CHAPTER ONE

SKELETAL, MUSCULAR AND INTEGUMENTRY SYSTEMS

1.1. The Skeletal System

In order to retain their shape and form, living things need some types of support. In single celled organisms, this support is provided by the cell membrane. In multicellular animals the support is provided by some form of skeleton. Among multicellular animals, skeletons range from the exoskeleton of arthropods to the endoskeleton of vertebrates.

Like that of all vertebrates, the skeleton of humans is composed of a special type of connective tissue called bone. Bone and their associated tissue – cartilage, tendons and ligaments make up the **skeletal system.**

Human Skeleton

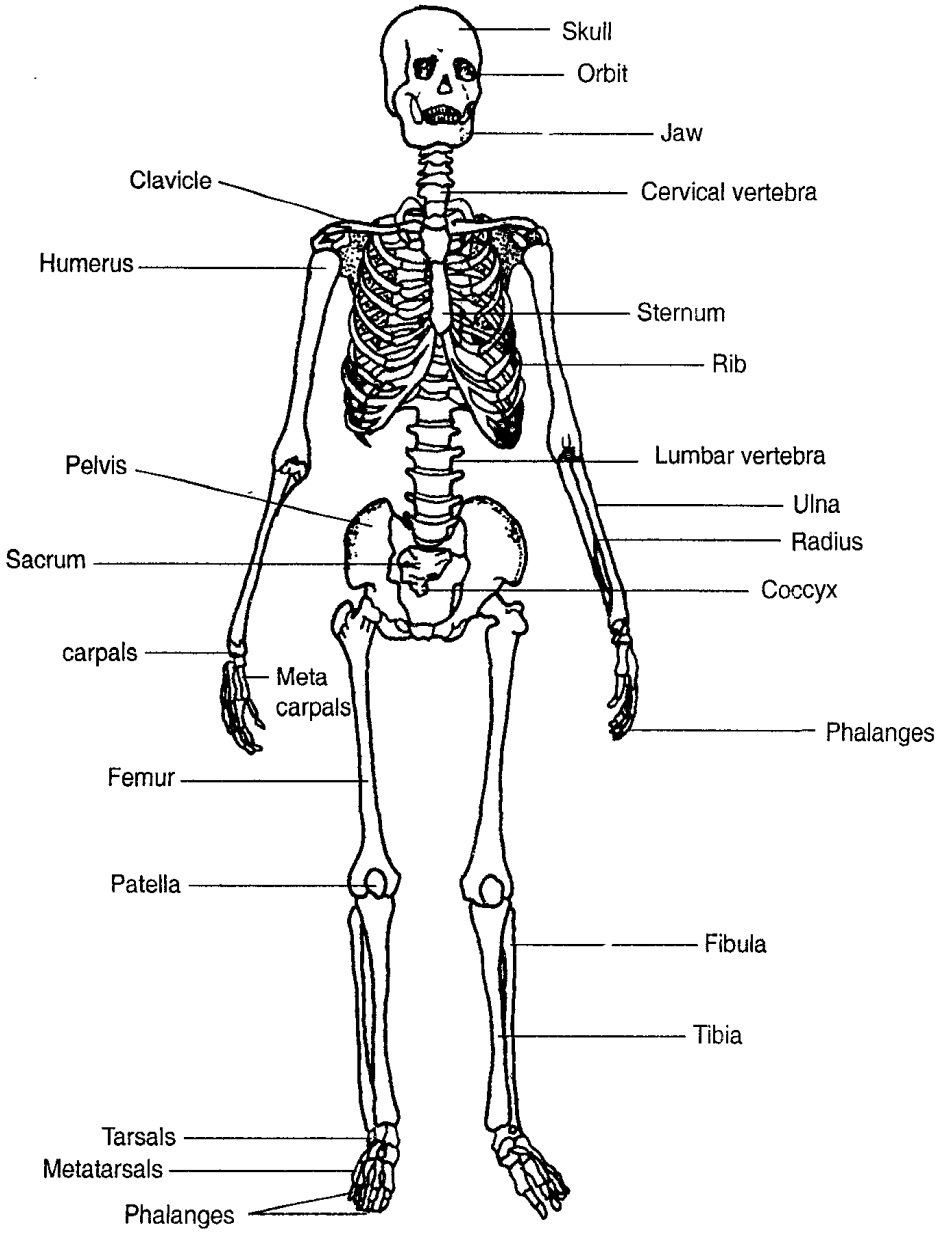


Figure: 1.1 (a)

Support and Movement in Mammals

In mammals the bones and muscle work together to bring support and movement. The skeleton system in mammals is divided into two parts; the axial and appendicular skeleton. See figure 1.1 (a) and (b).

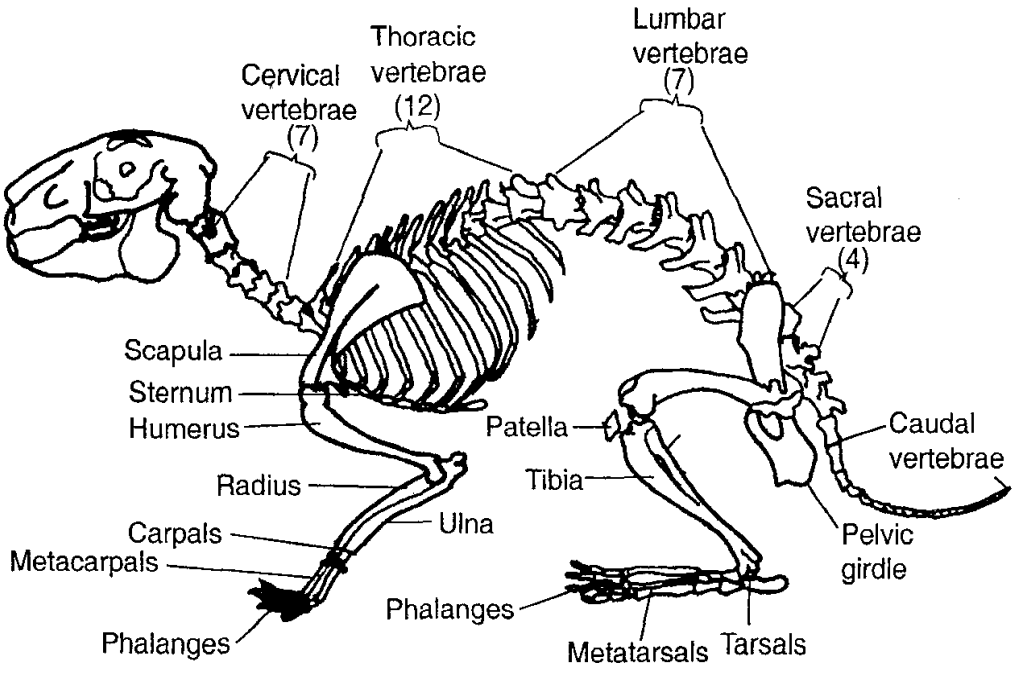


Figure: 1.1 (b)

1.2. The Axial Skeleton

This consists of the skull, the sternum, ribcage and the vertebral column.

The Skull

The skull is made up of many bones joined together to form the cranium as shown in figure 1.2 The cranium encloses and protects the brain. There are perforations on the cranium to allow blood vessels and nerves to pass to and from the brain. The facial skeleton consists of the upper and lower jaws.

Fused bones of skull

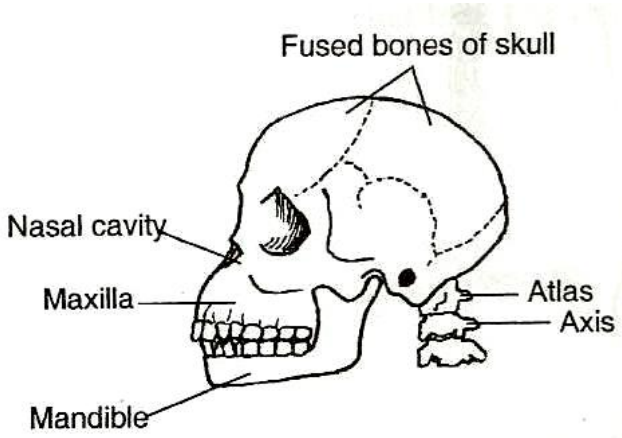


Figure: 1.2

The lower jaw or mandible articulates to the cranium with a moveable joint. The cranium protects the olfactory organs, middle and inner ear and the eyes. At the posterior end of the cranium are two smooth rounded proturberances, the occipital condyles, that articulate with the atlas vertebra to form a joint which permits the nodding of the head.

The Rib-Cage and Sternum

The rib-cage encloses the thoracic cavity protecting delicate organs such as the heart and lungs. The cage is made of ribs articulating with the vertebral column to the back and the sternum to the front. At these articulating points the ribs have cartilage as seen in figure 1.3

The sternum is a right bonny structure that supports the ribs and protects the organs in the thoracic cavity. In flying vertebrates the sternum is very prominent and often modified to form a keel which gives a large surface area for attachment of pectoral muscle (flight muscle). **Note:** At the lower end, the sternum and rib cage offers surfaces for attachment of muscles of the back and the abdomen. These muscles bringing about movement of the rib cage during the breathing process in mammals.

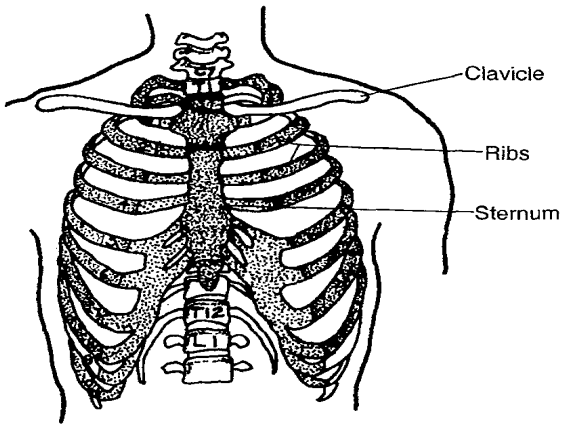


Fig. 1.3 The anterior view of thoracic cage

The Vertebral Column

The vertebral columns consist of bones called **vertebrae.** The number of vertebrae varies from one species of vertebrate to another. In humans, for example there are thirty three vertebrae. The **vertebrae** are separated from each other by cartilage called inter-vertebral discs. It acts as a cushion that absorbs shock and reduces friction. It also makes the vertebral column flexible by allowing for a certain degree of movement between the vertebrae.The vertebral column has five types of vertebrae. These are:

(i) The cervical vertebrae (ii) The thoracic vertebrae
(iii) The lumbar vertebrae (iv) The sacral vertebrae
(v) The caudal vertebrae. These vertebrae have got common basic plan as shown in figure 1.4

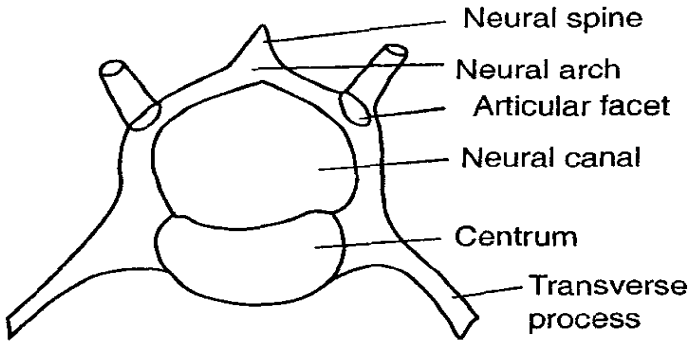


Fig. 1.4 Generalised vertebrae to show main features

The centrum is a solid structure of the vertebra. It supports the weight of the vertebra. Collectively the centrum supports the entire vertebral column.

