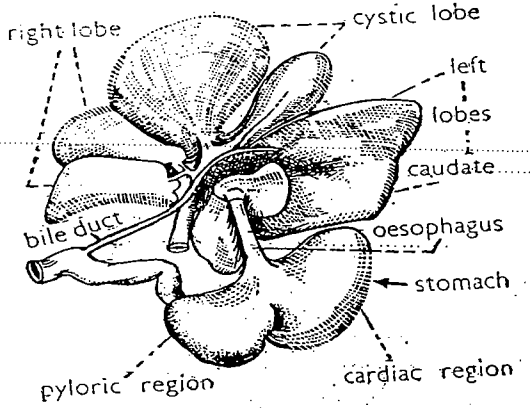


Fig. 5.8. Stomach and duodenum with liver

Each villus contains a network of fine blood capillaries around a lacteal embedded in a reticular tissue. Its surface is covered over with tall columnar cells whose nuclei lie at their thirds. They have striated cuticular borders at their free surfaces. These epithelial cells continue into the glands too. Numerous, oval goblet cells are present, scattered amongst the columnar cells. They are very numerous in the ileum. The muscularis mucosae is very delicate. The submucosa consists of loose connective tissue. In the submucosa of the duodenum lie the duodenal glands or *Brunner's glands*. These are coiled, tubuloalveolar mucous glands. They are lined by cuboidal epithelium. Their ducts open at the bases of the intestinal glands.

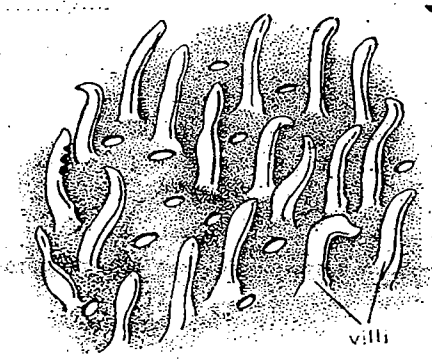


Fig. 5.9. The inner surface of the small intestine shows villi

An inner wall developed circular and a thin, outer, longitudinal layer of smooth muscles form the muscular coat. It is covered over by the seorsa.

In the ileum the wall shows numerous villi. Solitary lymph nodules occur in the submucuous coat. They often aggregate

together to form *Peyer's patches*. Where these patches are present the villi are either absent or shortened.

Large intestine—The small intestine is followed by the large intestine. At the junction of the two is a blind outgrowth called *caecum*. The large intestine shows two parts : *colon* and *rectum*. The latter opens to the exterior by the anus.

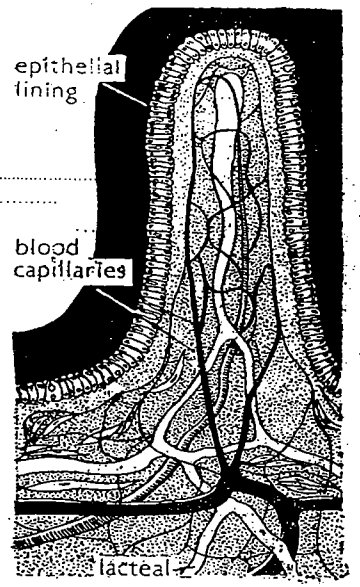
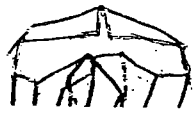


Fig. 5.10 Section of villus (diagrammatic)

The caecum is enormously developed in rabbit and herbivorous animals. Similarly it is provided with a conspicuous *appendix*. In rat, the caecum is well developed but not large and its blind end represents the appendix. However, there is no typical vermiform process. There is an ileo-caecal valve developed at the beginning. The typical villi of the ileum are absent in the caecum.

The colon shows conspicuous diagonal folds internally (about fourteen in number) in its first or ascending part. These are the folds of the mucous membrane; they are seen externally too, as the wall of the colon is rather thin. In the latter or descending part of the colon and in the rectum, the faecal matter appears pallet shaped : this often gives a beaded appearance to the rectum. The anus has thick, stratified, squamous epithelium, which becomes continuous with that of the skin. It is a sphinctered aperture with striated muscle fibres.

Liver—The liver is the largest gland in the body; it lies just beneath the diaphragm. It is attached to the diaphragm by the falciform ligament. It consists of four lobes : the right, left, median or cystic and caudate lobes. The right lobe is large and partially subdivided into two, the anterior ond posterior portions. The left lobe is also large but undivided. The cystic lobe has a



The glandular region contains the gastric glands proper. The part of the cardiac-region shows a large number of goblet cells forming glands similar to the oesophageal glands. The remaining part of the cardiac region shows simple cardiac glands secreting mucus. The main region in the middle is the fundus. The gastic glands in this region are the fundic glands; they produce the main active secretion consisting of the enzymes *pepsin* and remin together with hydrochloric acid and mucus. The pyloric region towards the duodenum contains the pyloric glands that mainly secrete mucus.

The opening of the oesophagus is guarded by an indistinct sphincter forming the cardiac valve. In the same way the opening of the stomach into the duodenum is guarded by a conspicuous sphincter, the *pylorus* or the pyloric valve.

At the boundary of the glandular and non-glandular part, the mucous membrane forms a ridge. It is more prominent towards the oesophagus into the stomach. It forms a channel-like extension of the non-glandular region. It probably serves the function of directing the swallowed food towards the non-glandular part for storage.

The wall of the stomach is composed of : (1) the serous layer, (2) the muscular layer, (3) the submucous layer and (4) the mucous layer.

(1) The serous layer consists of a loose connective tissue containing adipose cells; it is covered over by the peritoneal lining.

(2) The muscular layer is thin in the non-glandular part while it is more developed in the glandular part. It shows three layers of muscles : an inner, irregular oblique layer, a middle thicker, circular layer and an outer thin, longitudinal layer. All the muscles are of smooth type.

(3) The submucosa is composed of loose connective tissue with blood and lymph vessels. It is separated off from the mucous layer by the muscularis mucosae consisting of thin strips of circular and longitudinal smooth muscle fibres.

(4) The mucous layer of the stomach consists of a stratified, squamous epithelium in the non-glandular region towards the oesophagus. The rest of the mucosa is folded to form numerous depressions called the gastric pits. At the bottom of each pit

small groups of tubular gastric glands open. The inner surface of the gastric pits are lined by columnar cells with mucigen. The glandular area of the stomach as noted before, is divisible into a larger fundic region and a smaller pyloric region. The gastric glands of both these regions are compactly arranged. They are tubular, simple or branched glands lying parallel to one another and at right angles to the surface. The cells in the lower third of each tubule are zymogenic cells; these are columnar cells with large nuclei and granular cytoplasm. The granules are basophilic above the nuclei. At basal parts of the cells however there is a striated chromophil substance. The upper part of the tubule and its neck contains cells with lighter staining granules. These are of mucous nature. Scattered amongst the zymogenic cells and mucous neck cells, are parietal cells. These are more numerous in the upper parts of the tubules. The parietal cells are large, round or wedge-shaped cells with clear acidophilic cytoplasm.

Small intestine—The small intestine of rat is about six times the length of its body. It is approximately uniform in diameter; it is looped and coiled. The first part of the small intestine forms a loop extending towards the right side. It is the *duodenum*. It encloses the diffuse pancreas in its arms. The rest of the intestine is a long, narrow and coiled part, the *ileum*.

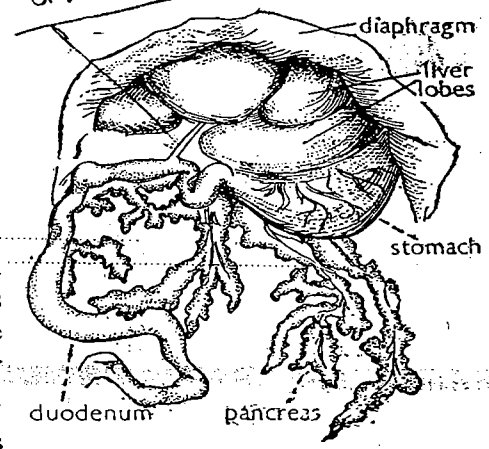
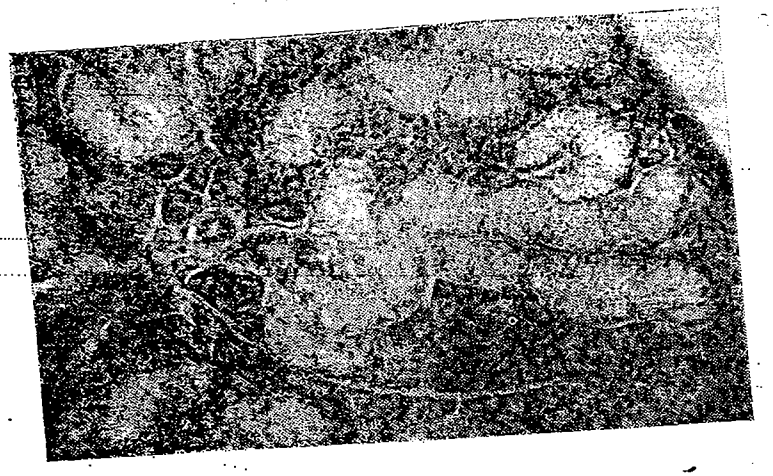


Fig. 5..7 Stomach and duodenum with associated parts

The duodenum receives a common bile duct (ductus choledochus). It is formed by the union of the bile duct and numerous small pancreatic ducts.

The wall of the small intestine is rather thin; the muscular layer is not so thick as in the stomach. The mucosa of the small intestine is roised into numerous, delicate, finger-like projections



T. S. of salivary gland - rat

T. S. of large intestine - rat

Functions of the liver—The liver performs many functions; its work is not concerned with digestion alone. The following are the important functions of the liver :—

(1) It secretes bile, which is mainly a waste product, made up of worn out blood cells and other wastes. It is alkaline in nature as it contains salts like sodium bicarbonate, glychocholate and tauocholate. The sodium bicarbonate is useful to reduce the acidity of the intestinal contents. The other two salts are responsible for the emulsification of fats and to activate the pancreatic lipase. The bile is greenish in colour; it contains the bile pigments, bilirubin and biliverdin. These are produced from the break-down of haemoglobin of the worn out red blood corpuscles. These are excretory in nature. Bile performs the following functions :—

(i) It neutralizes the acidity of the food (chyme) coming from stomach into the intestine and makes it alkaline in nature.

(ii) It emulsifies fats i. e. it mixes with the fats so that they become finely divided into small droplets. In this state fats can be better acted upon by the pancreatic juice.

(iii) It stimulates the peristaltic contractions of the intestine.

(iv) It has a slight antiseptic action; it prevents putrefaction of food in the intestine.

(2) It stores sugar in the form of glycogen. The blood brought by veins from stomach and intestine is rich in food. Excess of glucose is converted by an enzyme *glycogenase* into an insoluble compound—the glycogen (animal starch). This is stored in the hepatic cells in the form of granules. When the circulating blood falls short of its sugar content, the stored glycogen is reconverted by the same enzyme into glucose and is released into the blood.

(3) It deals with the excess of amino-acids and subject them to a process of *deamination*. Proteins cannot be stored in the body like carbohydrates and fats. The amino-acids absorbed in the intestine are passed on to the blood stream in suitable quantities. The excess and unwanted amino-acids are deami-

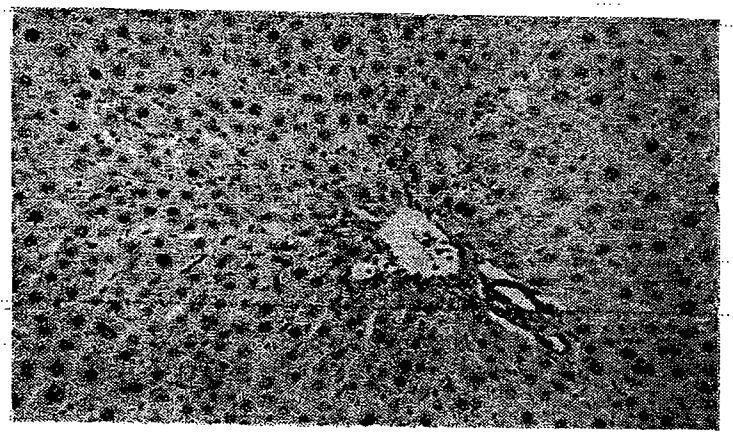
deep fissure for the hepatic ligament. Tha caudate or spigelian lobe consists of two portions surrounding the oesophagus and the post-caval vein. Rat has no gall bladder. Secretion from all these lobes is conveyed by the hepatic ducts which join to form a common bile duct (ductus choledochus), that opens into the duodenum.

Structure of the liver—The liver is covered over with a thin connective tissue capsule called *Glisson's capsule*. This sends numerous trabeculae or strands into the interior forming a sort of framework. Each lobe of the liver is thus divided by these trabeculae into a large number of lobules. The trabeculae form the inter-lobular framework in which blood vessels and bile duct lie. Each lobule is polygonal in shape and consists of hepatic cells arranged in a radiating manner forming hepatic cords.

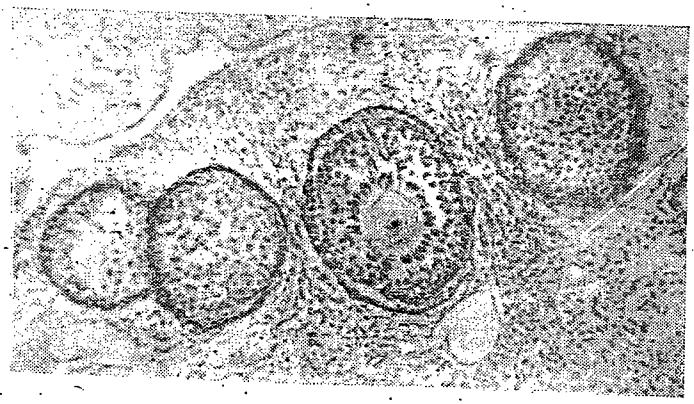
Blood supply of the liver—The hepatic branch of the caeliac artery supplies arterial blood to the liver. The hepatic portal vein collecting blood from parts of the alimentary canal enters the liver on its under surface. The smaller branches of both these vessels penetrate in between the hepatic lobules; they are called the *inter-lobular* vessels. These give out fine branches that run radially to the centre of the lobule. As the lining of these capillaries is deficient, they are called *sinusoids*. These converge to the centre of the lobule and form the *intra-lobular vein*. This is a factor of the sublobular vein. The intra-lobular veins open into the sub-lobular veins. These in their turn join together to form the hepatic vein.

Hepatic cells—The hepatic cells appear as radially placed cords lying in between the blood sinusoids. They are polygonal in form; they come in direct contact with the blood stream. Each cell has a large spherical nucleus and granular cytoplasm. Its protoplasm is pervaded by a network of canaliculi which would receive blood directly from the sinusoids.

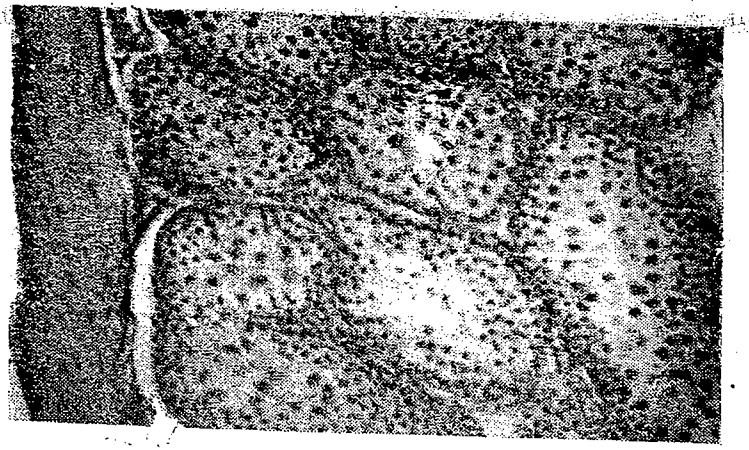
Bile duct—In between the hepatic cells lie small channels called *bile capillaries* or canaliculi. Towards the periphery of the lobule, these channels join to form the interlobular bile ducts. These in their turn join and form the hepatic ducts of the lobes. These join to form the common bile duct.



T. S. of liver - rat showing intra-lobular channels



T. S. of young ovary - rat



T. S. of testis - rat

the complex and insoluble food into simpler substances which are soluble and diffusible – *digestion* (4) *absorption* of the digested food, (5) convertion of the absorbed food into protoplasm – *assimilation*, and (6) throwing out the undigested and waste material – *egestion*.

Digestion—The food taken in is not immediately ready for use in the various parts of the body. Some of the substances like fats are not soluble; others like proteins may be soluble but not diffusible. It is therefore necessary to change the ingested food into soluble and diffusible form. This is done by digestion. It consists of a process of hydrolysis in which the molecular size of the food substance is progressivetly reduced until a true solution becomes possible. Such changes are brought about by chemical substances called *ferments* or *enzymes*. Different kinds of food materials are acted upon by different enzymes and are made soluble. An enzyme is a biological catalyst that brings about a chemical change but itself remains unaltered in the reaction. The action of an enzyme is specific i. e. it acts on a definite kind of food substance or a group of substances called the substrate.

Ingestion—The rat gnaws its food. With the help of the chisel-shaped incisor teeth, small portions of vegetable or animal matters are sliced off. These are siezed by the mobile lips and transferred to the mouth cavity. The tongue moves the food in such a way that fresh pieces of food are brought in between the molars. They are subjected to the grinding action (mastication) of the molars. The solid particles are ground into a semisolid mass. During this process the food is thoroughly mixed with saliva which is brought in the mouth cavity by salivary ducts. The mastication of food and mixing it with saliva (salivation) turn the food into a pulpy mass, the food bolus. This is a mechanical and preparatory process; the food can now be acted upon by chemical substances.

Saliva—It is a thin alkaline fluid. It contains an enzyme *ptyalin* which acts on insoluble starches and turns them into compound sugars like dextrin and maltose. The saliva contains a large amount of mucus. It mixes thoroughly with the food when it is being chewed; this necessarily moistens the food so that its taste can be noted by the tongue. It also lubricates the food, so that it can be easily swallowed. It dissolves some of the mineral matter.

By all these actions the solid food is turned into a sort of pulp; it is then called as food bolus. It can now be easily swallowed. The tongue helps it at this time in pushing it into the oesophagus. The backward movement of the tongue presses the epiglottis which closes the glottis leaving no chance for the food to be thrust into the trachea. The morsel of food is thus pushed into the gullet.

Steps of digestion in the mouth :

(1) The food is mechanically cut into smaller fragments with the help of the teeth.

(2) It is mixed with saliva, which lubricates it.

(3) Some soluble mineral matter is dissolved.

(4) The food is moistened by saliva for taste and swallowing.

(5) With the help of ptyalin, saliva changes insoluble starch into soluble sugar.

The walls of the oesophagus produce characteristic movements. The food bolus is thus driven to the stomach. The oesophagus thus acts as a passage for food, the action of saliva on starches meanwhile continues. As the food remains in the mouth cavity and the oesophagus for a short time, action of ptyalin is rather slight. However, the presence of saliva stimulates the actions in the stomach.

Stomach—Even when the food has entered stomach, the ptyalin digestion does not stop immediately, It goes on till a change in the chemical condition of the food occurs. The stomach retains the food for a considerable time. During this time a chain of events takes place whereby gastric digestion is effected.

(1) The presence of food in the stomach stimulates the pyloric end. It contracts with great vigor so as to prevent food from passing into the duodenum. It remains in this condition till the acidity in the stomach reaches a particular level. This is effected by the hydrochloric acid present in the gastric juice.

(2) The walls of the stomach are highly muscular. The rhythmical contractions and relaxations of these muscles pass like waves from the oesophageal end to the pyloric end. This end be-

nated. In this process, the amino (NH_2) group of the amino-acid is converted in the form of urea which is carried by blood to the kidneys, where it is excreted. The carbon (organic) group of the amino-acid is converted into glucose or fats. These can then be utilised as such.

(4) It stores vitamins A, B, D and iron.

(5) It plays an active role in the storage of haemoglobin of blood.

(6) It destroys the worn out red blood corpuscles. This is done by Kuffer cells of the liver. The waste substances thus produced are converted into bile pigments; these are removed along with the bile.

(7) It secretes an anti-coagulant factor which prevents blood from clotting while it is flowing in the blood vessels. It also secretes and stores fibrinogen and prothrombin, the useful agents in coagulation of blood.

(8) The liver deals with any toxic (poisonous) substances in the blood.

Pancreas—The pancreas is a diffuse type of gland lying in the mesentery of the duodenal loop. It consists of numerous scattered lobules. Ducts from these various lobules open into the common bile duct.

Each small lobule of pancreas is formed of a group of tubular or saccular alveoli or acni. Each acinus is enclosed by a base-ment membrane and consists of columnar or polyhedral cells. These cells produce the pancreatic juice. Scattered throughout the glandular substance are groups of clear cells. These are not connected with any ducts. They are known as the *islets of Langerhans*. These islets form an endocrine part of the gland. They secrete a hormone called insulin; it regulates the carbohy-drate metabolism.

6. PHYSIOLOGY OF NUTRITION

Food habits of animals—Animals have no power to make their own food. They select different kinds of food materials, derived either from plants or other animals. Animals vary with respect to the kinds of materials on which they feed. Some ani-mals feed exclusively on plant material, grass, leaves and other plant parts. They are said to be plant eaters or *herbivorous* ani-mals. Others utilise flesh of other animals as their food. These flesh-eating animals are the *carnivorous* animals. Some animals feed both on animals and plant materials. They are said to be *omnivorous* animals. These animals are probably at an advan tage as they can easily find their food under varied conditions. They have not to spend much time and labour in finding their food; hence they are the successful animals. Rat is an omnivorous animal.

Foods—Whatever form the food material takes, it contains the essential food materials for the building up of protoplasm or for the supply of energy required for the life activities. The food of vertebrates contains the carbohydrates, fats, proteins, minerals, salts, water and vitamins. Proteins comprise a large part of the solids in the protoplasm. They make up most of the active tissues in the body, hence they are known as tissue builders. Carbohydrates are starches, sugars and cellulose; fats occur in animal and vegetable oils. Vitamins are absolutely essential for the normal maintenance of health and growth of the animals. They need be present in very small quantities; they are normally taken in with food. Various mineral salts of sodium, potassium, calcium, magnesium and iron form a part of the constitution of organs and tissues. They are also useful in many metabolic processes. Water forms a large proportion of the composition of the protoplasm and is essential as a means of transportation of food, oxygen and waste.

Nutrition—The processes by which food is obtained, prepared and built up into the body substance are grouped together under the term ' nutrition '. It includes – (1) selecting and getting the food material in the alimentary canal – *ingestion*, (2) preparation of the food material to be treated chemically, (3) breaking down

It requires the enzyme enterokinase from the intestinal juice to activate it by converting it into trypsin. The enzymes from the pancreatic juice act as follows :—

(i) Alkali soluble proteins, proteoses and peptones + trypsin → amino acids.

(ii) starch and dextrin + amylopsin → maltose (disaccharide).

(iii) fats + steapsin → fatty acids and glycerol.

(c) *Succus entericus*—This is the intestinal fluid. It is also slightly alkaline and contains six enzymes. These act as follows :—

(1) Trypsinogen (inactive) + enterokinase → trypsin (active). The enterokinase is thus an activator.

(2) Peptones + erepsin → amino acids.

Erepsin does not act directly on proteins but on peptones it converts them into amino-acids. It thus completes the digestion of proteins.

(3) Fats + lipase → fatty acids and glycerol.

(4) Sucrose (disaccharide) + invertase → glucose and fructose,

(5) Maltose + maltase → Glucose.

(6) Lactose + lactace → Glucose and galactose.

As a result of all these enzymatic actions, the proteins are reduced to amino-acids, the carbohydrates to glucose or similar monosacharide sunars and the fats are turned to fatty acids and glycerine.

Absorption—The digested food diffuses through the wall of the alimentary canal to the blood stream. This passage of the digested food through lining of the blood vessels and lacteals and thence to the blood or lymph is known as absorption. It takes place in mouth and gullet to a very little extent as the food remains there for a short time. Though the food remains in the stomach for a long time, its absorption in the stomach is not considerable. The food is there being churned and hence the digested food does not remain in contact with its walls long enough to be absorbed. The absorption takes place mainly in the region of the small intestine. In the ileum, the absorptive area is made enormous by the presence of the thin-walled villi containing blood capillaries and lacteals.

Simple sugars, amino-acids and mineral salts pass by diffusion through the cells of mucous membrane directly into the blood stream. The fatty acids combine with alkaline salts of the bile and form liquid soaps. They enter the cells in this condition together with glycerol. There the soaps are broken down and fatty acids recombine with glycerol to form droplets of fat. This fat is passed on to the lacteals in the villi. The fact that glycerol and fatty acids are synthesized into fat in the cells of the mucous membrane shows that absorption is not merely diffusion or osmosis, but it requires protoplasmic activity. From the lacteals fats are taken to the lymphatic system, ultimately reaching the blood stream.

Large intestine—The undigested residue is passed on to the large intestine. As it passes along the colon, water is absorbed so that the residue becomes more and more solid. The semi-solid mass thus produced is the faeces. If more amount of water is absorbed from the residue, the faeces appears like pellets and the rectum thus gives it a beaded appearance. The faeces are given out through the anus periodically; this process is called *defaecation*. The rat often eats its own faeces; it is therefore called pseudo-ruminating or *coprophagus*.

Assimilation—The absorbed food is distributed to all the tissues in the body with the help of blood and lymph. Thus all the cells in the body receive the materials they need for their maintenance. The substances brought to the cells are synthesized, under the influence of the cellular enzymes, to form constituents of protoplasm. The kind of protoplasm would depend upon the protoplasm in which the synthesis occurs. This process of synthesis of protoplasm is known as assimilation.

ing closed by the pyloric valve, the food cannot pass into the duodenum. These movements toss the food to and fro and thus churn it. As a result of churning the food is mechanically broken into smaller fragments and the softer particles are separated. The food is thoroughly mixed with the gastric juice. These movements also produce a little heat; this breaks down fats into smaller droplets which can be evenly distributed in the gastric fluids. The fat is thus turned into an emulsion.