Transverse Processes are lateral in relation to centrum while the **neural spine** is dorsal to the centrum. These are projections which offer surfaces for muscle and ligament attachment.

Centrally running through the vertebra is a **neural canal** which is a passage for the spinal cord. The neural arch is an arch of bones which arises from the centrum. Together with the centrum they protect the spinal cord. The vertebrae articulate with each other anteriorly and posteriorly by facets (zygapophysis).

At the anterior (front) and posterior (back) of each vertebra is a pair of smooth facets for articulation of successive vertebrae. Facets at the anterior part are the **prezygapophyses.** These facets face upwards and inwards. The facets of the posterior part are the **postzygapophyses.** These face downwards and outwards.

The Cervical Vertebrae

The cervical vertebrae are found in the neck region. There are seven cervical vertebrae. All cervical vertebrae have vertebraterial canals in the transverse processes for the passage of vertebral artery. The first two **atlas** and **axis** are distinct from the rest of the cervical vertebrae.

The atlas has a small neural spine and the centrum. The neural canal is wide for passage of the large spinal cord in the neck region. Its transverse processes are broad and wing-like offering a large surface area for attachment of neck muscles. It has broad facets for articulation with the condyles of the skull. This forms a joint which allows for up and down movement of the head (nodding).

See fig. 1.5 (a) and (b)

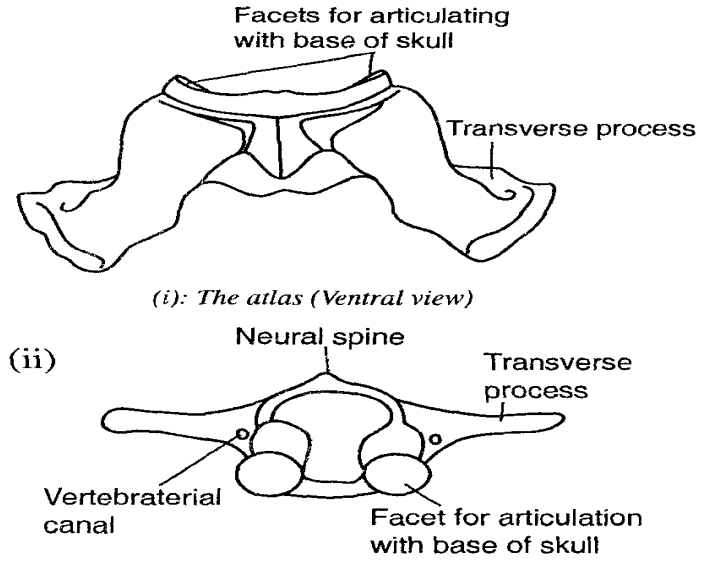
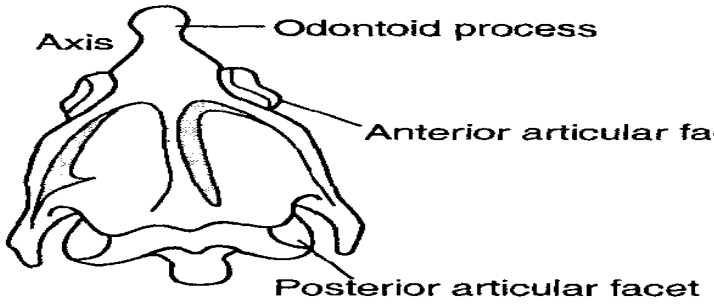


Figure: 1.5 (a)

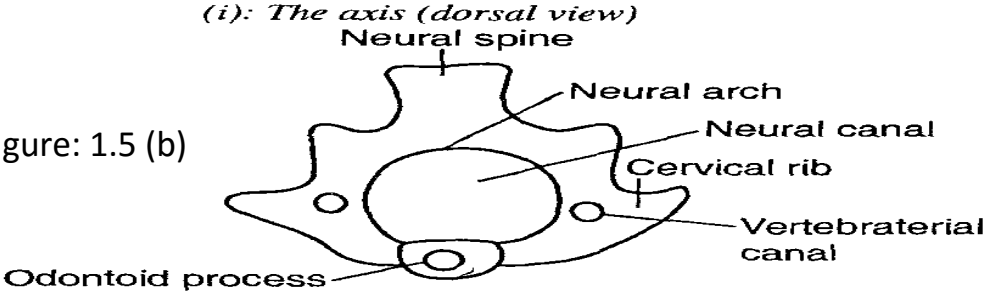
The axis is the second cervical vertebra on the neck region. Its special feature is that the centrum is broad and projects in front to form an ***odontoid*** process. This forms a peg which fits into the ventral side of the neural canal of the atlas. The joint formed allows the turning (rotatory) movements of the head. See figure 1.5 (b). The axis has broad neural spine, wide neural canal and wing-like transverse processes.

The other five cervical vertebrae possess broad and branched transverse processes. These features offer large surface area for attachment of neck muscle. These cervical vertebrae have short neural spines but wide neural canals and wide centrum. They possess the prezygapophysis and postzygapophysis. See fig. 1.5 (b).



(i): The axis (dorsal view)

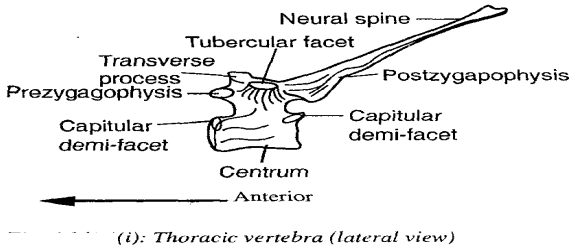
Figure: 1.5 (b)



(b)(ii): The axis (anterior view)

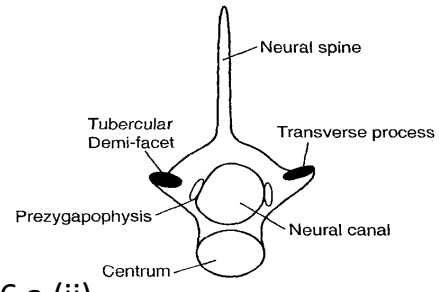
The Thoracic Vertebrae

The thoracic vertebrae are found in the thoracic region articulating with the ribs. In human beings they are twelve in number. A thoracic vertebrae has a long neural spine which offers large surface for the attachment of back muscles. The centrum is large but the transverse processes are short. The neural arch is small. The ribs articulate with the vertebrae at two points, namely, the capitulurn and the tuberculum. The tuberculum facet on each transverse process articulates with tuberculum of rib while the capitular demifacets on the centrum articulate on capitulum of rib. See figure 1.5 (a) and (b).



(i): Thoracic vertebra (lateral view)

Figure: 1.6 a(i)



'ii): Thoracic vertebra (anterior view)

Figure: 1.6 a (ii)

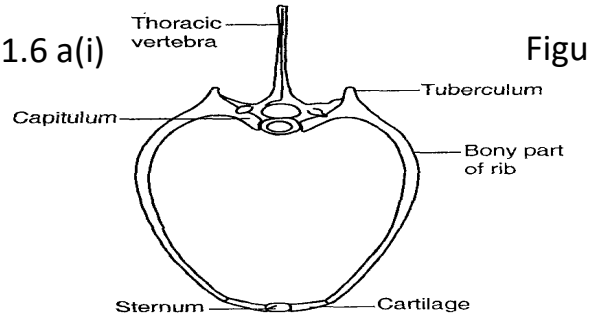


Figure: 1.6 (b) (i)

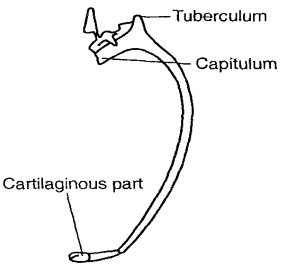


Figure: 1.6 (b) (ii)

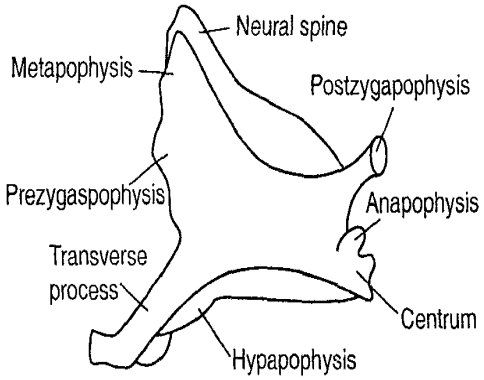
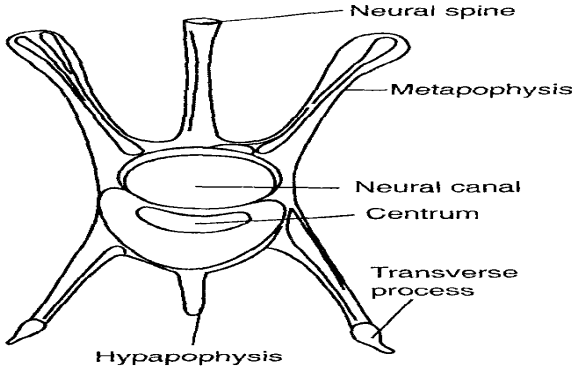


Figure: 1.6 (c) Lumber vertebra (lateral view)

The Lumbar Vertebrae

These are found in the lumbar region of the body. In human beings there are five vertebrae. Each lumbar vertebra has a large and broad centrum to offer support. These have broad and long transverse processes projecting forwards and downwards from the centrum. They also have a broad neural spine. These therefore offer a large surface for attachment at abdominal muscles. On either side of the neural spine are two projections called **metapophyses.** Also project dorsally near the transverse processes are **anapophyses.** In some animals such as rabbits another projection the **hypapophysis** arises ventrally to the centrum. All these projections offer additional surfaces for the attachment at abdominal muscles. See figure 1.7.



(a): Lumbar vertebra (anterior view)

Figure: 1.7

The vertebrae in the lumbar region are therefore adapted to support the weight of the body and to withstand strains of movement.

The Sacral Vertebrae

These are situated in the sacral region. Human beings have five in number while rabbits have four of the vertebrae. Sacral vertebrae have large and broad centrum to offer support. The neural canal is narrow and neural spine is much reduced. The first anterior sacral vertebra is large with wing-like transverse process which are fused to the pelvic girdle. The transverse processes of the remaining vertebrae are not attached. They all provide surfaces for attachment of back muscles. All the sacral vertebrae are fused to form a rigid structure, the sacrum. This makes the sacrum strong and firm to bear the body weight and spread it to the legs through the pelvic girdle. See figure 1.8.

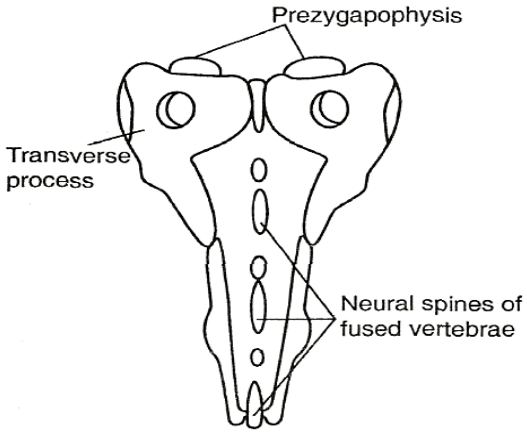


Figure: 1.8

The Caudal Vertebrae

These are found in the tail region. The number of the vertebrae differs from one animal to another depending on the size of the tail. In human beings where the tail is vestigial, there are four caudal vertebrae which are fused to form a coccyx. In the caudal vertebrae, neural spines and zygapophyses are very much reduced. The neural canal and neural arch are absent hence the entire bone is essentially the centrum.

Study Theses Question

Describe how the following vertebrae are adapted to their function.

(a) Cervical
(b) Thoracic
(c) Lumbar
(d) Sacral

1.3. The Appendicular Skeleton

The appendicular skeleton consists of the girdles and the limbs attached onto them. The girdles are the pectoral girdle on the anterior side and pelvic girdle to the posterior. The limbs to the anterior part of the body are fore-limbs and those to the posterior are hind-limbs. The limbs of all mammals are designed on the same basic plan, that of the pentadactyl limb, so named because each limb terminates in five digits (fingers or toes). See figure 1.9.

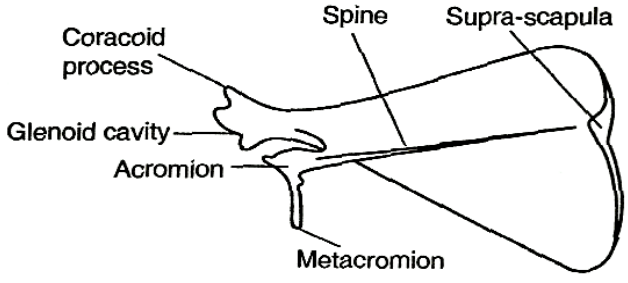


Figure: 1.9

Bone of the Fore Limbs

(i) The Pectoral Girdle

This is made up of two halves each of which consists of three bones, the scapula, the coracoid process and clavicle. These bones are attached to the upper part of the vertebral column. The two halves are not fused but are attached firmly by muscles.

The scapula is a flat, triangular-shaped bone which overlies a number of anterior ribs, is shown in figure 1.9. At its apex is concave cavity or depression, the glenoid cavity, which articulates with the head of the humerus to form the ball and socket joint A spine runs along the outer surface of the scapula, and at its free end, close to the glemoid cavity are two projections, the acromion and metacromion which are both for muscle attachment. The clavicle articulates on one end with acromion process and the other with sternum. It is for muscle attachment and aids in movement of arms.

(ii) Humerus

This is the bone found in the upper arm. Its head articulates with the scapula at the glenoid cavity of the pectoral girdle where it forms a ball and socket joint. Near the head are two roughened projections, the greater and lesser tuberosities. These extend into a shaft which provides surface for muscle attachment. Between the tuberosities is a groove.

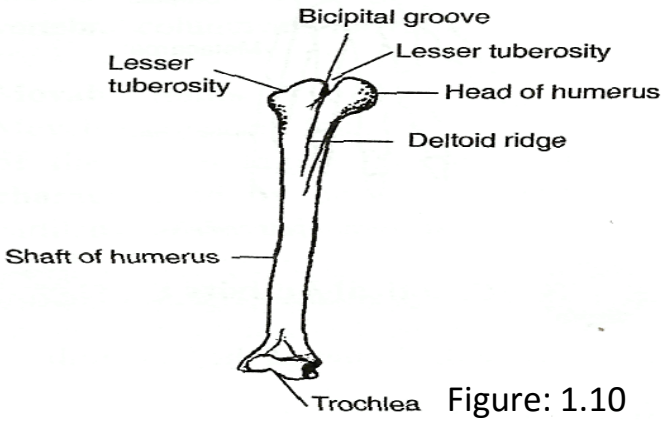


Figure: 1.10

It is along this groove that the tendon of the biceps muscles passes. At the lower end is the trochlea which articulates with the forearm to form a hinge joint at the elbow. See figure 1.10.

(iii) Ulna and Radius

These are two bones found in the forearm. The radius is found on the side of the thumb. The ulna on the side of the small finger has a projection called the **olecranon process.** This has a sigmoid notch which articulates with the humerus forming a hinge joint. The olecranon offers a large surface for attachment of tendons, and overstretching of the forearm at the joint. See figure 1.11

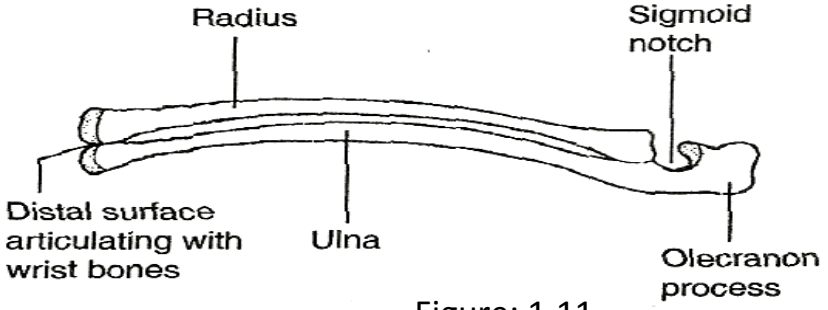


Figure: 1.11

(iv) **Carpals, Metacarpals and Phalanges**

The carpals are small bones found in the wrist. Away from the wrist are the metacarpals which are much longer than the carpals. To the end of the hand are the figures made of bones called phalanges. See figure 1.12.

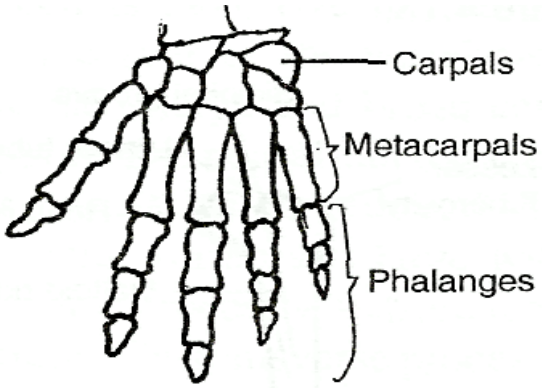


Figure: 1.12

Bones of the Hind limb

The bones of the hind limb are the pelvic girdle, the femur, the tibia, fibula and the bones of the foot.

(i) The Pelvic Girdle

The pelvic girdle consists of two halves fused at the pubic symphysis. Each half is made of three fused bones, the ilium, ischium and pubis. Each half has a cup-shaped cavity the acetabulum. This articulates with the head of the femur to form a ball and socket joint. Dorsally, the ilium articulates with the sacrum.

The ilium is above the acetabulum. It provides large surface to which thigh muscles are attached. Between the ischium and pubis is a hole, the orbturator foramen. This is an aperture through which blood vessels, nerves and muscles pass.

This design is an adaptation to reduce the weight of the pelvic girdle and hence lighten the load to be supported by the hind lirnb. The pubic symphysis is composed of flexible cartilage which permits widening of the female's girdles when giving birth. The ilium, ischium and pubis are fused to form the innominate bone.Figures 1.13 (a) and (b) show pelvic girdles of a rabbit and human being respectively.

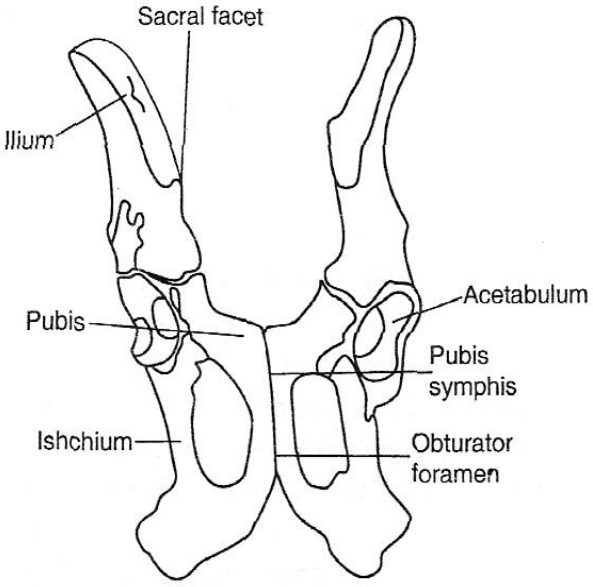


Figure: 1.13 (a)

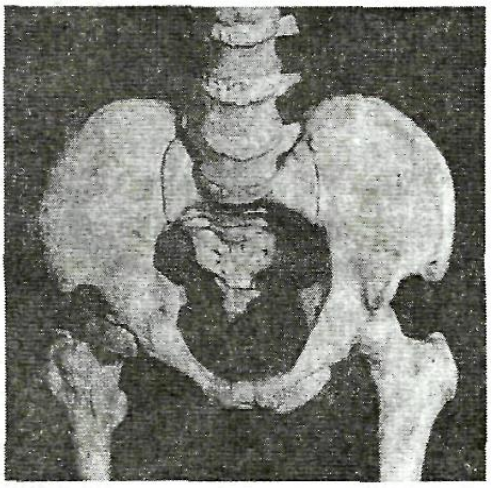


Figure: 1.13 (b)

(ii) The Femur

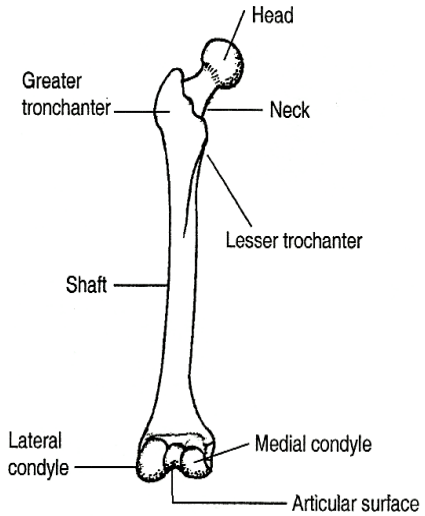


Figure: 1.14 (b)

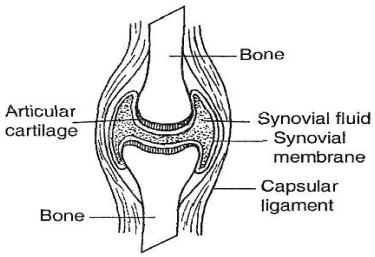
The femur is a long bone found between the hip and the knee. The head of femur fits into the acetabulum forming the hip joint. At the tip of the shaft, are the greater and lesser trochanters which are extensions for muscle attachment. The shaft of the femur leads to the lower end with expanded and rounded knobs called **condyles.** The condyles articulate with the patella (knee cap). They also articulate with tibia to form hinge joint at the knee. See figure 1.14

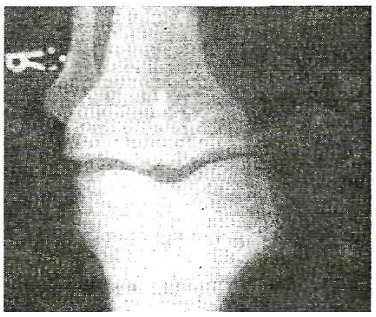
1.4 Joints

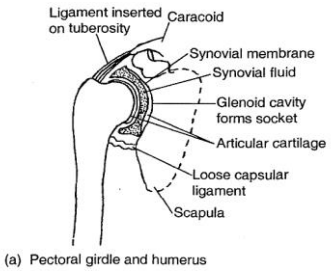
A joint is a connection between two or more bones. There are various types of joints which permit varying degree of movement. In mammals there are three main types of joints; **immovable** joint e.g. fused bones in the skull and the pelvic girdle; gliding joints e.g. at the wrist, ankle and between vertebrae in the vertebral column and **movable joints.**

Movable Joints

Movable joints are found at various points of the appendages. These joints are characterised by bones covered with cartilages at the ends and bones being held together by tough ligaments. The joint area is filled with a lubricating synovial fluid and are also called synovial joints. Synovial joints are of two types - ball and sockets, and hinge joints. See figure 1.15 (a) and (b) and plate 1.