(3) The mucosa of the stomach secretes a hormone, gastrin; it activates the gastric glands. These secrete a digestive fluid, the gastric juice. It is acidic in nature as it contains dilute hydrochloric acid. The acid is secreted by the oxyntic cells of the peptic glands, The gastric juice also contains two enzymes, pepsin and rennin.

Steps of digestion in the stomach—The hydrochloric acid from the gastric juice plays an important role in the stomach.

(i) The acid penetrates the food bolus and gradually changes the medium of food. The medium is made acidic for the action of pepsin.

(ii) The aeid stops the action of ptyalin.

(iii) It kills bacteria and other harmful micro-organisms that may be present in the food or the stomach ; it thus acts as an antiseptic.

(iv) It dissolves some of the mineral matter present in the food.

(v) It activates the enzyme pepsin. In fact the enzyme is secreted in the form of *pepsinogen* ; this has no effect on the food. Only when it is converted by hydrochloric acid into pepsin that it can act on proteins.

Chemical digestion in the stomach.

(vi) Pepsin secreted by the oesophageal and gastic glands acts on acid-soluble proteins. It starts the hydrolisis of proteins to proteoses and peptones. This reactions takes place in an acid medium.

Proteins + pepsin $\xrightarrow{\text{in an acid medium}}$ Peptones.

(vii) Rennin curdles milk forming casein. Rannin is plentiful in the young when they are feeding on milk but in adults it may be absent.

Caseinogen (milk protein) → Casein (curdled milk).

As a result of the combined effect of the mechanical and chemical actions taking place in the stomach, the food is now converted into a thick acidic paste, called the *chyme*. By this time the acidity of the food has reached such a limit that the duodenum is stimulated. Is secretes a hormone—*secretin* which activates liver and pancreas. Under such conditions, when the pH of food has reached certain acidity, the pyloric sphincter relaxes and the contration of the wall of the stomach now sends the chyme in small jets into the duodenum. Here the chyme meets three juices; bile from the liver, pancreatic juice from the pancreas and succus entericus from the small intestine.

Steps of digestion in the small intestine :

(a) *Bile*—It is an alkaline fluid containing salts like sodium bicarbonate, glycocholate and taurocholate. It contains excretory products in the form of bile pigments like bilirubin and biliverdin, produced by the break-down of haemoglobin of red blood corpuscles. The bile has no digestive ferments, hence it does not take any active part in digestion. It acts in the following manner :—

(i) It neutralizes acidity of the chyme. This is mainly done by sodium bicarbonate that is present in the bile and the pancreatic juice. It then turns the food alkaline. This puts an end to the action of pepsin.

(ii) It emulsifies fats. The salts like glycocholate in the bile emulsify fats. In other words fats are broken into very fine particles. This makes the task of the fat digesting enzymes rather easy.

(iii) In both these ways bile helps to prepare the chyme for the pancreatic juice it meets.

(iv) It acts as an antiseptic; it checks the development of bacteria in the chyme.

(b) *Pancreatic juice*—This is a watery, alkaline fluid, rich in enzymes. It contains three enzymes : *trypsinogen amylopsin* (distase) and *steapsin* (lipase). Trypsinogen by itself is inactive.

6.3 in diameter. The number of R. B. C. is rather more in the female than in the male rat.

(3) The *leucocytes* (white blood corpuscles)—These are the nucleated and irregularly shaped blood cells. These lack the colouring matter and are hence called as the white corpuscles. They are often classified according to the form of the nucleus, the nature and staining reactions of the cytoplasm. The white cells are of two main types : (i) *lymphocytes* or non-granular leucocytes and (ii) *granulocytes*. (i) The *lymphocytes* have a large and single nucleus and non-granular cytoplasm; naturally the cytoplasm forms a small proportion as compared to the nucleus. Lymphocytes are produced from special cells in the lymph nodes. Most of them are not capable of clear amoeboid movement. They constitute about 76% of the total number of white cells. *Monocytes* are transitional lymphocytes which tend to become amoeboid and phagocytic. They are small cells with bean-shaped nuclei. In rat they form 1% of the total count of leucocytes.

(ii) *Granulocytes*—They are also known as polymorphonuclear leucocytes. They have a lobed nucleus. The common conditon of the nucleus in these cells is that of an irregularly lobed form; the nucleus is said to be polymorphous. These are irregular cells with granular cytoplasm. They are produced in the bone marrow. Their cytoplasmic granules react to certain stains. Accordingly they are distinguished into three vertieties.

(a) *Neutrophils*—They have lobulated nuclei. They are phagocytic in nature and are able to ingest bacteria. They form about 20% of the total count of W. B. C.

(b) *Eosinophils* form a small group. Their cytoplasm shows large granules; they have two-lobed nuclei. Normally they are about 2% of the leucocytes but their number increases in certain types of infections.

(c) *Basophils*—These have large granules in the cytoplasm stained with basic dyes. They also possess two-lobed nuclei. They constitute about 1% of the leucocytes.

All types of granulocytes are capable of amoeboid movement; during these movements they engulf germs (foreign bodies) and damaged tissue cells. This process is called *phagocytosis*.

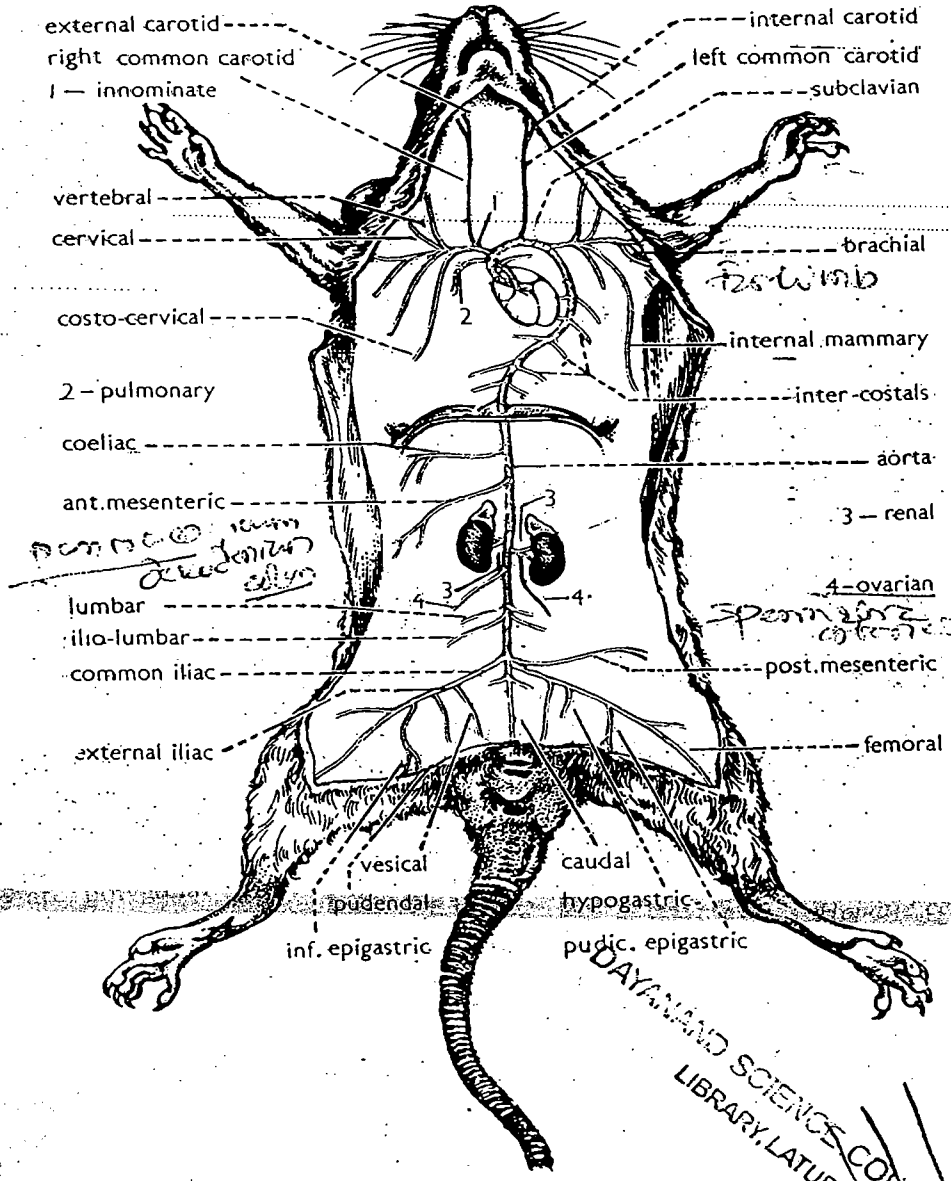


Fig. 7.4. The arteriai system of rat

while others form a part of the plasma itself. These can be grouped into (blood) plasma proteins, organic substances and inorganic salts.

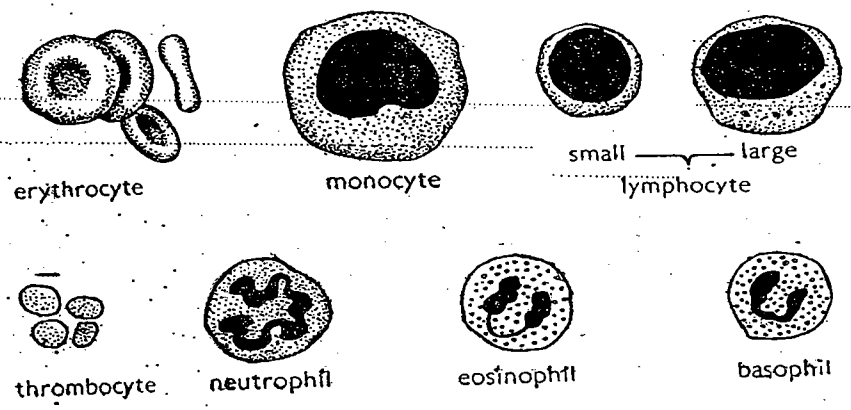


Fig. 7.3. Blood of rat

(a) *Blood proteins*—These include serum albumin, serum globulin and fibrinogen. These are in a colloidal form and are responsible to make the blood viscous. The globulin is formed from the leucocytes; it is very useful in the defence mechanism. The albumin and fibrinogen are however derived from the liver. The albumin regulates the osmotic pressure of the blood whereas the fibrinogen brings about the coagulation of blood. In this process it is converted into fibrin.

(b) *Organic substances*—These include the nutrients and wastes. Many nutrients are usually present in the blood; these are the end products of digestion of food. They are being transported to the tissue. They include amino-acids, glucose and fats. Amino-acids are in small quantities while glucose and fats are very often in about the same proportion. The waste substances in the form of urea, uric acid are being carried from various organs to the excretory organs for elimination.

(c) *Salts*—Total amount of salts presenti n the plasma, form about 1% by weight. Chlorides, carbonates and phosphates of sodium, potassium, calcium, magnesium and iron are the salts present in the plasma. However, sodium chloride and sodium bicarbonate form the greater part. It is the presence of these salts that give an alkaline reaction to blood. These salts maintain a constant osmotic internal environment for the tissues.

The plasma also contains the dissolved gases, enzymes, hormonces, antibodies and antitoxins.

(d) *Hormones and enzymes*—Many substances are present in the plasma, whose presence cannot be detected by analysis. However, physiological tests prove their presence. Of these, hormones or secretions of ductless glands, antibodies and antitoxins concerned with the neutralization of foreign bodies and toxins are worth noting.

(e) *Gases*—Little oxygen is also dissolved in plasma, though it is mainly carried by the red corpuscles. Carbon dioxide is mainly transported by the plasma.

(2) *Red blood corpuscles (erythrocytes)*—The red corpuscles in rat, as in most of the mammals, are biconcave circular discs (in camel they are oval discs). When these red cells are first formed, they have nuclei; but during maturation, they lose their nuclei. Thus when they enter into circulation, they are non-nucleated cells. Each corpuscle is bounded by a thin elastic envelope probably of a lipoid nature It contains a spongy cytoplasm called stroma. A respiratory pigment, *haemoglobin*, is dissolved in this cytoplasm. This gives a yellowish tint to the corpuscle; however, when the corpuscles are seen in bulk, the colour appears to be red. Haemoglobin is a complex substance containing protein (globin) united with haematin, an organic substance containing iron. It has an affinity for oxygen. When blood circulates through lungs, it takes up oxygen and becomes *oxyhaemoglobin;* the blood then becomes bright red in colour. In oxyhaemoglobin, oxygen is held in loose combination wlth haemoglobin. When the blood in circulation reaches the tissues, the red cells part with their oxygen and the blood becomes purplish in colour. Thus the red corpuscles with their haemoglobin are carriers of oxygen from the lungs to the tissues; they also carry CO_2 from the tissues to the lungs.