Figure: 1.15 (a)



(a) Pectoral girdle and humerus

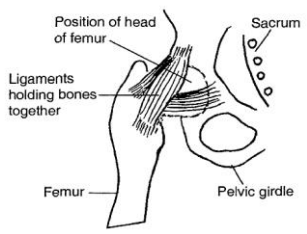
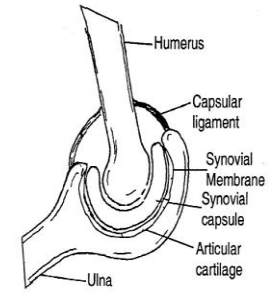


Figure: 1.16 (b)

Ball and Socket Joints

This is a type of joint with two bones, one with a round head and the other one with a depression or cavity into which the head of the first bone fits and moves freely. In ball and socket joints, movement is possible in all directions. Examples of ball and socket joints include hip and the shoulder joints. The ball and socket joint allow the limbs to rotate through 360°. However, these joints are unable to bear very heavy loads. See figure 1.16 (a) and (b).

Hinge Joint



The depressions in one bone allows the smooth condyles of another bone to fit and articulate to allow movement in one direction. The maximum stretch of the limb at this joint is 180°. Hinge joints are found at the elbow, knee and phalanges. See figure 1.7 and plate 2.

Movement at a Joint

At a movable joint the bones are held together by an inelastic tissue called a **ligament.** The **ligaments** restrain movement of the bones thus preventing dislocation.

At the joint muscles are attached to the bones by an inelastic tissue called **tendon.** A muscle is attached at two points; the origin on an immovable bone and the **insertion** on a movable bone.

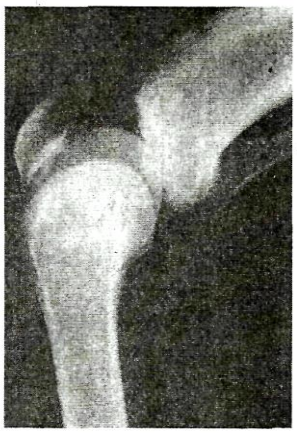


Figure: 1.17

Muscles which operate joints are in pairs and are antagonistic. A muscle may bring about bending at a joint. This type of muscle is called **flexor muscle** while the other which straightens the limb is called the **extensor muscle.**

Movement at a joint can be illustrated by the action of the binge joint of the elbow. In the arm there are two antagonistic muscles; the biceps and the triceps.

The biceps are the flexor muscles while the triceps are the extensor muscles. See figure 1.18.

Biceps muscles flex the arm while the contraction of triceps extend the arm. The biceps contract the triceps relax. This pulls the ulna-radius upwards hence bending the arm. See figure 1.18(a).

While the triceps contract the biceps relax thus straightening the ulna-radius leading to extension of the arm. See figure 1.18(b).

During this movement of the arm, the hinge joint at the elbow serves as the fulcrum with the biceps muscles providing the effort to lift the load at the forearm.

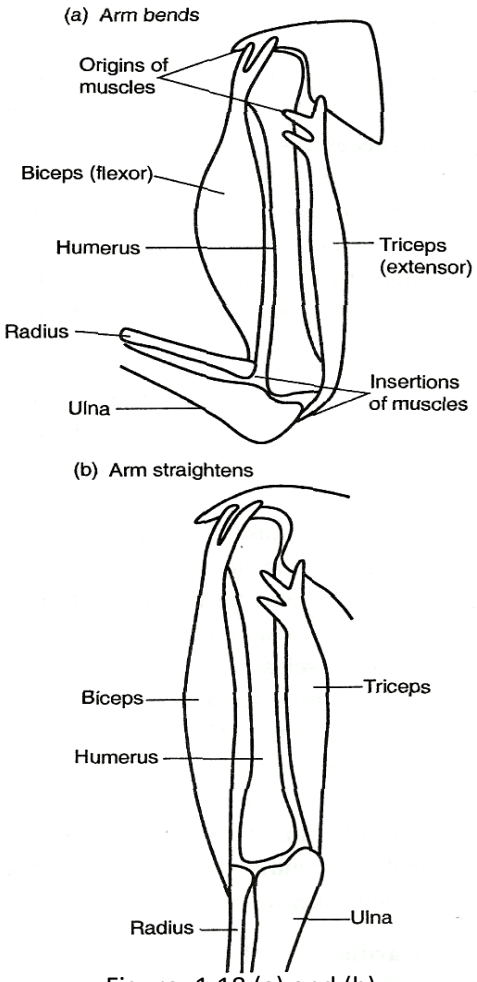


Figure: 1.18 (a) and (b)

1.5. Muscular System

Structure and Function of Muscles

Muscle is a tissue specialized for contraction. There are three types of muscles:

- Skeletal muscle
- Smooth muscle
- Cardiac muscle

(i) Skeletal or striated muscle

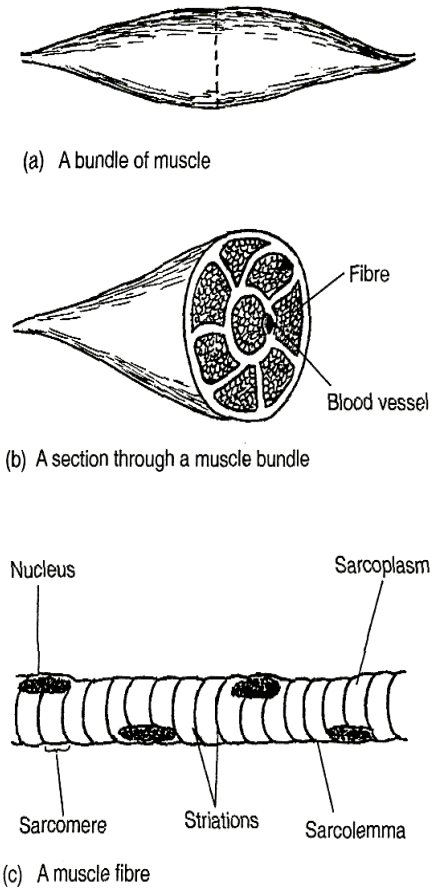
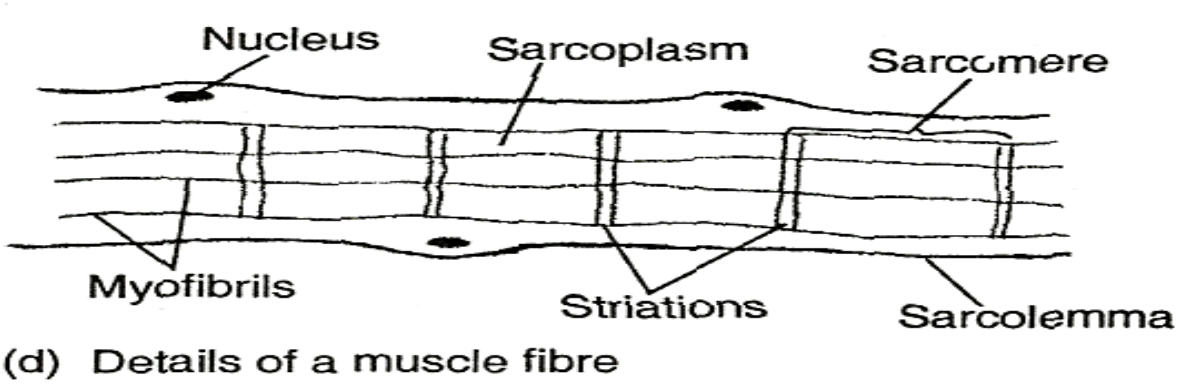


Figure 1.19 (a), (b) and (c)

These muscles are attached on the skeleton and play an important role in locomotion. The **striated muscle** are innervated by the voluntary part of the nervous system and are therefore known as **voluntary muscles.** When viewed under the microscope its fibres are seen to have stripes running across them, for which reason it is called **striated** or **striped muscle.** Characteristically it contracts and fatigues rapidly.

A skeletal muscle is made up of a bundle of long fibres running the whole length of the muscle. An individual fibre is an equivalent of one cell but containing many nuclei (multinucleated). Each fibre contains many myofibrils running parallel to each other. The covering of a muscle fibre is called a **sarcolemma.** See figure 4.27. The myofibrils are in turn composed of two protein strands.



(d) Details of a muscle fibre

The functional unit of the muscle is the myofibril which has the ability to contract muscles requires large amounts of energy to contract. This energy is provided by the numerous mitochondria present in the sarcoplasm. Sodium ions and calcium ions are also necessary for muscle contraction. The contraction of the muscle creates a force. The force created by the contraction is transmitted onto the skeleton in the same magnitude by the tendon. This brings about the appropriate movement of the skeleton.

(ii) Smooth or Visceral Muscles

Smooth muscles are found on the walls of tubular visceral organs. These include the blood vessels, gut, urinary tract, reproductive tract and respiratory tract. The cells which make up smooth muscles are spindle-shaped each with a single nucleus. They contain myofibrils enclosed by plasma membrane. They lack cross striations hence referred to as **smooth muscles.**

Smooth muscles are capable of slow involuntary contractions. The smooth muscles are innervated by the autonomic part of the nervous system for which reason they are also called **involuntary muscles.** They are capable of contracting slowly and fatigue slowly unlike skeletal muscles. See figure 1.20.

(iii) Cardiac Muscle

This is the heart muscle. Each muscle fibre consists of short cells with centrally placed nuclei and numerous striated myofibrils. The ends of the cells are marked by thickened regions called **intercalated discs.** These form bridges between fibres hence transmit impulses rapidly throughout the heart. The contractions of the heart muscle are generated from within the heart itself without nervous

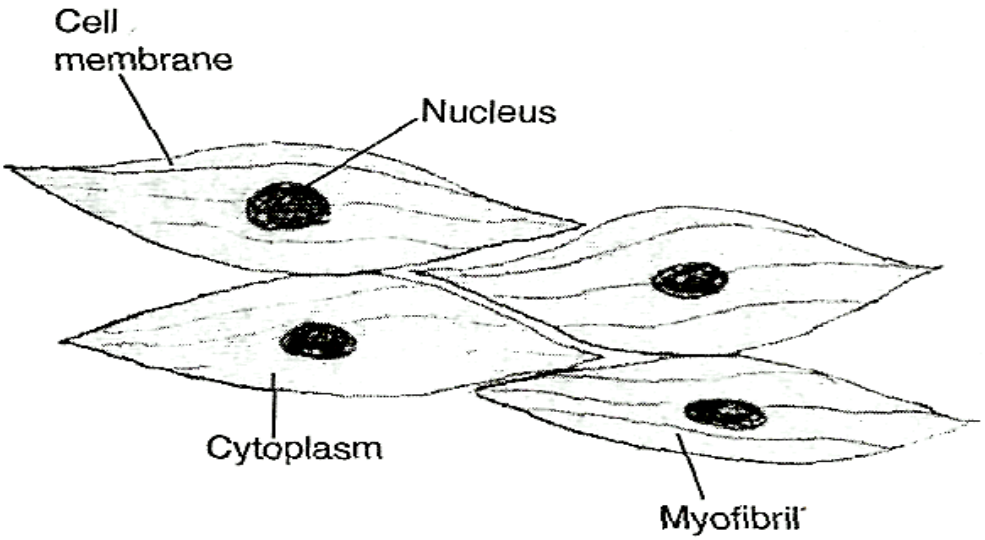


Figure 1.20

Stimulation. Therefore the heart muscle is said to be myogemc. The cardiac muscle is capable of continuous rhythmic contractions without fatigue throughout the life of the mammal. They have more mitochondria than skeletal muscle to sustain the energy demands. See figure 1.21.

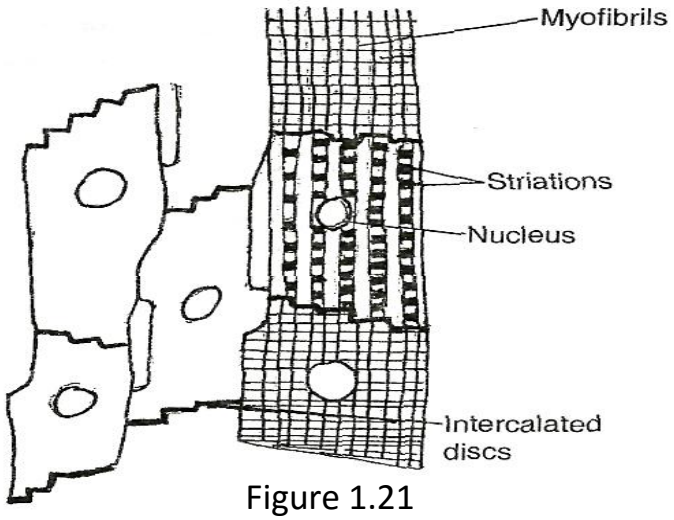


Figure 1.21

1.6. The Integumentary System

The Skin

The major characteristics of the skin

1) Waterproof, stretchable, washable, and permanent-press, that automatically repairs small cuts, rips and burns and is guaranteed to last a lifetime.
2) Surface area of up to 2.2 square meters.
3) 7% of total body weight Pliable yet tough

Layers of the skin

1) **Epidermis (epi-upon)**
   Composed of epithelial tissue (stratified squamous), non-vascularized
2) **Dermis – underlies the epidermis**
   Tough leathery layer composed of fibrous connective tissue. Good supply of blood
3) **Hypodermis (not considered skin)**
   Made of adipose and areolar tissue, stores fat, anchors skin and protects against blows

The different types of cells in the epidermis

1) **Keratinocytes:** Produce a fibrous protein called keratin**.** Are formed in the lowest levels of the epidermis. Pushed upward by the production of new cells beneath them. Become dead and scale like**.** Millions rub off everyday
2) **Melanocytes :** Synthesizes the pigment melanin**,** melan-black Can transfer melanin to keratinocytes these protects skin from ultraviolet light.
3) **Langerhans' cells:** Formed in bone marrow. Move to the skin Macrophages
4) **Merkel Cells:** Has a spiked appearance**,** connected to nerve cells from dermis. Function as sensory receptors for touch.

Stratum basale: deepest layer of the epidermis undergoes rapid cell division.
Stratum spinosum: intermediate layer, contain spiny shaped keratinocytes.
Stratum corneum: outermost layer 20-30 cells thick of dead keratinized cells.

Dandruff

Average person shed 40 pounds of these cells in their lifetime.

Characteristics of the dermis

1) Made up of connective tissue
2) Richly supplied with blood vessels and lymph vessels
3) Has hair follicles, oil and sweat glands and sensory receptors
4) Ridges formed from the papillary layer can form finger prints.
5) Reticular layer of the dermis
6) Filled with dense irregular fibrous connective tissue
7) Matrix is filled with thick bundles of collagen fibers (give the skin strength)

Less dense regions are called lines of cleavage or tension lines; surgeons use these to make incisions because they heal quicker.

What causes the color of skin?

Three pigments contribute to skin color.Melanin- protein pigment (natural sunscreen)Can range in color from yellow to reddish-brown to black. Everyone has the same number of melanocytes but make varying amounts and colors (differences in skin color) Increased melanin production can caused by sunlight. Carotene-yellow to orange pigment found in carrots.

Most commonly found in the palms or soles. Most intense when large amounts of carotene-rich foods are eaten. Hemoglobin- Red blood gives a pinkish due to fair skin

What are the major appendages of the skin?

a) Sweat glands
b) Sebaceous glands
c) Hairs
d) Nails

What are the types of glands found in the skin?

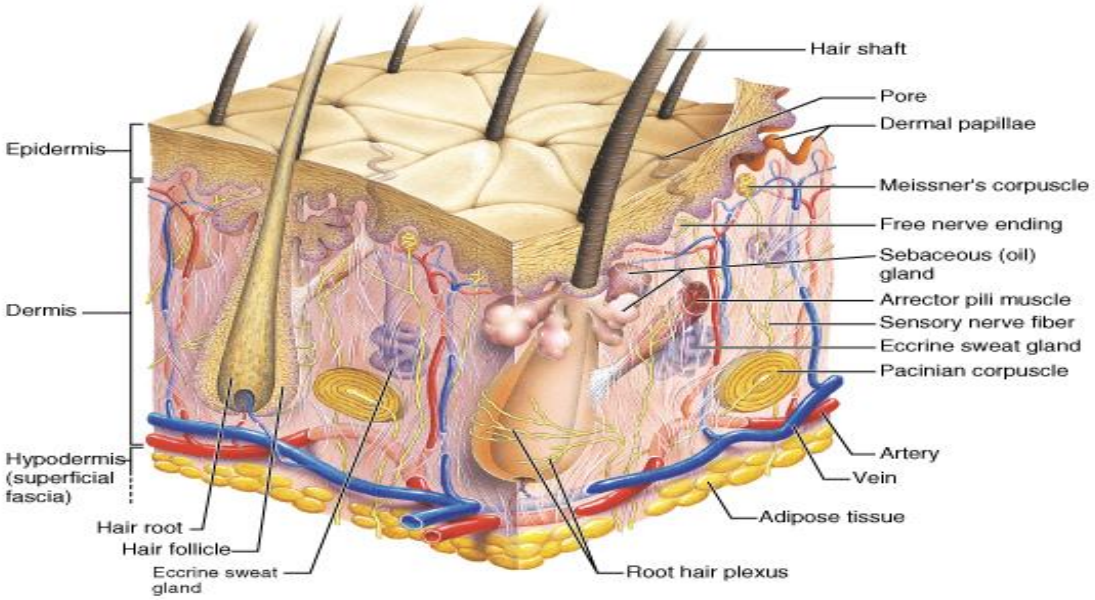
a) Sweat glands-sudoriferous - Merocrine- common sweat glands. Hot sweats vs. Cold sweats. Apocrine- produce sweat plus a milky or yellowish substance composed of fat and protein. Found in the arm pits and genitalia Thought to be scent glands.
b) Ceruminous- produce cerumen (ear wax)
c) Mammary glands- produce milk

Sebaceous glands- oil glands (sebum) Softens and lubricates hair and skin,slows water loss and kills bacteria

Main Functions of the Skin

1) **Thermoregulation**- skin contains sweat glands that secrete watery fluid, that when evaporated, cools the body.
2) **Sensation-** Skin contains sensory receptors that detect cold, touch, and pain.
3) **Vitamin D synthesis**- cholesterol in the skin is bombarded by sunlight and converted to vitamin D (calcium cannot be absorbed from digestive tract)
4) **Blood reservoir**- blood will be moved from skin to muscles during strenuous activity.
5) **Excretion**- Sweating is an important outlet for wastes such as salt and nitrogen containing compounds. (urine)

6) **Physical barrier**: Very few substances are able to enter the skin. Substances able to pass. Lipid-soluble substances: oxygen, carbon dioxide, some vitamins
Oleoresins- poison (poison ivy



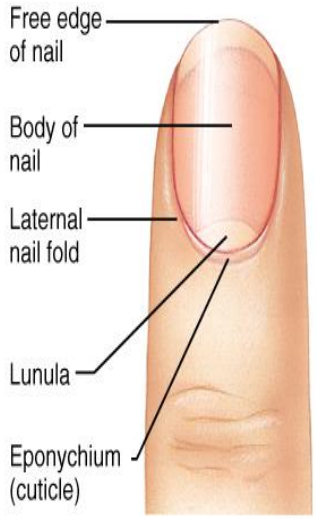
The Hairs

The hairs are useful because, senses insects that land on the skin.
Hair on the head protects the head from a blow, sunlight and heat loss. Eyelashes shield the eye. Nose hairs filter the air.

What are hairs?

- Made from hair follicle and dead keratinized skin cells.
- Composed of two parts shaft and root. The shaft has 3 layers of cells
  (i) Medulla (central core)
  (ii) Cortex (bulky layer)
  (iii) Cuticle (heavily keratinized; protects hair)

What are the parts of nails?



A nail is a scalelike modification of the epidermis. Made of tightly compressed keratinized cells. Nails are useful tools to pick up small objects or scratch an itch. Nail matrix is the region responsible for nail growth.

Revision Questions

1. What is the importance of support in animals?
2. Name two different types of skeleton in animals, giving an example of an animal for each named skeleton.
3. (a) List down the different types of bones found in:
   (i) Axial skeleton
   (ii) Appendicular skeleton in human
   (b) What is the difference between exoskeleton and endoskeleton?
4. Name the bones of fore limbs and hind limbs?
5. Define Joints? What are the types of joints
6. Distinguish between the ball and socket joint and the hinge joints
7. Name the three types of Muscles found in human body
8. State one characteristic each of the muscle mentioned above and how each is adapted its functions.
9. Define and State the function of tendons and ligaments
10. Explain the structure of cardiac muscle and its role for heart functioning
11. State the types the skin and their cells.
12. Mention the main Functions of the skin.
13) Explain the structure and importance of hairs?
14) Explain the structure and importance of nails?

CHAPTER TWO
NUTRITION AND DIGESTION

2.1. Chemical Compounds Which Constitute Living Organisms

Cells, tissues and organs are composed of chemicals which are referred to as **chemicals of life** and are obtained from the environment. The study of chemical compounds found in living organisms and reactions in which they take part is known as **biochemistry.** This study attempts to review the chemical composition of living systems. Many of these chemicals are identical to those found in non-living organic matter. However, we shall consider carbohydrates, lipids and proteins.