The red blood corpuscles of rat are about 9–9½ million in number per cu. mm of blood. The average size of the corpuscle is

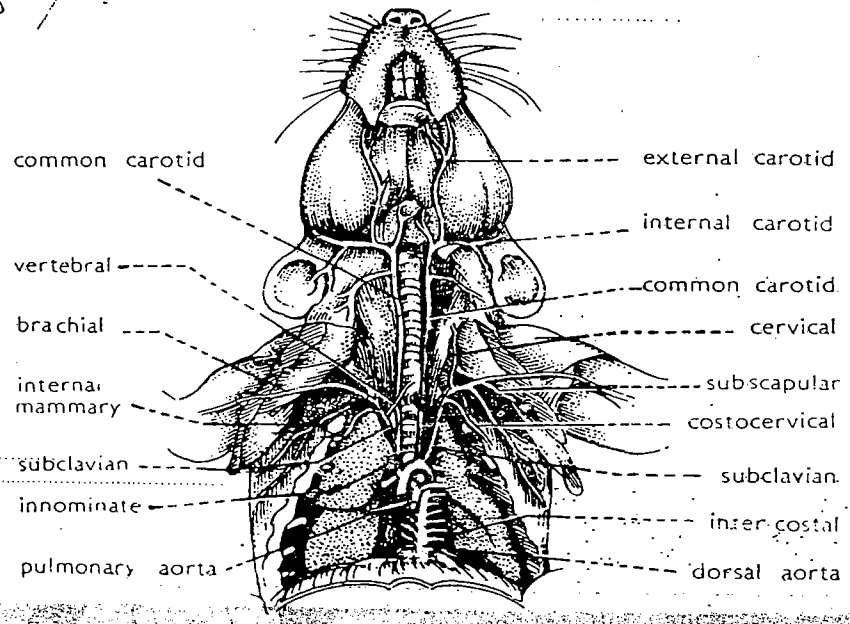


Fig. 7.4 (a). The anterior part of the arterial system in rat.

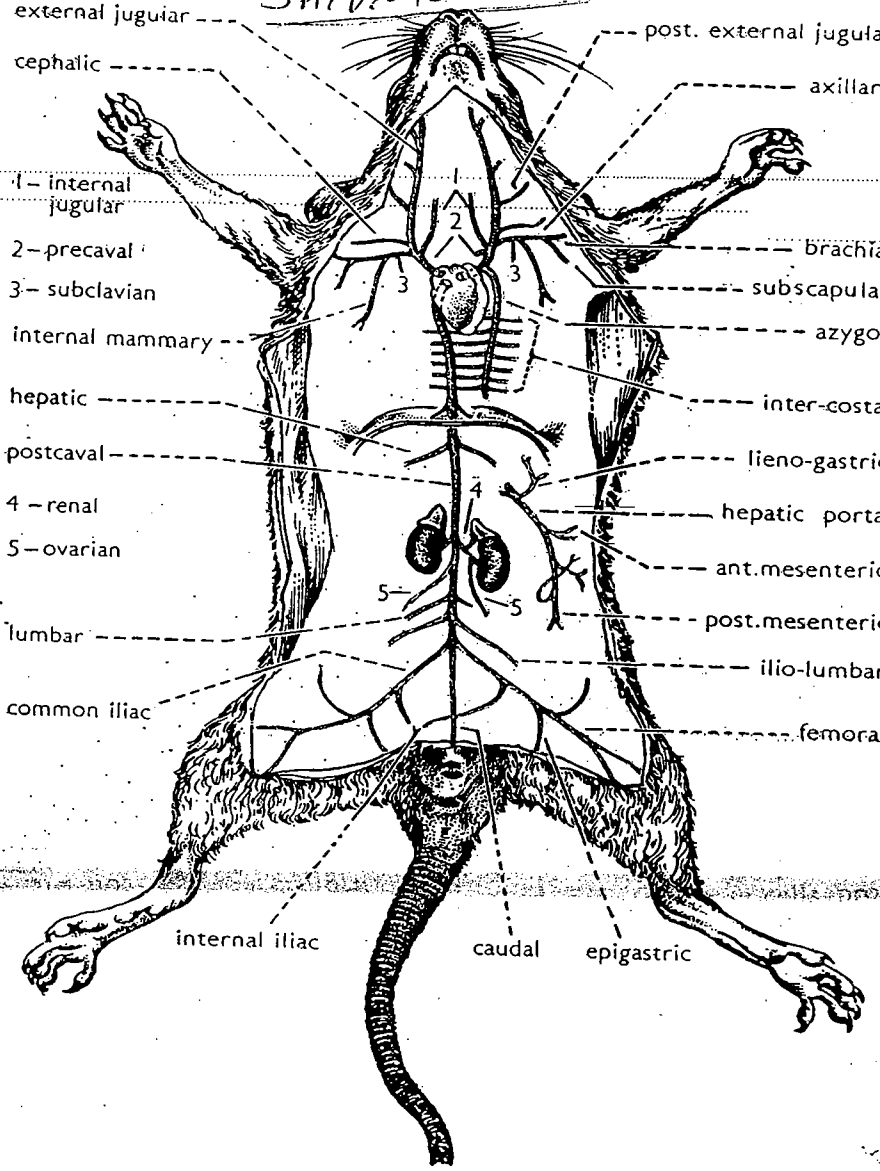


Fig. 7.5. The venous system of rat.

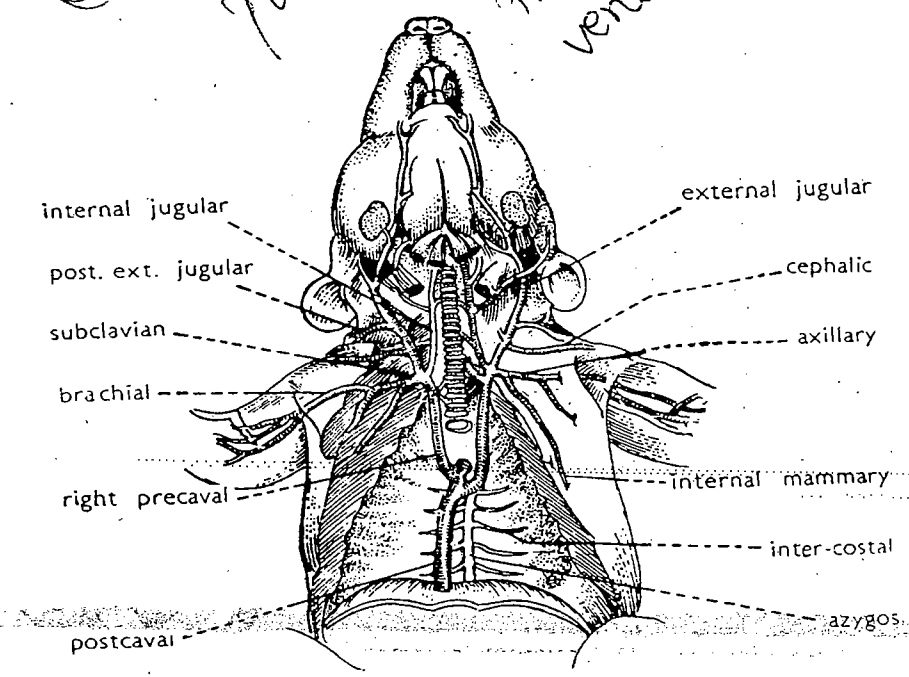


Fig. 7.5 (a). The anterior part of the venous system in rat.

called the pericardial fluid. The pericardial sac becomes attached dorsally and ventrally to the body wall by a mediastinal septum.

The heart is an ovoid part consisting of four chambers; two *atria* (auricles) and two ventricles. The greater portion of the heart consists of two ventricles; these together form a thick-walled cone with a broad anterior base and a pointed posterior apex. An oblique groove separates the two ventricles. The groove extends from the right side of the base to the left side of the apex. The groove contains the branches of the coronory artery and vein which ramify over the surface of the ventricle. The left ventricle is much larger than the right one. In front of

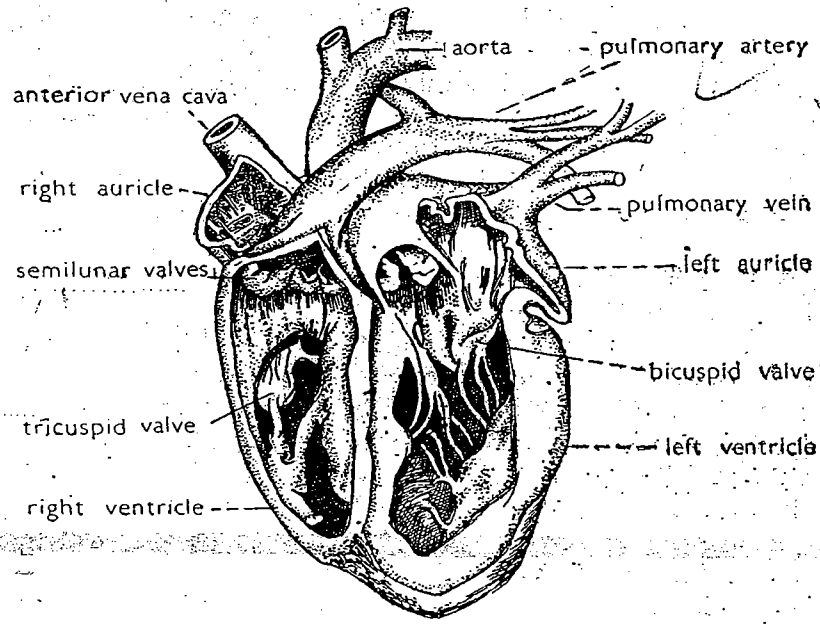


Fig. 7.8. Mammalian heart—internal structure

each ventricle is a much smaller chamber, the auricle. Each auricle in a contracted state presents a lobe, the auricular appendage, that projects over the ventricle. Between the two auricles lies a large pulmonary artery. It originates from the right ventricle and soon curves to the dorsal and left side : it then bifurcates into the

8. RESPIRATORY SYSTEM

In a complex animal like a rat, there cannot be a direct access of oxygen to the living tissues. The transport of oxygen from the surrounding atmosphere and conveyance of CO_2 and water (the end products of respiration) takes place with the help of blood. Even though the actual release of energy takes place in the cells of the living tissues, a set of organs concerned with the exchange of gases forms the respiratory system of the animal. It consists of a pair of lungs connected to the exterior by the respiratory passages. The latter comprise the nasal cavities, the pharyax, the larynx, the trachea and bronchi.

(a) *Nasal cavities*—The external nares or nostrils lead to the nasal chamber. The latter is divided by the nasal septum into right and left portions called the nasal cavities. This septum is cartilagenous anteriorly but its posterior part is bony. In rat the nostrils lie on a region of naked skin above the upper hare-lip. This region, in healthy rats, is moist and cool. Within the nasal cavities much space is occupied by the turbinal bone (the scroll-like maxillo- turbinals and ethmo- turbinals). These bones are covered ove- by mucous membran- lining the nasal cav- ties. The membran- is highly vascular, ci- ated and moist. It is kept moist by t- secretion of numero- glands present in t- mucous membrane. this epithelial lin- of the nasal regio- olfactory nerve en- ing are unevenly dist- buted. The membra-

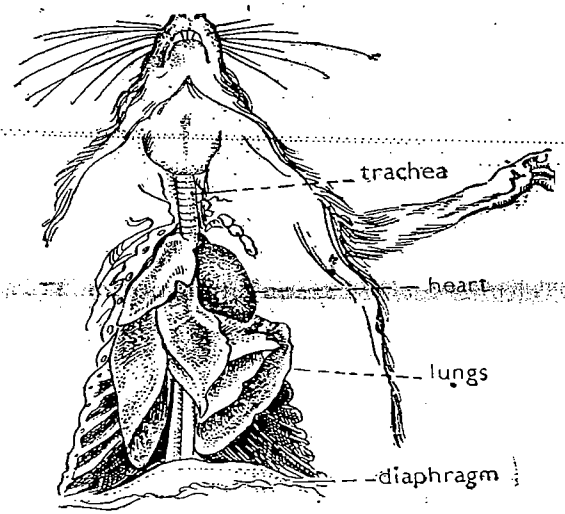


Fig. 8.1. Contents of the thorax of rat

moistens the air breathed in and warms it to the body temper-

-re. Dust particles that may be present in the air adhere to the -ucus and thus the air passing inside is cleansed. The nasal -vities join together to form a large internal or posterior naris -hich opens into the naso-pharynx.

(b) *The pharynx*—As noted before it is divided into the -so-pharynx above the palate, the oropharyx below the palate -d the laryngopharynx behind the buccal cavity. Thus the -arynx consists of three regions; the nasopharynx antero- -rsally, the oropharynx antero-ventrally and the laryngopharynx -stero-ventrally. The oropharynx and laryngopharynx are not -stinctly demaracted. The former is the portion of the pharynx -ntral to the soft palate. The laryngopharynx is the region -tween the soft palate and the oesophagus. It is continuous with -th the oropharynx and nasopharynx. The oesophagus and -rynx open into this region.

(c) *Larynx*—The larynx or voice box is the anterior enlarged -rt of the trachea. It communicates with the pharynx by the -ening called glottis. An antero-ventral flap forms a lid-like -iglottis. This helps to guide the food, past the glottis. It -rms a sort of a valve not to allow the food to enter the trachea.

Besides being a part of the tracheal (respiratory) passage, -e larynx serves as an organ of sound production. It is support- -d by four cartilages. These include a large, shield shaped -hyroid cartilage antero-ventrally, a ring-shaped cricoid cartilage -ing posterior to it; this encircles the larynx. Dorsally it -ecomes much larger and wedge-shaped. Two small arytenoid -artilages articulate with the anterior wedge-shaped part of the -ricoid and each is attached to the dorsal end of the vocal cord. Within the larynx are two pairs of dorso-ventral folds extending -etween the arytenoid and thyroid cartilages. Of these the upper -r anterior ones are the false vocal cords, whereas the lower or -osterior ones are the true vocal cords. When the vocal cords -re in a relaxed condition, the air passes through the larynx -easily and without producing any sound. But when the muscles -of the larynx contract, the cords become stretched. Under such -conditions, the air passing out causes them to vibrate. These -vibrations produce sound. The pitch of this sound varies accord-

ing to tension, and the stretched condition of the cords. The rat produces a variety of sounds.