2.2. Carbohydrates

Carbohydrates are compounds of carbon, hydrogen and oxygen. The elements are in the ratio of 1 carbon: 2 hydrogen: 1 oxygen. This gives the carbohydrates a general formula $(CH_2O)_n$ where "n" represents the number of carbon atoms a molecule of a carbohydrate has. Carbohydrates can be divided into the following types: **monosaccharides, disaccharides and polysaccharides.**

(i) Monosaccharides

These are the simplest carbohydrates and have a general chemical formula of $(CH_2O)_n$ where n = 6. Hence their chemical formula is $C_6H_{12}O_6$. For example, glucose, fructose and galactose are simple carbohydrates which have the formula $C_6H_{12}O_6$.

Properties of Monosaccharides

Monosaccharides are soluble in water and form sweet tasting solutions. Sweet tasting fruits owe this property to the abundant content of monosaccharides in them. When monosaccharides are mixed with Benedict's solution and heated, the copper sulphate is reduced to red copper (I) oxide. Thus, they are described as **reducing sugars.** They are cry stall is able. Molecules of monosaccharides link together to form complex carbohydrate molecules. This process is called **condensation.** In this reaction, water molecules are also formed. For example, two glucose molecules can be condensed and linked together to form one molecule of disaccharide.

Functions

a. Monosaccharides are oxidised during respiration to **release energy.** Glucose is the common respiratory substrate and the most common monosaccharide.
b. When condensed together, they form polysaccharides such as starch and cellulose in plants. Glucose can be converted into glycogen which is stored in animal tissues.

(ii) Disaccharides

They are formed by linking two monosaccharide molecules through the process of condensation. Therefore, they are more complex than monosaccharides.
Their formation from two mono-saccharides results to loss of water molecules. For example:

Monosaccharide + Monosaccharide $\xrightarrow{\text{Condensation}}$ Disaccharide + Water

$C_6H_{12}O_6 + C_6H_{12}O_6 \xrightarrow{\text{Condensation}} C_{12}H_{22}O_{11} + H_2O$

Glucose + Glucose $\xrightarrow{\text{Condensation}}$ Maltose + Water

Glucose + Fructose $\xrightarrow{\text{Condensation}}$ Sucrose + Water

Glucose + Galaciose $\xrightarrow{\text{Condensation}}$ Lactose + Water

From the above equations, it can be concluded that the type of disaccharide formed depends on the monosaccharide units that enter into its composition.

Properties of Disccharides

Like the monosaccharides, disaccharides are soluble in water to produce sweet tasting solutions. The sugar cane juice is rich in sucrose. This juice is processed to make ordinary sugar. Some disaccharides such as sucrose cannot reduce copper sulphate in the Benedict's solution unless they are first broken down to their constituent monosaccharides. They are therefore known as **non-reducing sugars.** However, some dissaccharides such as maltose reduce copper sulphate in Benedict's solution when heated together. They are known as **complex reducing sugars.** Disaccharides can readily be broken into their constituent monosaccharide molecules in a process known as **hydrolysis.** The process involves splitting of complex molecules in the presence of water. For example:

Disaccharide + water $\xrightarrow{\textit{Hydrolysis}}$ 2 Monosacharides

$C_{12}H,0_H + H_20 \xrightarrow{\textit{Hydrolysis}} C_6H,_20_6 + C_6H_{12}0_6$

Sucrose + water $\xrightarrow{\textit{Hydrolysis}}$ Glucose + Fructose

Lactose + water $\xrightarrow{\textit{Hydrolysis}}$ Glucose + Galactose

Maltose + water $\xrightarrow{\textit{Hydrolysis}}$ Glucose + Glucose

In nature, disaccharides are hydrolysed by enzymes. In the laboratory, hydrolysis can be carried out by heating them with an acid such as dilute hydrochloric acid.

Functions

Disaccharides are hydrolysed by enzymes into monosaccharides which are then oxidised to release energy.

(iii) Polysaccharides

Polysaccharides are made up of many monosaccharide molecules. Thus, their molecules are long and more complex. They have a general formula $(C_6H_{10}O_3)n$ where the value of n is very large. The Polysaccharides commonly found are starch and cellulose in plants while glycogen is found in animal tissues.

Starch

Starch is present as stored food in plant tissues. It is formed by condensation of a large number of monosaccharides. Plants that are rich in starch include maize, wheat, potato and rice. These plants are grown as sources of food.

Cellulose

It exists as a component of the cell wall in plants. It is made up of more molecules of monosaccharides than starch. Cellulose gives the plant cells their definite shape.

Glycogen

It is present as stored carbohydrates in animal tissues. Glycogen is synthesised from excess glucose.

Properties of Polysaccharides

All polysaccharides are insoluble in water and do not have a sweet taste. Therefore, they are referred to as non-sugars.

Study these Questions

(a) Name the carbohydrate that is:
  (i) stored in plant seeds.
  (ii) stored in mammalian muscles
  (iii) most abundant in human blood.

(b) Summarize the main functions of carbohydrates in living organisms.

2.3. Lipids

These are fats and oils. Fats are found in animals while oils are found in plant leaves, fruits and seeds. However, a few animals such as whales contain oil. Fats and oils are similar except that oils are liquid while fats are solid at room temperature. Like carbohydrates, they are compounds of carbon, hydrogen and oxygen. However, the number of oxygen atoms are fewer in lipids than in carbohydrates. The building units of lipids are fatty acids and glycerol. Synthesis of lipid molecules requires three fatty acid molecules condensing with one molecule of glycerol. See figure **2.1.**

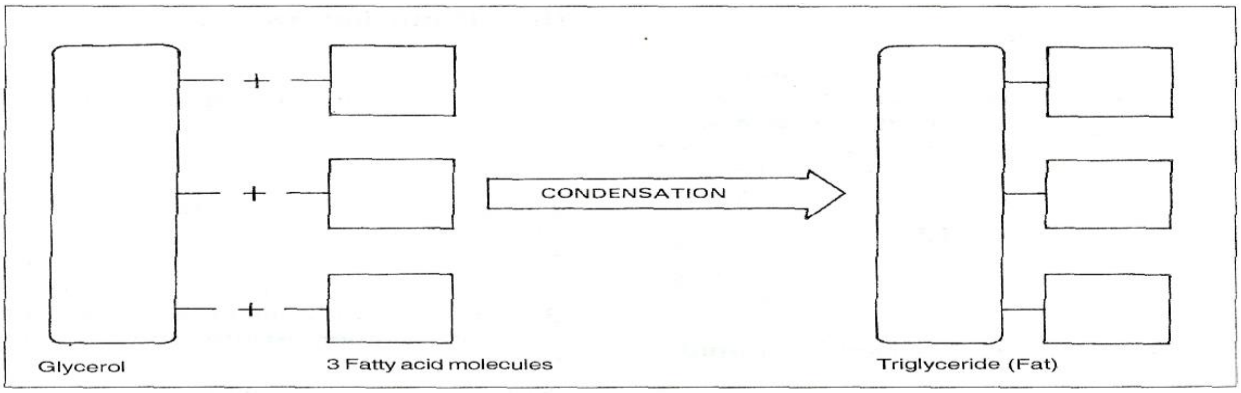


Figure 2.1

Fatty acids are of different types. Therefore, the nature of a lipid depends on the fatty acids it contains even though the glycerol is the same in all lipids. Like carbohydrates, complex lipids are also formed by a condensation process. Examples of complex lipids include phospholipids, waxes, steroids and cholesterol.

Properties of Lipids

When fats are heated, they readily change into liquid, while oils solidify if subjected to low temperatures. Both fats and oils are insoluble in water. However, they will readily dissolve in organic solvents such as alcohol, ether and chloroform. When fat and oils dissolve in these organic solvents, they form emulsions and suspensions. Lipids are quite inert, a property which enables them to be stored in the tissues of organisms.

The presence of fats or oils in a substance can be easily detected by using Sudan III dye, grease spot test and emulsion test.

Functions of Lipids

(i) Lipids as Source of Energy

Lipids are sources of energy just like monosaccharides. A given weight of a lipid will liberate almost twice as much energy as an equivalent weight of a monosaccharide.

(ii) As a Source of Metabolic Water

When oxidised lipids, release more water and energy than monosaccharides. Such water is known as **metabolic water,** which supplements the requirements in the body. This explains why some animals such as camels accumulate large quantities of fat reserves in their body. They metabolise these fats to obtain the metabolic water in addition to the energy released.

(iii) As **Structural Compounds**

Lipids are constituents of plasma membrane and protoplasm. Oils are storage materials in some seeds e.g. groundnuts, castor seed, maize grain.

(iv) Heat Insulation

In animals, fat is deposited under the skin where it forms the adipose tissue which acts as a heat insulator. In this way, fats assist to reduce heat loss from the bodies of mammals. Mammals living in temperate regions have thick adipose tissue which greatly reduces heat loss. In addition, the thick adipose tissue in some acquatic mammals helps them to be buoyant in water.

(v) Protection

Fat is deposited around the major organs such as the kidney, heart and at the back of the eyeball where it acts as a shock absorber. On the other hand, the wax in plant cuticles reduces excessive water loss.

Study these questions

(a) If glycerol is the same in all lipids, why is corn oil different from coconut oil?

(b) Outline three properties of lipids.

2.4. **Proteins**

Proteins, like carbohydrates and lipids, are compounds of carbon, hydrogen and oxygen. However, unlike carbohydrates and lipids, they contain nitrogen and sometimes phosphorus or sulphur or both. Some proteins such as haemoglobin also contain other elements such as iron. Haemoglobin is a protein containing iron. Proteins are made up of small units called amino acids. There are about 20 different types of amino acids occurring naturally. All amino acids contain amino group (-NHJ which consists of hydrogen and nitrogen but the number of carbon atoms differ from one amino acid to the other. Proteins are referred to as nitrogenous compounds because of the presence of nitrogen in their structure.

A single molecule of protein can have hundreds or even thousands of amino acid units which are joined together. Like carbohydrates, proteins are also formed by condensation. The process involves combination of two amino acids to form a **dipeptide** molecule. The bond between the two amino acids is called a **peptide bond.** During this process, a water molecule is formed. Continued condensation leads to the addition of more amino acids to a protein chain. A long protein chain known as polypeptide results. Figure 2.2 is a diagrammatic representation of a polypeptide formation. The uniqueness of a particular protein is determined by the **type** and **sequence of amino** acids that it contains. Theoretically, the possible number of ways in which amino acids could combine may lead to an infinite number of proteins. However, this is not the case since organisms possess mechanisms which control the synthesis of specific proteins. Hence, the number of proteins in life is much lower than is expected.