(d) *Trachea*—The trachea (wind-pipe) is a long tube extending throughout the neck. It lies ventral to the oesophagus and is supported by C-shaped cartilagenous rings, whose dorsal portions are incomplete. The soft dorsal region of the trachea lies against the oesophagus. The cartilagenous rings give rigidity and flexibility to the elastic walls of the trachea. They help to keep the lumen of the trachea in an open and uncollapsed condition. The trachea extends into the thorax and divides to form two bronchi.

(e) *Bronchi*—The two bronchi, right and left, lead to the respective lungs. The bronchi are smaller and are supported by incomplete cartilagenous rings. Each bronchus while entering the lung divides into secondary bronchi. In the substance of the lungs these further subdivide to form tertiary bronchi and bronchial tubes. The finest branches are called *bronchioles*. These are not supported by cartilagenous rings. The terminal part of a bronchiole is subdivided into smaller branches called *alveolar ducts*. These end in dialated air sacs. The air sacs give out smaller air pockets called *alveoli*.

The trachea, bronchi and bronchioles are all lined internally by a ciliated mucous membrane. It also contains a large number of goblet cells. These secrete mucus in which dust particles that might have entered the lungs and the respiratory passages are caught. The ciliated lining slowly moves the mucus away from the lungs, thus preventing them to accumulate in the lungs.

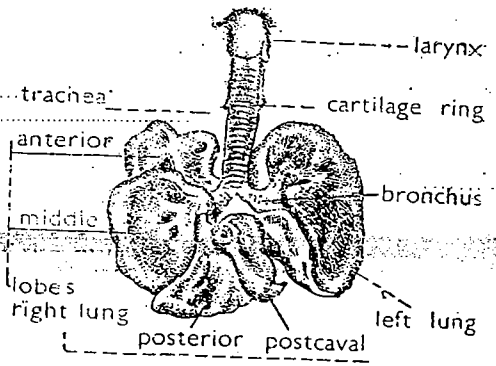


Fig. 8.2 Lungs and trachea of a rat

(g) *Lungs*—The rat has a pair of lungs. The two lungs lie in the thorax on either side of the heart. Each lung lies in its own pleural cavity. The two pleural cavities are separated by a *mediastinal septum*; they form a major part of the thoracic coelom. Parietal pleurae line the inner walls of the pleural cavities and the visceral pleurae cover the lungs. The left lung consists of a single lobe whereas the right lung is divided into four smaller lobes. These are the anterior, middle, posterior and the postcaval lobes. The postcaval lobe is almost in contact with the diaphragm and is somewhat notched to accomodate the postcaval vein.

Each lung is a pink coloured, spongy bag. Its internal cavity is greatly subdivided to produce numerous air sacs, on the walls of which microscopic pockets called alveoli are present. The air sacs are bound together by loose connective tissue in which numerous blood vessels lie. The blood capillaries lie in close contact with the thin walls of the alveoli. This facilitates the gaseous exchange between the air and the blood.

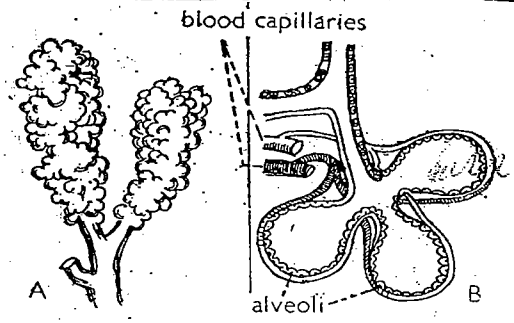


Fig. 8.3. Alvoli. B. section.

(h) *Diaphragm*—This is a muscular, domeshaped partition. Its central portion is tendinous; towards the periphery it has muscle fibres extending to the adjacent body walls. The diaphragm is perforated by the dorsal aorta, oesophagus, and the postcaval vein. When the muscles of the diaphragm contract, the dome is flattened. In the relaxed position of the muscle the diaphragm assumes the domeshape.

Physiology of respiration

The process of respiration mainly consists in the release of energy. This is brought about by the breaking down of complex food like sugar or fat into simple substances like CO_2 and water. In other words the potential energy stored in the complex food is liberated in a kinetic form during a chemical reaction It takes

place with the help of certain enzymes, in all the living cells. It is often called as the "tissue respiration" or "internal respiration". This is essentially a process of oxidation in which oxygen is taken in; with the aid of enzymes it combines with complex food to release energy; at the same time the process yields wastes like carbon dioxide and water. Usually the process involves the taking in of oxygen and giving out carbon dioxide. In all land vertebrates, the gaseous exchange necessary for respiration occurs in the lungs. The oxygen is transported from the lungs to all parts in the body through the medium of blood. For this purpose lungs must be filled with fresh air and emptied at least partially to give out the used air. This regula intake and give out of air are necessary to provide the tissues with the oxygen they need. This process of inhailing and exhailing air is ealled breathing or "external respiration".

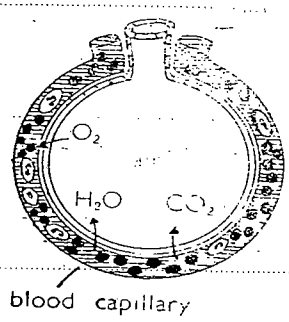


Fig. 8.4. Exchange of gases takes place through the thin walls of the alveoli.

(1) *External respiratian* or *breathing*—For the active tissue respiration, fresh air from outside is constantly taken in and the stale air given out by the lungs in the process of breathing. This process is naturally carried out in two stages : (a) inspiration or inhalation, and (b) expiration or exhalation.

Mechanism of respiration. To understand how breathing is effected, the following features of the respiratory apparatus must be noted : (1) The walls and the floor of the chest cavity are muscular and therefore mobile. (2) The pleural cavities are completely closed. Air can neither enter nor leave them. (3) The lungs are non-muscular. They cannot change their own size, but being elastic can be stretched by external forces.

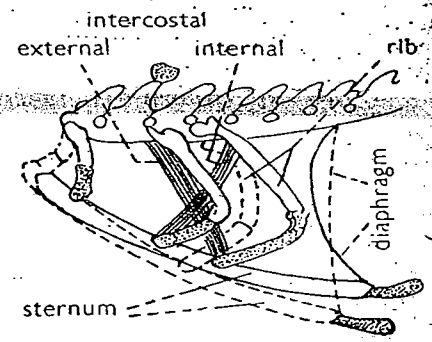


Fig. 8.5 Mechanism of breathing

(a) *Inspiration*—The inspiration or intake of air occurs when chest cavity is reased in size. The largement of the st cavity involves following movents : (i) The exterl intercostal muscles tween the ribs conact; this lifts the ribs forwards and upwards; at the same time sternum is swung forwards. This widens the chest cavity. (ii) The muscles of the domeshaped diaphragm contract. This ttens the diaphragm, thus increasing the length of the chest vity.

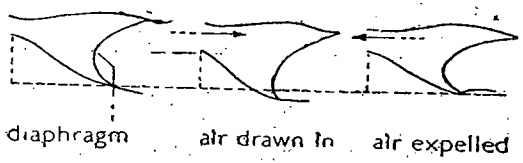


Fig. 8.6 Change in the capacity of the thoracic cavity

The enlargment in the thoracic cavity makes greater space vailable to the elastic lungs. Thereby the pressure within the ngs is lowered. As the lungs open to the outside by way of achea and nasal passages, some of the outer air rushes in until e pressure of air within the lungs and that outside the body comes equal. In fact the air from outside is sucked in. This rocess is known as inspiration or inhalation.

During inspiration the air enters through the nostrils. As it asses over the mucous membrane of the nasal passages, it is armed to the body temperature. The dust particles that ay be present in the air adhere to the mucus secreted by the membrane. The nasal passages thus act as 'air filters'. The mucous ining of the trachea and bronchi also retain the dust particles if ey are still present; these are moved slowly away from the lungs y the cilia in this membrane. Thus the air is completely filtered nd warmed before it reaches the lungs. In the lung a gaseous exchange takes place.

(b) *Expiration*—Expelling the air from the lungs or expiration takes place when the chest cavity is again reduced in size. This action involves the following movements :

(i) The internal intercostal muscles contract so as to relax the external intercostal muscles. This pulls the ribs downwards and backward; the sternum is brought to its original position.

(ii) The muscles of the abdominal wall press the abdomina viscera against the posterior surface of the diaphragm. This helps to restore its normal dome-shaped position.

The flattening of the diaphragm exerts a pressure on the ab dominal viscera. These parts tend to be free from this pressur by reacting in an opposite direction. With the return of the rib and diaphragm to their normal positions, the thoracic cavity be comes smaller and the walls of the thorax close in upon the lungs As a result, the pressure in the air-sacs rises above that of th atmosphere. The elastic tissue of the lungs tries to get relief b forcing out some of the contained air. This is expiration. Expi ration is therefore accomplished without much muscular effort It must be clearly noted that the lungs are never completel emptied; some amount of air always remains in the lungs.

(2) *Internal* or *tissue respiration*—It has been noted that the true respiratory activity that results in the release of energy takes place in the living tissues. This release of energy is the result of the chain of chemical reactions; every one of these re actions is brought about by a special respiratory enzyme within the protoplasm of the living cells.

When the air comes in contact with the moist mucous membrane of the lungs, a little amount of oxygen enters into solution in this moisture, thus bringing about a higher oxygen concentration at this respiratory surface. The blood flowing in the capillaries of the lung contains *haemoglobin* in its red blood corpuscles. It combines with oxygen to form bright red *oxyhaemoglobin*. The blood now becomes scarlet red in colour; it is oxygenated. A li tle oxygen also dissolves in the blood plasma. At the same time the CO_2 brought by the blood from the living tissues of the body is exchanged. Part of the CO_2 is dissolved in the plasma; a little part is brought along the plasma as sodium bicarbonate. Similarly a little amount of CO_5 is carried as potassium bicarbonate in the corpuscles. At the respiratory surface of the lung the bicarbonates are split up and carbon dioxide is liberated.

In the living tissues the blood does not directly come in contact with the cells, as it always remains in closed capillaries. The tissue cells are however bathed by lymph that exudes through the

thin walls of the capillaries. The tissue cells are however bathed by lymph that exudes through the thin walls of the capillaries. The lymph serves to convey oxygen to the cells. This happens as a simple physical process. The concentration of oxygen in the blood is higher than what it is in the tissues. The oxyhaemoglobin of the blood, being unstable, parts with its oxygen in such situa tions of low oxygen concentration and the blood becomes deoxygenated. It takes place where the medium is slightly acid due to the presence of higher carbon dioxide concentration. These actions are brought about by certain enzymes. The entire process in carried about as follows :

(1) The *glucose* is acted upon by enzymes called *dehydrogenases* so that some of its hydrogen atoms are activated and liberated.

(2) This free (liberated) hydrogen is transferred to a protein called *cytochrome;* this acts as a *hydrogen accepter*. By this transference the cytochrome is converted to reduced cytochrome. These actions can thus be shown :

glucose + dehydrogenases – free hydrogen H
cytochrome + free H – reduced cytochrome

(3) Another enzyme called *cytochrome oxidase* oxidises the reduced cytochrome at the expense of oxygen conveyed to the tissues. It is thus brought to its original cytochrome condition. This results in the release of energy, carbon dioxide and water.

reduced cytochrome + O_2 brought to the tissue – cytochrome + energy + CO_2 + H_2O. (in the presence of cytochrome oxidase)

Carbon dioxide produced in this reaction is a waste material. If it accumulates, it is harmful to the tissue. It is carried from the tissues to the lungs for elimination. It is removed partly dissolved in plasma and partly in the form of salts. About 5% of CO_2 is carried in the plasma as carbonic acid. 2 to 10% combines with haemoglobin to form *carbamino-haemoglobin* and the rest is carried as bicarbonates of sodium and potassium respectively in the plasma and the red blood corpuscles. In the lungs the oxygenation of haemoglobin into oxyhaemoglobin brings about the breakdown of carbamino-haemoglobin and bicarbonates. This is due to the strong acidic nature of oxyhaemoglobin. This releases CO_2 which easily diffuses out.

9. NERVOUS SYSTEM

Though rat is a mammal of small size, several characteristics of its central nervous system indicate the high degree of specialization attained by the mammals. Like all other vertebrates, the rat has a hollow, dorsal, *central nervous system*. It consists of the brain and the spinal cord. The nerves arising from these two parts form the *peripheral nervous system*. They supply all parts of the body. The autonomic nerves associated with both the brain and spinal cord form the *autonomous* system.

Thus the nervous system can be conveniently divided under the following three heads :

(1) Central or cerebro-spinal nervous system consisting of the brain and the spinal cord.

(2) The peripheral nervous system consisting of the cranial nerves originating from the brain and spinal nerves from the spinal cord.

(3) The autonomous nervous system that controls the involuntary activity. It consists of the *parasympathetic* system and the *sympathetic* system.