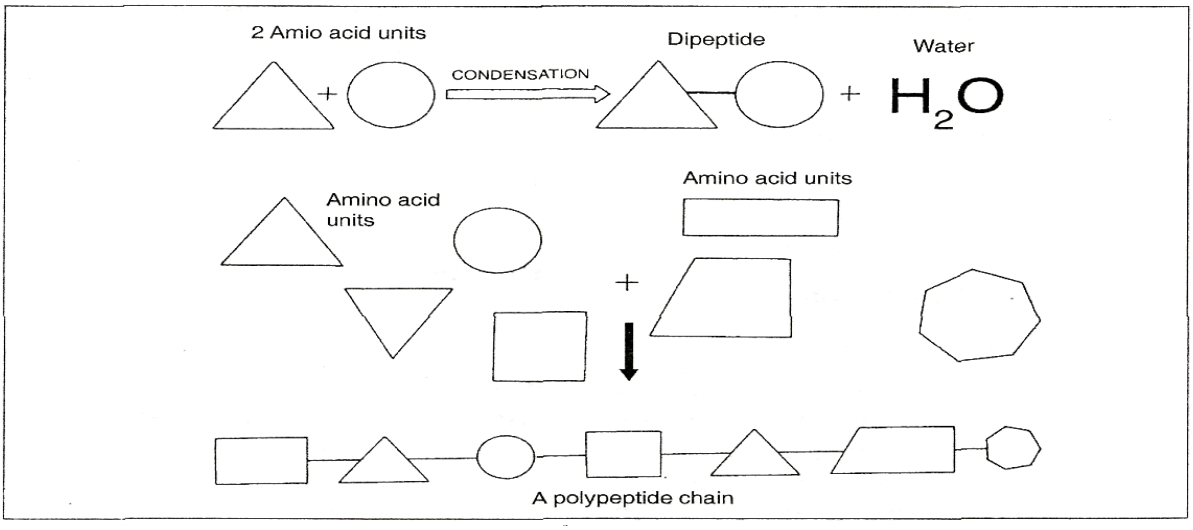


Figure 2.2

Properties of Proteins

Most proteins dissolve in water but do not form true solutions. They form **colloidal suspensions** where particles remain suspended in water. Collectively, the colloidal particles have a very large surface area and since they have a strong capacity to absorb water and other substances, they are important in holding molecules in position within the cell.

Most proteins are **denatured** at temperatures above 40°C. The heat alters the structure of the protein molecule. This changes chemical and physical properties of proteins and hence, their physiological activity. Denaturing can also be caused by chemicals such as acids, bases, detergents and organic solvents. Denaturing is irreversible hence it permanently damages the protein in the tissues.

Proteins have both acidic and basic properties. Due to these properties, proteins are described as **amphoteric.** They therefore, react with acids and bases. This property enables the proteins to combine with non-protein compounds to form **conjugated proteins.** For example, in mucus, the non-protein compound is a carbohydrate while in haemoglobin; the non-protein compound is iron.

Functions of Proteins

(i) Structural Functions

Plants synthesise amino acids which build up the proteins. Animals obtain proteins from the plants and then break them up during digestion and use the amino acids to form animal proteins.

In both plants and animals, proteins are used to make the framework of living systems. For example the plasma membranes, connective tissues, muscle fibres, hair, hooves, nails and skeletal materials.

(ii) As Metabolic Regulators

Enzymes and some hormones are protein in nature. Enzymes are organic **catalysts** which speed up metabolic reactions. Thus, they control the rate at which metabolism takes place. **Hormones** are **chemical messengers** which act as regulators of many body processes for example growth, reproduction and regulation of chemical substances such as salt, water and sugar.

(iii) As **Sources of Energy**

Like carbohydrates and lipids, proteins can be broken down to release energy. However, amino acids cannot be stored in the body like carbohydrates and fats. Proteins are normally used as a source of energy in conditions of starvation.

Study these questions

(a) Name the building blocks of proteins.
(b) Differentiate between a dipeptide and a polypeptide.
(c) List three properties of proteins.

2.5. Enzymes

These are **organic catalysts** which are protein in nature. They are produced in living cells. As catalysts, they speed up or slow down the rate of chemical reactions in the body without themselves being used up. There are two types of enzymes: **intracellular** and **extracellular** enzymes. Intracellular enzymes are secreted and used within the cells which produce them for example respiratory enzymes. Extracellular enzymes are produced within the cells but used outside the cells which produced them for example digestive enzymes.

Naming of Enzymes

(i) Trivial naming: The method involves names given to the enzymes by the people who discovered them. The names end in-in, for example: pepsin, trypsin, and ptyalin. Some of these names have been retained to date.

(ii) Use of Suffix-ase. This is the modern method of naming enzymes. The suffix -ase is added to the substrate (type of food) or the reaction which the enzyme catalyses. The following are examples of enzymes that act on certain substrates:

Substrate	**Enzyme**
Carbohydrate	- carbohydrase
Starch e.g. amylose	- amylase
Sucrose	- sucrase
Maltose	- maltase
Protein	- protease
Lipids	- lipase

Similarly, the following are some of the examples of enzymes which catalyse certain reactions.

Reaction	**Enzyme**
Hydrolysis	hydrolase
Oxidation	oxidase
Reduction	reductase

Properties of Enzymes

1. Enzymes are protein in nature. They are therefore affected by temperature and pH.
2. Enzymes are substrate-specific.
3. They are efficient in small amounts since they are not affected by the reactions they catalyse. They can be used again and again.
4. They are catalysts that speed up the rate of cellular reactions. They are not used up in the reactions they catalyse.
5. Many of these enzyme catalysed reactions are reversible.

Factors Which Affect Enzyme Controlled Reactions

The following factors affect enzyme controlled reactions:

1) Temperature

Enzymes are protein in nature hence they are sensitive to changes in temperature. They work best only within a narrow range of temperature. As the temperature increases, the optimum temperature is attained where the rate of enzyme reaction reaches its maximum. Above the optimum temperature, reaction decreases sharply due to destruction of enzyme structure. That is, the enzyme is denatured. This makes the enzyme ineffective. Most enzymes have optimum temperature between 35-40°C. Figure 2.3 shows the effect of temperature on the rate of an enzyme reaction. When the temperature decreases, rate of enzyme reaction decreases due to inactivation of the enzyme. However, low temperature does not destroy the enzyme because when temperature is increased, the enzyme becomes active again.

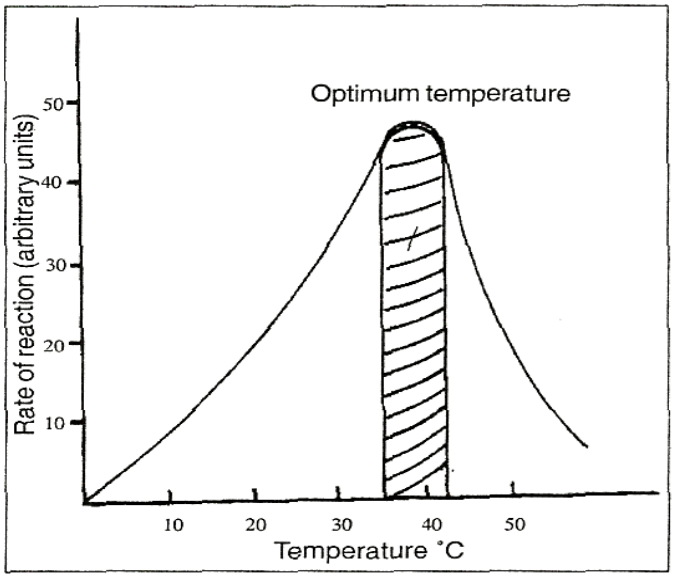


Figure 2.3 (Effect of temperature on the rate of enzyme activity

2) PH

PH refers to acidity or alkalinity of a substance. Most enzymes have optimum pH close to 7 which is the mtra-cellular pH. However, some enzymes work best in acidic conditions while others work best in alkaline conditions. As pH changes from optimum, the enzyme activity decreases. Extreme acidity or alkalinity denatures most enzymes. See figure 2.4.

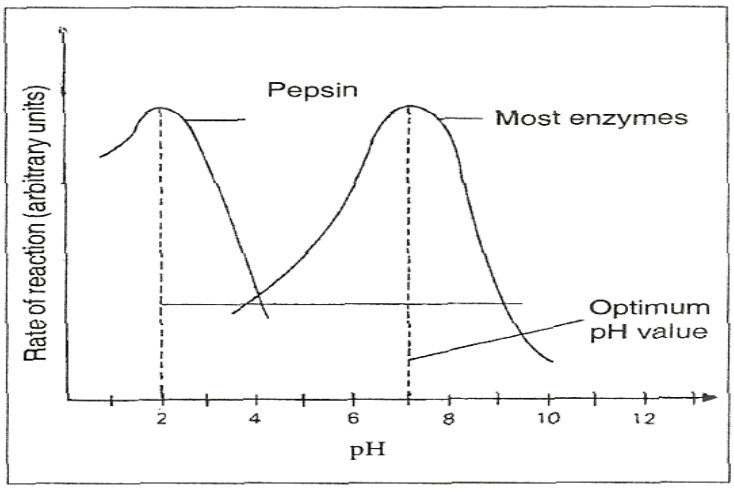


Figure 2.4 Effect of pH on the rate of an enzyme controlled reaction

Specificity

Enzymes are specific in nature. Aparticular enzyme will only act on a particular substrate. For example, salivary amylase will only speed up the break down of starch to maltose. In other words, two different enzymes cannot act on the same substrate to bring about similar products.

Substrate Concentration and Enzyme Concentration

When the substrate concentration is increased, the rate of enzyme reaction also increases up to a certain level. However, further increase in substrate concentration does not increase the rate of enzyme reaction. This can be explained in terms of active sites of enzyme. When the substrate concentration is increased, all active sites of an enzyme are occupied This condition makes the number of enzyme molecules to be the limiting factor. When the enzyme molecules are increased, there is a proportional increase in maximum rate of enzyme action as shown in figure 2.5.

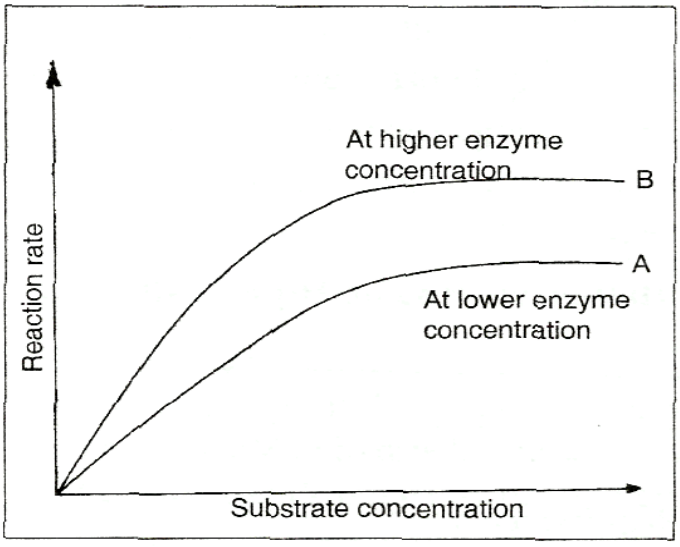


Figure 2.5

However, the enzymes are required in small amounts. They speed up the rate of enzyme reaction but do not alter the equilibrium.

Enzyme Co-Factors and Co-enzymes

Co-factors are non-proteinous substances which activate the enzymes. Most of the enzymes will not work without them. Some of the co-factors are metallic ions such as those of iron, magnesium, zinc, copper while others are vitamins. Co-factors are required in small quantities. Like enzymes, co-factors are substances that can be used again and again. Substances that affect enzyme controlled reactions. These are organic non-protein molecules that work in association with particular enzymes. Many Co-enzymes are derived from vitamins.