The cerebro-spinal nervous system : The brain and the spinal cord together form the central nervous system. As in all other vertebrates, the medullary plate of the embryo becomes rolled up into a neural or nerve tube. It gets differentiated into an enlarged anterior part forming the brain. The posterior part of the tube becomes the spinal cord. The brain lies within and protected by the cranium (skull) while the spinal cord is protected by the vertebral column.

Meninges—The brain and spinal cord are completely sheathed by three layers of membranes called *meninges*. The outermost is the tough *dura mater ;* it lines the cranium and the vertebral canal. The middle layer is the *arachnoid mater*. It is rather delicate; it is separated from the dura mater by the subdural space. It is also separated from the inner layer by the sub-arachnoid space. The innermost of the meninges in the *pia mater*. It is very delicate and vascular. It follows all the ups and downs of the brain and the spinal cord, extending even into the fissures of the brain. It is more or less a nutritive layer.

The sub-dural and sub-arachnoid spaces are filled with a

lymph-like cerebro-spinal fluid. This fluid acts as a lubricant and shock absorber. It thus helps to protect the delicate nervous tissue from mechanical injuries.

In amphibians, reptiles and birds, only two membranes, the dura mater and pia mater are present. The pia mater in mammals, however, gets differentiated into the arachnoid and pia mater. Thus in mammals three coverings are present as mentioned above.

The brain

The brain (Fig. 9.1.) lies within and protected by the cranium. The cranial nerves arising from the brain emerge through a number of formina in the skull. The brain is divided into three regions; the fore brain, mid-brain and hind brain. The latter becomes continuous with the spinal cord.

Fore brain—The fore brain or prosencephalon is subdivided into anterior telencephalon and the posterior thalamencephalon.

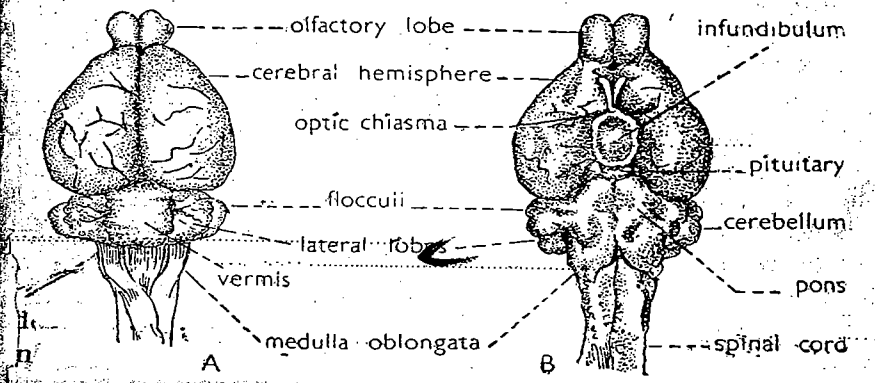


Fig. 9.1. Brain of rat—A. dorsal and B. ventral views.

Telencephalon—The telencephalon mainly consists of the olfactory lobes and the large cerebral hemispheres. In all vertebrates the telencephalon is divided by a median partition into two parts, so that its cavity forms the two lateral ventricles. The telencephalon forms many parts in the brain. Anteriorly it forms the *olfactory lobes*, *olfactory tracts* and *hippocampi*. Its postero-ventral part forms the *corpora striata ;* while its dorsal part forms the *spallium*.

The olfactory lobes constitute the most anterior part of the (telencephalon.) They are relatively small. They appear to be situated more towards the ventral side because of the overhanging cerebral hemispheres. They project a little in front of the cerebrum. Posteriorly they are continuous with the olfactory tracts; these connect the olfactory lobes with the hippocampi (the hippocampal lobes of the cerebral hemispheres). The latter are the association centres for the sense of smell. The olfactory regions are demarcated from the cerebral hemispheres by the longitudinal grooves called the *rhinal fissures*. The olfactory lobes and the hippocampal lobes are often said to constitute the *rhinencephalon*.

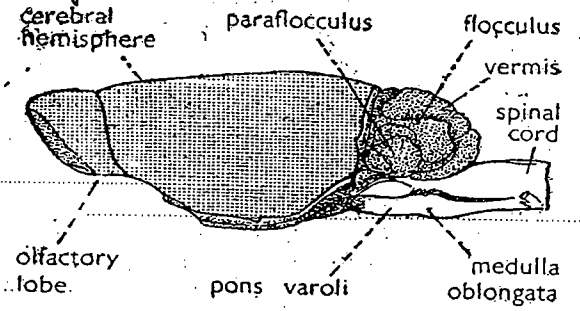


Fig. 9.2. Brain of rat—lateral view

The *pallium* in the higher vertebrates has an increasing number of nervous cells forming the *cerebral cortex*. The portion of the telencephalon dorsal to the rhinal fissure has no olfactory function, and it is known as neo-pallium. In mammals it is enlarged and constitutes the major portion of the brain. It consists of two large *cerebral hemispheres*. They form the anterior 2/3 part of the brain. They have become so large that in front they overshadow the olfactory lobes and posteriorly they hide from view the thalamencephalon and a part of the mid-brain. The two hemispheres are separated from one another by a deep groove called the median *saggital fissure*. The cortex or outer portion of the neopallium consists of vast numbers of cells forming the grey matter. Internal to the grey matter is the white matter; this consists of inter-connecting fibre tracts. A broad band of such tracts called *corpus callosum* runs transversely and connects the cerebral cortex of one side with that of the other. It lies in the floor of the median fissure but above the roof of the lateral ventricles. This connection adds to the efficiency of co-ordination of two sides of the brain.

The cerebral hemispheres contain centres of co-ordiation and intelligence. In many mammals the extent of cerebral cortex is

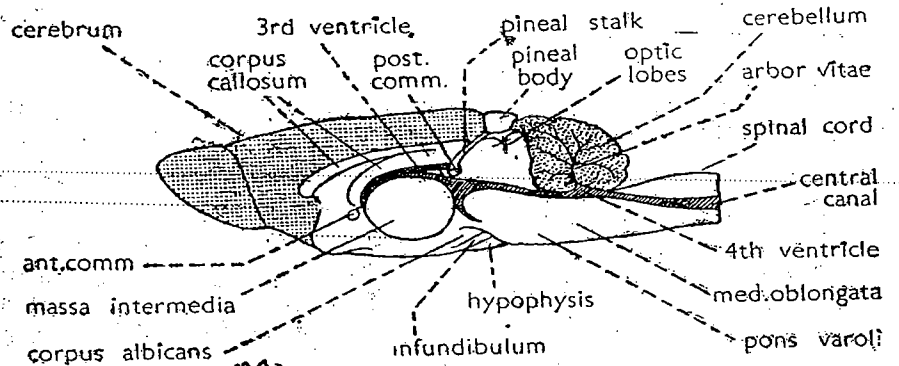


Fig. 9.3 Brain of rat—gagittal section

increased by convolutions of the surface. Many such convolutions are seen in the brain of man. This fact is correlated with different levels of intelligence. The deeper and more the convolutions, the intelligence is supposed to be more. In rat few such convolutions can be marked. Ventrally a longitudinally running fissure demarcates the hippocampal lobe on either side.

The corpora striata developing from the postero-ventral part of the fore-brain are large internal masses of the grey matter. They occupy a major part of the anterior region of the floor of the lateral ventricles. They are concerned with the instinctive behaviour. They are very well developed in birds but are poorly developed in rat and in all mammals.

Thalamencephalon—The thalamencephalon is also called as diencephalon (twin-brain or 'twixt brain'); it lies between the telencephalon and mesencephalon. It contains a cavity, the third ventricle. It is completely masked in dorsal view by the overhanging cerebral hemispheres. Three regions are distinguished in the diencephalon: (a) The small dorsal epithalamus, (b) the ventral hypothalamus and (c) the lateral walls forming the thalami.

(a) The *epithalamus* consists of a thin roof covering the III ventricle. Its anterior part is a much folded region containing numerous blood vessels, forming an *anterior choroid plexus*. A small *pineal body* (epiphysis) arises from the posterior part of the

epithalamus. It is raised on a long and slender pineal stalk. The pineal body of a rat is rounded and lies between the cerebral hemispheres and the cerebellum. It is taken to be the vestigeal remains of the third (median) eye and has an endocrine function.

(b) The sides of the thalamencephalon are thickened to form the *optic thalami*. The two thalami meet one another and fuse together across the cavity of III ventricle to form the intermediate mass. The *optic chiasma* formed by the crossing of the optic nerves lies at the anterior end of the hypothalamus. However, the fibres of the optic nerves end in the posterior part of the optic thalami. The optic thalami thus become the association centres of the sense of sight. The thalami thus bear the same relationship to the optic sense as the hippocampi to the olfactory sense. They are also the nerve centres where most of the sensory impulses reaching the fore-brain are relayed before transmitting them to the cerebral cortex.

(c) Just behind the optic chiasma is a slight 'elevation' the *tuber cinercum*, to which the stalk of the *pituitary* gland is attached. This gland (body) consists of two portions : the *infundibulum* and *hypophysis*. The infundibulum is a small outgrowth from the hypothalamus. It becomes incorporated in the pituitary body as its stalk. The hypophysis is derived from the non-nervous tissue of the roof of the stomodeum by invagination. The infundibulum connects the hypophysis with the tuber cinercum. The stalk of the pituitary body is produced posteriorly to form a rounded swelling, the *corpus albicans* or *corpus mammilare*.

• *Mesencephalon*—The mid-brain or mesencephalon undergoes the least modification during its development. It is a thick-walled region connecting the fore-brain and the hind-brain. Its cavity is a narrow canal called iter; it connects the third ventricle with the fourth ventricle. The mesencephalon forms optic lobes dorsally and crura cerebri ventrally. In lower vertebrates there is only one pair of optic lobes containing centres for visual impulses. In mammals, these are subdivided to form four optic lobes or *corpora guadrigemina*. The anterior two are smaller and are often called as the superior colliculi; these are the homologues of the optic lobes of the lower vertebrates. They contain the centres of visual impulses and have the optic connections. They are thus concerned

with the sense of sight. The larger two posterior lobes are the *inferior colliculi*. They contain centres for auditory impulses. The *crura cerebri* are thick bands of nerve fibres formed on the floor of the mid-brain. They connect the optic thalami of the fore-brain with the hind-brain and spinal cord.

• *Rhombencephalon*—The hind-brain is the rhombencephalon. Its anterior part gives rise dorsally to an elevated surface, the metencephalon. The rest of its dorsal part and the ventral part form the myelencephalon. (medulla oblongata)

• *Metencephalon*—The dorsal part of the metencephalon gives rise to the *cerebellum*. It is greatly thickened and well developed region. It projects forwards until it meets the posterior margin of the cerebrum; it also extends laterally. It is divisible into many regions, whose surfaces are characterised by convolutions (folds and grooves). Its median lobe is called the vermis; its lateral extensions are called *flocculi* and *paraflocculi*. Flocculi are often called as the lateral lobes and in that case, the paraflocculi are the flocculi. The cerebellum has the superficial grey matter forming the cerebellar cortex; it covers the inner white matter, the medullary region. The white matter forms a characteristic dendritic (tree-like) pattern called *arbor vitae*. This can be well seen in a longitudinal section of the cerebellum.

The cerebellum is directly connected to the organs of balance in the internal ears; it contains the centres that coordinate the muscular activity and thus maintain the posture.

Immediately behind the hypophysis is a heavy, fibrous band, the *pons Varolly*. It is a characteristic of the mammalian brain. It connects the two sides of the cerebellum. It also contains relay centres from the cerebral cortex to the cerebellum.

Below the cerebellum, the metencephalon contains the anterior portion of the third ventricle by an aqueduct of Sylvius or *iter*.

• *Myelencephalon*—This region on the ventral side forms the *medulla oblongata*. It forms the greatly thickened lateral and ventral walls of the fourth ventricle, contained internally. The thin roof of the ventricle is highly vascular. Together with the overlying pia mater, it forms the *posterior choroid plexus*. The fourth ventricle extends posteriorly, narrows down and becomes

continuous with the central canal of the spinal cord. The medulla oblongata is the posterior most part of the brain. It becomes continuous with the spinal cord. In fact it appears like an enlarged part of the spinal cord and hence is sometimes called as the spinal bulb. The medulla oblongata contains the centres that govern the involuntary activities such as the rate of heart beat, respiration, swallowing, vomiting etc.

Functions of the brain

Fore–brain :—

1. Olfactory lobes are concerned with the sense of smell.
2. The hippocampal lobes act as the association centres for the sense of smell.
3. The cerebral hemispheres are the centres of coordination and intelligence. The neopallium or the cerebral cortex is the seat of memory, will, intelligence and all conscious sensations and actions.
4. The corpus callosum adds to the efficiency of the coordination of the two sides of the hemispheres.
5. The corpora striata are connected with the instinctive behaviour.
6. The pineal and pituitary bodies have endocrine functions.
7. The optic thalami act as association centres for the sense of sight. They also act as centres where all the sensory impulses are relayed before transmitting them to the cerebral cortex.
8. The anterior choroid plexus forms the cerebro-spinal fluid.

Mid–brain :—

9. In the corpora quadrigemina, the anterior pair of lobes is concerned with the sense of sight; while the posterior pair of lobes is concerned with the relay of auditory sensation.

Hind–brain :—

10. The cerebellum controls the muscular activity and maintains the posture. It is concerned with the sense of balance and equilibrium.
11. The pons Varolli contains the relay centres that transmit impulses from the cerebral cortex to the cerebellum.
12. The medulla oblongata controls the involuntary activities such as the the heart beat, breathing, swallowing etc.
13. The posterior choroid plexus, like the anterior one, is concerned with the formation of the cerebro-spinal fluid.

The spinal cord

The spinal cord in rat, as in all vertebrates, lies in the neural canal i. e. the canal formed by the neural arches of the vertebrae. Like the brain it is covered over by the meninges. The cerebro-spinal fluid fills the spaces between these protective membranes and also lies around them. It is roughly cylindrical but slightly flattened dorso-ventrally. It is marked by two deep longitudinal grooves, the dorsal and ventral fissures. The diameter of the spinal cord is almost uniform except for two slight enlargements, one in the cervical region at the base of the neck and another in the lumber region. From the cervical enlargement arise the nerves supplying the fore-limbs, while the nerves to the hind limbs arise from the lumbar enlargement. Posteriorly, behind the lumbar enlargement, the cord abruptly narrows to a fine thread, the *filum terminale*. In rat the filum terminale starts from the second lumbar vertebra and extends into the tail for a short distance.

Internally, the spinal cord is hollow; it is traversed by a

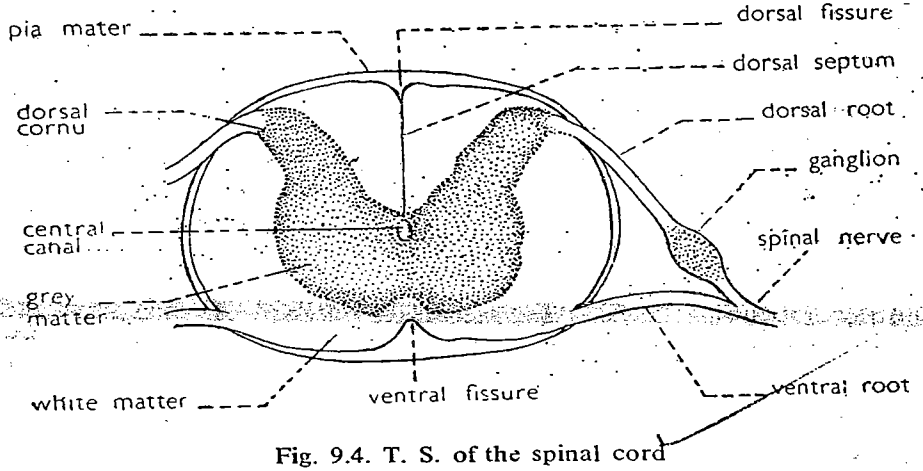


Fig. 9.4. T. S. of the spinal cord

narrow central canal, which anteriorly becomes continuous with the fourth ventricle of the brain. The spinal cord is composed of the central grey matter surrounded by the white matter. The

grey matter consists mainly of the neuron cell bodies and is arranged roughly in H–shaped pattern. It shows two pairs of horns, dorsal and ventral horns. The surrounding white matter consists mainly of the tracts of medullated nerve fibres.

Peripheral nervous system

The peripheral nervous system comprises the cranial nerves originating from the brain and the spinal nerves from the spinal cord.

(a) *Spinal nerves*—These are paired nerves arising from the spinal cord. Each spinal nerve has two roots : the dorsal root and the ventral root. The dorsal root bears a ganglion containing sensory neurons. Its fibres are only of a sensory type ; they carry impulses from the periphery to the central organs where sensations are produced. The ventral root has only motor fibres whose cell bodies are situated in the spinal cord. The two roots join together before the spinal nerve emerges out through the inter-vertebral notches. Each nerve soon after its formation divides into a small dorsal ramus to the skin and muscles of the back and the main ventral ramus supplying the ventral and lateral parts. In the thoracic and sacral regions most of spinal nerves give a third branch, the *ramus communicans* connected with the sympathetic ganglia.

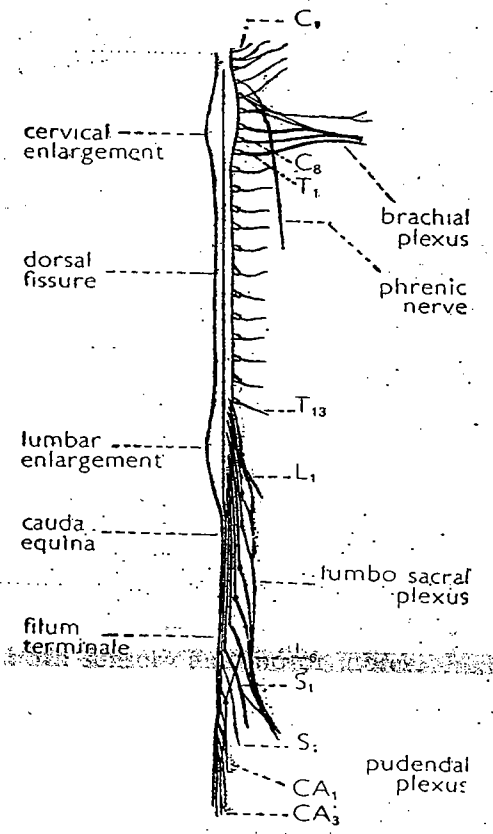


Fig. 9.5 Spinal cord with spinal nerves

The rat has 34 pairs of spinal nerves : 8 cervical, 13 thoracic, 5 lumbar, 4 sacral and 3 caudal. The ventral rami of many of the spinal nerves unite in such a manner as to form networks or plexuses. Three such plexuses are seen in rat.

At the level of the fore-limbs a conspicuous *brachial plexus* is formed. It is composed of the ventral rami of 4th to 8th cervical and the first thoracic spinal nerves. It supplies the shoulder region and the fore-limb. The lumbo-sacral plexus is formed from seven nerves ; 1 to 6 lumbar and the 1st sacral nerve. This supplies the hip region and the hind limbs. A small pudental plexus can be marked posteriorly on either side. It consists of branches from 7 nerves : 6th lumbar, 1–4 sacrals and 1–2 caudals. It serves the anal region and the muscles of the tail. The femoral and sciatic nerves from the lumbo-sacral plexus are very conspicuous. The femoral lies in the middle of the leg while the sciatic is located on the side of the thigh.

Many of the spinal nerves emerge considerably posterior to their points of origin in the spinal cord. Some of the lumbo-sacral and caudal nerves are of this type. These lie parallel with the filum terminale. The latter together with these nerves constitutes the *cauda equina* (named after its resemblance with the horse's tail).

(b) *Cranial nerves*—There are twelve pairs of cranial nerves in rat as in all mammals. They are designated by Roman numerals as well as names are assigned to them. These nerves lack the regularity of occurance characteristic of the spinal nerves. Some of them are entirely sensory, some purely motor and the rest of a mixed type, including both sensory and motor fibres. The name, origin, nature and distribution of these nerves is given below in a tabular form.

Autonomic nervous system—This system is sometimes called as the visceral nervous system. It is a special division of the peripheral nervous system that controls involuntary activity. It is concerned with the activities of the visceral parts like the intestine,

A. *Sympathetic system*—In the sympathetic system, the preganglionic fibres are relatively shorter than the postganglionic fibres. The system consists of a double chain of ganglia joined together by sympathetic cords, one on either side of the vertebral column. Rat shows 24 pairs of sympathetic ganglia : 3 cervical, 10 thoracic, 6 lumbar, 4 sacral, and 1 caudal. In the thoracic and lumbar regions, the sympathetic ganglia correspond to the spinal nerves, to which they are connected by the *rami communicantes*. Whereas in the cervical and sacral regions, there are additional sympathetic ganglia. From the sympathetic trunks nerves are also extended to some unpaired collateral ganglia or plexuses. In rat a large *coeliac* or *solar plexus* lies near the root of the coeliac and anterior mesenteric arteries. It supplies nerves to the diaphragm and abdominal viscera like the stomach, pancreas, liver and small intestine. A hypogastric ganglion supplies the colon, rectum, gonads, kidneys and bladder.

B. *Parasympathetic system*—It is made up of cranial and sacral autonomic ganglia. Their preganglionic fibres are relatively long. In the cranial region, the fibres arise from the third, seventh, ninth and tenth cranial nerves. In the sacral region, the preganglionic fibres arise from some of the sacral nerves. These autonomic fibres go to the eye, salivary glands, heart, bronchi, stomach, intestines, liver, pancreas, kidney etc. The parasympathetic ganglia lie in the organs served by them.

The two systems are antagonistic in their actions i. e. they work opposite to each other. If the sympathetic fibres accelerate any activity, the parasympathetic would retard the same. For example, the parasympathetic system increases the secretions of glands, whereas the sympathetic system decreases the secretions. Thus they regulate the working of the organs innervated by them. It can be noted that the autonomic system has both afferent and efferent fibres and it is without any voluntary control. It is concerned with such vital activities as the heart beat, respiratory movements, etc. Most of the internal organs receive a double set of nerves, one from each of these two divisions, one set being excitatory and the other inhibitory.

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10 : SENSE ORGANS

The organs of special sense are concerned with touch, smell, taste, sight, hearing, temperature and the like. They are the receptors for stimuli in the environment. They select certain kinds of stimuli from the changes in the environment. The stimulus received by a sense organ is transformed into a nervous impulse, which is transmitted by a sensory nerve to a group of nerve cells in the brain and the spinal cord. Each such organ has a basic plan ; such one consists of a cell (or cells) called the receptor cell. It receives the stimulus, then initiates and transmits nerve impulse by way of a nerve fibre either directly or indirectly through a chain of neurons to the brain or spinal cord where impulses are interpreted.

1. *Sense of touch*—The sense of touch is distributed all over the body. The skin possesses a large number of nerve endings in the form of *tactile* or *touch corpuscles*. These are tufts of cells at the nerve endings. Whenever an object comes in contact with the surface of the skin it stimulates these corpuscles. They convey the stimuli through the nerves to the central nervous system. It is there that the sensation of touch is noted. Rat is very sensitive to touch. It has touch fibres attached to the hair follicles so that the movements of the hairs can be felt. The whiskers or vibrissae are specially long hair developed by the side of the nostrils. These are highly sensitive ; rat can avoid obstacles even in the dark with their help.

2. *Sense of smell*—The sense of smell plays a very important role in mammals as compared to any other class of vertebrates. Even amongst mammals, the flesh eating mammals have a highly developed sense of smell as it helps them to locate track of the prey. In rat, the sense of smell is extremely well developed. It is used for the search of food at night.

The nasal cavity, which is innervated by the olfactory nerve, is lined internally by the olfactory epithelium. The cells of this membrane are columnar in nature ; many of these cells are secreting mucus. In certain regions, there are patches of olfactory cells (receptor) and supporting cells. Each olfactory cell bears a sensory hair on its outer surface ; from its basal end there arises a

nerve fibre going to the brain. These fibres are the components of the olfactory nerve.

The sense of smell is perceived when the gaseous or odourous particles carried by the respiratory current of air are dissolved in the mucus surrounding the olfactory epithelium. The chemical stimulus thus felt by the olfactory cells is carried to the olfactory lobe where the interpretation of smell takes place.

In the nasal cavities of rat, accessory organs of smell, called the *Jacobson's organs* are also present. These connect the nostrils with the buccal cavity. They convey smell of food in the buccal cavity to the olfactory cells.

3. *Sense of taste*—This sense is restricted to the tongue and palate. Taste is appreciated by taste buds, that lie embedded in the stratified epithelium. Each taste bud consists of a group of sensory (*gustatory*) cells surrounded by non-sensory supporting

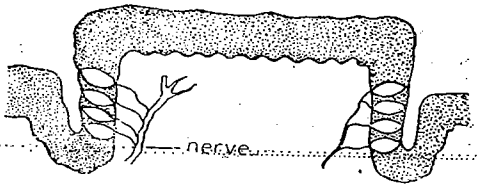

Fig. 10.1. A. Papilla with taste buds.

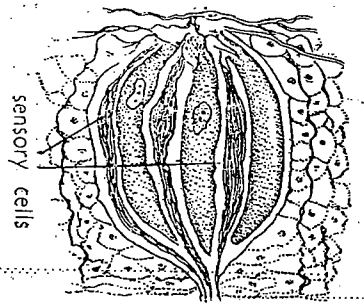

Fig. 10.1. B. Taste bud.

(*sustentacular*) cells. The sensory cells are long and narrow; each sensory cell has a minute hairlike process on its free surface. These processes project through an opening of the taste bud called as the taste pore. The basal portions of these sensory cells are wrapped round by nerve fibres.

The sensory processes are stimulated by the substances dissolved in mucus. Each taste bud can react only to a restricted number of dissolved substances, thus giving the sensation of salty, bitter, sour or sweet taste, according to the type of the taste bud. The taste buds in rat are distributed around the circumvallate papilla at the base of the tongue and in the mucous membrane of the palate.

4. *Sense of sight*—The sense organ which receives the light stimulus from outside is the eye. A mammalian eye is enclosed in a socket of bones which forms a protective cover all round except in front. It is controlled by three pairs of eye-ball muscles. A pair of oblique muscles, superior oblique and inferior oblique, is attached approximately to the equator of the eye-ball. The four rectus muscles—superior, posterior or external, anterior or internal and inferior rectus muscles—lie at the back of the eye. These can move the eye up and down or from side to side. The eye is protected by two folds of skin, forming upper and lower eyelids. The lids bear eye-lashes along their free edges. At the inner corner of the eye, the vestigeal third eyelid is present; it is known as the nictitating membrane. It is transparent and has a slightly thickened rim. The inner lining of the upper and lower eyelids, forming the nictitating membrane and covering the front of the eye-ball, is very thin and transparent. It is called conjunctiva.

The eyeball in most of the mammals is spherical but in rat it is ovoid in shape. Between the eyeball and the wall of the orbit most mammals have a pad of fat but the rat has a large intra-orbital *lacrymal* and large *harderian glands* that fill the space completely.

Structure—The eyeball is formed of three distinct layers : the outer sclerotic, the middle choroid and the inner retina.

(1) The *sclerotic* layer is composed of a dense fibrous tissue; it supports and protects the soft inner layers. It is opaque at the back of the eye forming the *sclera*. It is modified in the front of the eye, it becomes transparent and is known as *cornea*.

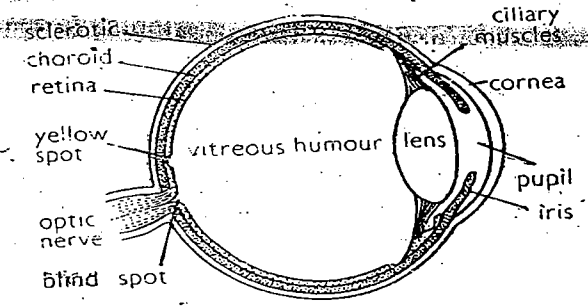

Fig. 10.2. Section of the vertebrate eye.

(2) The *choroid* coat is a soft layer. It contains blood capillaries and pigment cells. Due to these pigment cells, the refraction of light inside the eyeball is prevented. (Pigment is absent in albino rats). The choroid adheres to the sclera but behind the cornea it forms vertical disc-like portion called iris. The iris has a central opening called the pupil. The iris contains radial and circular bands of muscles that can alter the size of the pupil. Thus the iris serves as the diaphragm for regulating the amount of light. In rat, however, the muscles of the iris are poorly developed. This is in keeping with the rat's nocturnal habits. The pupil therefore maintains more or less a constant diameter.

At the junction of the cornea and sclera, the choroid layer is thickened to form a ciliary body with ciliary processes to which the transparent biconvex lens is attached by suspensory ligaments. In rat the ciliary processes are double. The ciliary body contains the ciliary muscles; these run both in circular and meridoneal directions. These muscles are useful for focussing or accomodation of the lens.

(3) *The retina*—The retina or the inner layer has a complicated structure containing the end organs for sight. It has in fact a double structure. Its outer part is normally heavily pigmented to prevent the internal reflection. In albino rat, however, it is not pigmented. It is this layer alone which continues forwards to cover the posterior surface of the iris. The inner part of the retina extends around the back of the eyeball and ends at a line known as ora serrata. It consists of light sensitive cells, relay cells and ganglion cells.

The light sensitive cells (photoreceptors) are of two kinds in most of the vertebrates: *rods* and *cones*. Rods respond to dim light; they contain pigment called rhodo sin or visual purple. They however cannot differentiate light of different wave lengths so that the image is seen as black and white. Cones can only function in bright light; they can descriminate lights of different wave lengths and thus can get a coloured image. A rat has no cones, in keeping with its nocturnal habits.

The next layer consists of bipolar nerve cells. These form synapses. They connect the rods and cones on the one hand and the ganglion cells of the retina on the other. Thus they receive the impulses from the visual cells and relay them to the large ganglion cells, whose axons are the component fibres of the optic nerve. The optic nerve perforates all the three coats and passes to the brain. The place where the optic nerve leaves the eyeball has no rods and cones. This spot always lies excentrically and is called as the blind spot. At this place as there are no end organs of the nerve, no image can be formed, and hence the name blind spot.

Working of the eye—Vision or sight implies the formation of a distinct image of the external object on the light sensitive retina. The image is then interpreted by the brain. The animal then becomes aware of the particular aspects of the surroundings. Sight in man comprises at least three sensations : colour, light intensity and form of objects. The light rays from an object are focussed by the lens on the sensitive retina. For this purpose the curvature of the lens can be adjusted to focus the rays from both the near and distant objects. This is accomodation of the lens; it is accomplished by changing the shape of the lens.

The rods and cones play a different role in sight. The cones are meant to receive stimuli of high intensity and they are associated with colour vision. The rods, on the other hand, mainly operate when the light is less intense. That is why in nocturnal animals rods are present but cones are usually absent. In rat as noted before cones are absent so that rat can have only black and white images.

Sense of hearing—The ear is the organ of hearing and equilibrium. It receives sound waves from outside and puts the animal in touch with its surroundings. It is thus a phonoreceptor.

The ear of rat, as in other mammals, consists of three parts—external ear, middle ear and the internal ear.

The external ear contains a lobular structure known as the pinna. It can suitably be moved with the help of muscles to collect sound waves from different directions. At its base, it leads to a tubular passage, the external auditory meatus. This passes through the tympanic bone and leads to the middle ear. At its inner end, lies the delicate tympanic membrane or ear drum. It connects the external ear with the middle ear.

The middle ear contains an air-filled tympanic cavity supported by the bony tympanic bulla. This cavity communicates with the pharynx by a narrow passage called Eustachian tube. This tube helps to keep the pressure in the middle ear equal to that of outside. A chain of three small bones stretches across the middle ear from the tympanum to the opening of the inner ear. These bones are the malleus, incus and stapes. The malleus is hammer-shaped; it abuts on the inner surface of the tympanic membrane on the one hand and is attached to the incus on the other. The incus is anvil-shaped; it connects the malleus with the inner stapes. The latter is stirrup-shaped; its inner end fits into a small oval opening, the fenestra ovalis. Another round opening, the fenestra rotunda, lies by the side the oval opening. Both these openings are covered with membranes. Through these openings the middle ear is connected with the inner ear.

The inner ear is made up of bony and membranous parts. Be-

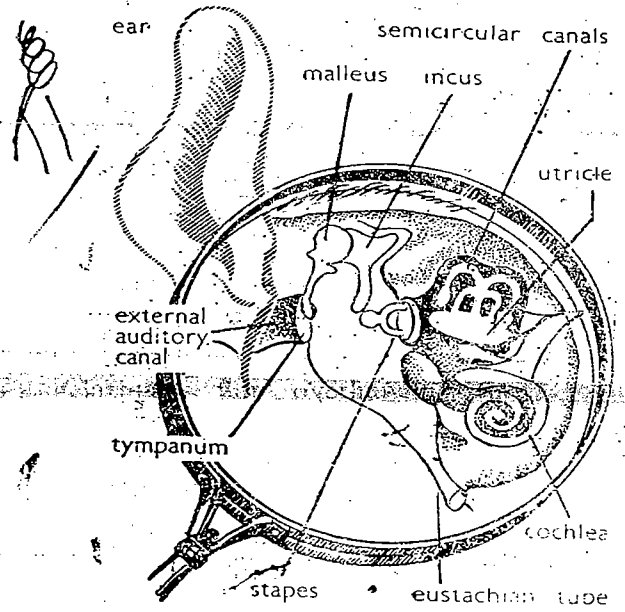

Fig. 10.3. Structure of the ear (diagrammatic).

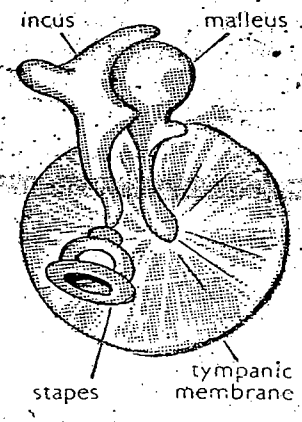

Fig. 10.4. Ear-bones in the middle ear.

cause of its shape the inner ear is often celled labyrinth. The bony labyrinth is a sereis of odd-shaped cavities in the temporal bone; it encloses and protects the membranous labyrinth. The latter in general follows the shape of the bony labyrinth. The space between two labyrinths is filled with a fluid called perilymph. This fluid receives vibrations from the middle ear and transmits them to another fluid inside the membranous labyrinth, the endolymph.

The membranous labyrinth is divided into two main chambers: the upper large utriculus and the smaller sacculus. From the utriculus three semi-circular canals are given off. They are arranged in three contrasting planes, at right angles to each other. Each canal has a swelling called ampulla at one end. The ampulla contains patches of sensory cells, called cristae; these bear long processes. From the sacculus an outgrowth originates; it is spirally coiled like a snail shell. Together with the bony part that encloses this tube, it is known as the cochlea. A transverse section of the cochlea shows that it is a bony tube lined by connective tissue. It is crossed by two membranous partitions so that it is divided into three chambers—scala vestibuli, scala media, and scala tympani. The middle scala media is the cochlear duct; it is filled with endolymph. The other two chambers represent the upper and lower cavities of the bony cochlea. They contain perilymph.

The scala media (cochlear canal) is separated from the overlying scala vestibuli by a membrane called as the vestibular membrane and from the underlying scala tympani by the basilar membrane. It is lined by an epithclium. The part of the epithelium that overlies the basilar membrane is modified to form the supporting and receptor or hair cells. Each receptor cell possesses a single hair. There is a gelatinous flap overhanging these cells. The structure thus formed is known as the organ of Corti. Thousands of such organs of Corti are present in the scala media. Nerve fibres from these organs unite to form the cochlear nerve, a part of the auditory nerve.

Functions of the ear—The ear has two distinct functions: it is a balancing organ as well as an organ of hearing. These two distinct functions, orientation and hearing, are associated with two different parts of the membranous labyrinth.

The sense of balance—The sacculus, utriculus and the semi-circular canals play a major role in the sense of equilibrium. The three semi-circular canals lie at right angles to one another in three different planes. They contain a fluid and a great number of receptors (cristae). When the head changes its position, the fluid rocks in these canals and stimulates the cristae. These are connected to the auditory nerve. Impulses travel from the cristae through the auditory nerve to the cerebellum. The brain thus becomes aware of the position. Reflex muscular actions are brought about to maintain the correct position.

Hearing—The sound waves are collected and concentrated by the external ear. They pass through the auditory canal (meatus) to the tympanum; this is set in vibration. The tympanum in turn causes the chain of bones in the middle ear to vibrate. The stirrup transmits the vibration to the membrane covering the fenestra ovalis. This sets the endolymph in cochlea in motion. The vibration of this fluid stimulates the organs of Corti. These impulses are taken by the auditory nerve to the cerebrum, where the sensation of sound is perceived.

11 : ENDOCRINE SYSTEM

The endocrine system consists of glands which secrete internally. They do not possess ducts to lead out their secretions. Hence these are also known as the *ductless glands*. Their secretion passes into the blood stream. They secrete chemical substances called '*hormones*'. These are the chemical messengers. Unlike the glands with ducts like the liver and pancreas, these glands secrete hormones; these are transported by the blood stream to appropriate places in the whole of the body. These hormones bring about a chemical coordination of various bodily activities.

The endocrine organs in rat can be grouped according to their position as follows :

(1) Cranial glands : lying in the cranial cavity - the pineal and pituitary glands.

(2) Cervical or pharyngeal : associated with the neck - the thyroid and parathyroid glands.

(3) Thoracic : the thymus gland.

(4) Abdominal glands : associated with the abdomen – the adrenals, the pancreatic and gonidial glands.

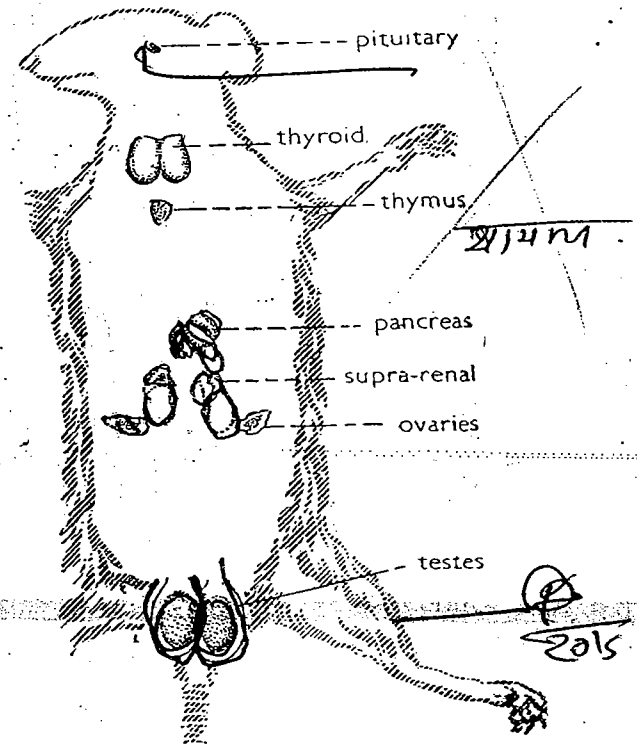

Fig. 11.1. Endocrine glands in rat (diagrammatic)

(1) *Pineal gland (epiphysis)*—The pineal body is a small structure developed as an evagination from the roof of the dien-