Enzyme Inhibitors

Inhibition occurs when action of an enzyme is slowed down by another substance. The inhibitor competes with the normal substrate for the active sites. In other cases the inhibitor takes up the active site of the enzyme permanently.

(i) **Competitive Inhibitors**

These are chemicals closely related to normal substrate and their shapes are very similar. When both substrate and inhibitor molecules are present, they compete for active sites so that the action of the enzyme is slowed down. The inhibitor is not normally affected by the enzyme so it stays in the active site longer than the substrate. This type of inhibition has no permanent effect on the enzyme action. The inhibition they cause can be overcome either by increasing the substrate concentration or reducing the concentration of the inhibitor.

(ii) Non-competitive Inhibitors

They are called non-competitive because they do not compete with the substrate. They combine permanently with enzyme molecules thus blocking the active site. This prevents the enzyme from interacting with the substrate. Such inhibitors include poisons such as cyanides, mercury and silver-arsenic compounds. The list is long.

Importance of Enzymes

Enzymes speed up cellular reactions so that they proceed at a pace that is appropriate for sustaining life. Enzymes not only speed up cellular reactions but also control them. This prevents violent incidents in the cell.

2.6 Nutrition in Animals

Heterotrophism is a mode of nutrition that involves taking in complex food materials such as carbohydrates, proteins and fats obtained from bodies of other plants and animals. The organisms that feed on these already synthesised foods are called **heterotrophs.** The heterotrophs break down or digest these foods into simple soluble molecules which can pass through the cell membrane during absorption. Heterotrophs obtain their foods using the following heterotrophic modes of nutrition.

(i) Holozoic - This is a type of nutrition characteristic of animals where solid complex substances are ingested, digested and assimilated in the body.

(ii) Saprophytism - This is a type of nutrition where organisms obtain nutrients from dead organic matter causing decomposition.

(iii) Parasitism - This is an association where one organism, the parasite, feeds on or obtains nutrients from the tissues of another living organism, the host.

(iv) Symbiosis - It is an association where two organisms live together and mutually benefit from each other.

Heterotrophs are dependent on autotrophic organisms as a source of preformed organic materials. The following sub-topic considers specifically the main aspect of nutrition in humans and other animals. Many big-sized animals take in large particles of food of different types and are, therefore, grouped into three categories namely: herbivores, carnivores and omnivores. These animals have four different types of teeth i.e. **incisors, canines, pre-molars** and **molars** and are thus referred to as **heterodonts.** Other vertebrates have teeth of the same sizes and shapes and are therefore called **homodonts.** The description of types of teeth, their arrangement and specialisation is known as **dentition.**

Teeth are arranged in groups to occupy specific positions in the jaws. Incisors are Flat, chisel-shaped with sharp ridged edges for cutting and biting food. They have one root. Canines are conical with sharp pointed tips especially modified in carnivores for seizing prey and tearing flesh. They normally have one root. Premolars have two roots while molars have two or three roots. Both have broad surfaces and may be ridged with cusps on their crown for crushing and grinding of food. Figure 2.6 shows the four types of teeth in a human being.

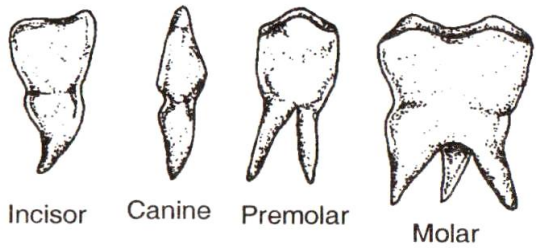


Figure 2.5

Study these Questions

1. Define the following terms:
   (i) Symbiosis
   (ii) Saprophytism
   (iii) Parasitism.
2. How are the four types of heterodont teeth adapted to their functions?

Dental Formula

This describes the number, type and position of teeth in the jaws of mammals. The numbers of teeth recorded represent half the total teeth in the upper and lower jaws. The names of types of teeth are abbreviated as follows: incisors as /, canine as *c*, premolar as *pm* and molar as *m.*

The dentition determines the mode of feeding that is whether herbivores, carnivores or omnivores.

Herbivores

These are animals which feed exclusively on vegetation. They are grouped as grazers and browsers. Grazers for example cows, donkeys and zebras feed on grasses while browsers such as giraffes, goats and antelopes feed on shrubs and herbs.

Herbivores have several adaptations on their dentition that suit them to the kind of food they take in. Most herbivores do not have upper incisors but instead have a horny pad against which grass is pressed and cut by the lower incisors. The long tongue assists in the cutting and turning of grass and also moving the food during grinding. These functions are made possible by the **diastema.** This is a gap in the lower jaw separating the canines from premolars. The jaws move side by side to enable premolars and molars to grind the food. There are four different types of herbivore teeth namely incisors, canines, premolars and molars. These teeth have open enamel in the crown, a condition which allows continuous growth to replace worn out surfaces due to grinding. Figure 5.18 (a) and (b) show the dental formula of two herbivores.

Study this question

Identify with reasons the mode of feeding of the animal whose dental formula is given below.

$$i\ \frac{0}{4}\quad c\ \frac{0}{0}\quad pm\ \frac{3}{3}\quad m\ \frac{2}{3} = 30$$

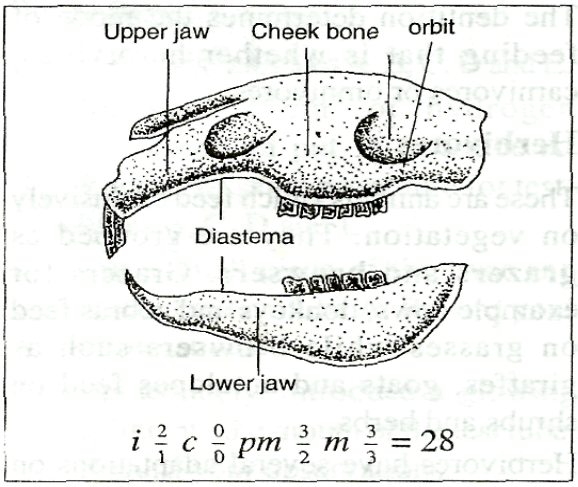


Figure 2.7 (a)

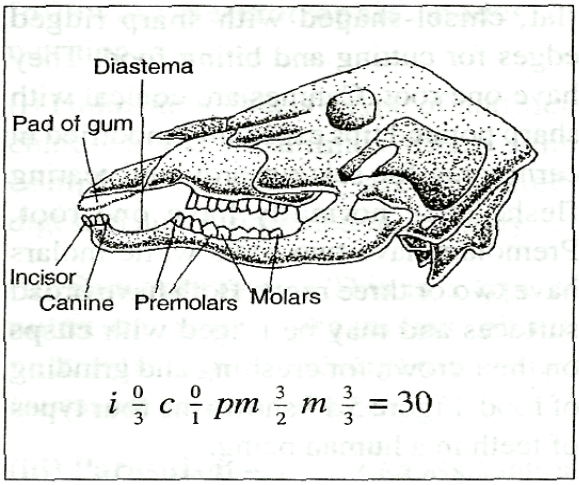


Figure 2.7 (b)

Carnivores

These are animals which feed exclusively on flesh. Most carnivores are hunters. Some are adapted to fast running and have well-developed leg muscles that facilitate this movement. The cheetah is one such animal that moves very fast. They also have strong jaws and sharp teeth to grasp their prey. They have four different types of teeth.

Incisors are chisel-shaped and closely fitting to seize the prey. They are used for gripping and stripping flesh from the bone. Canines are long conical and curved to hold, kill and tear the prey. Premolars and molars are small except for special premolars in the lower and upper jaws which are modified into **carnassial teeth.**

The camassial teeth have smooth sides and sharp edges to slice through flesh and crush bones. Jaws are attached to powerful muscles that move the jaws up and down by snapping.

Omnivores

These are animals which feed on both vegetation and flesh. Omnivores are discussed in this topic with special reference to the human being in relation to dentition, dental formula and structure of teeth.

Mammals produce teeth in two sets, **milk teeth** and **permanent teeth.** Milk teeth are the first set of teeth to be produced and then lost between the age of 6 - 12 years. In human beings 20 milk teeth are produced. Permanent teeth replace the milk teeth lost. An adult person has 32 permanent teeth.

Structure of a Tooth

Externally, a tooth is made up of three regions. These are: the **crown** that projects above the gum; the **root,** the part that is embedded in the jaw and the **neck,** the region between the crown and root. The crown is covered with a hard nonliving layer called enamel that is made of calcium phosphate and carbonate. The

Structure of a Tooth

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Study this question: Examine figure 2.8 (a) and (b) and 2.9 (a) & (b)

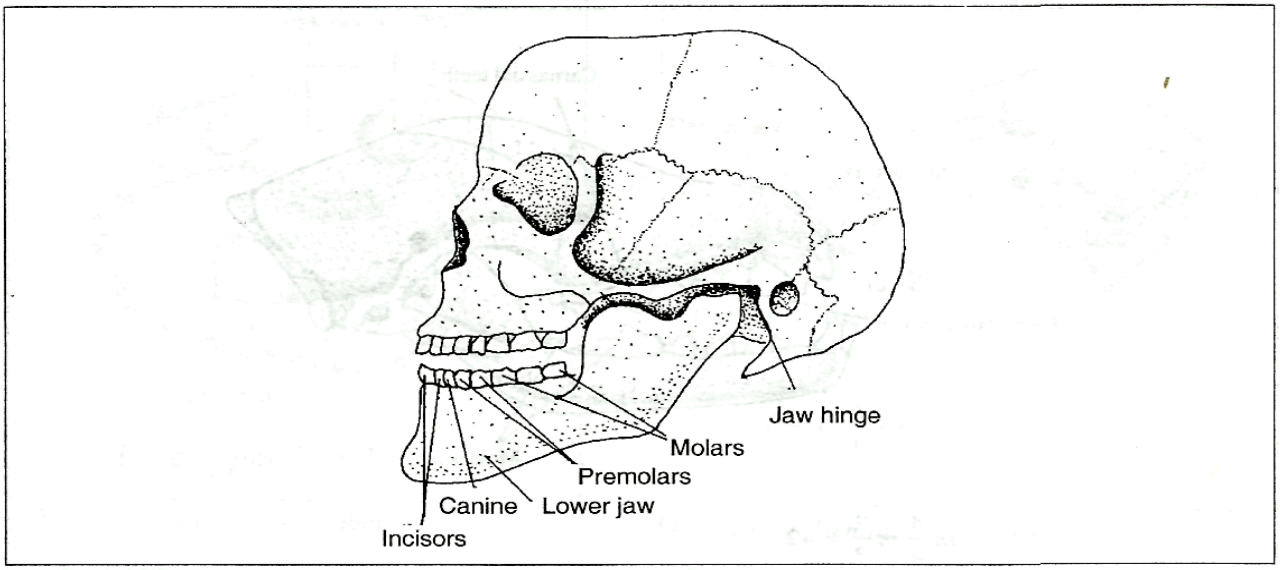


Figure 2.8 (a)

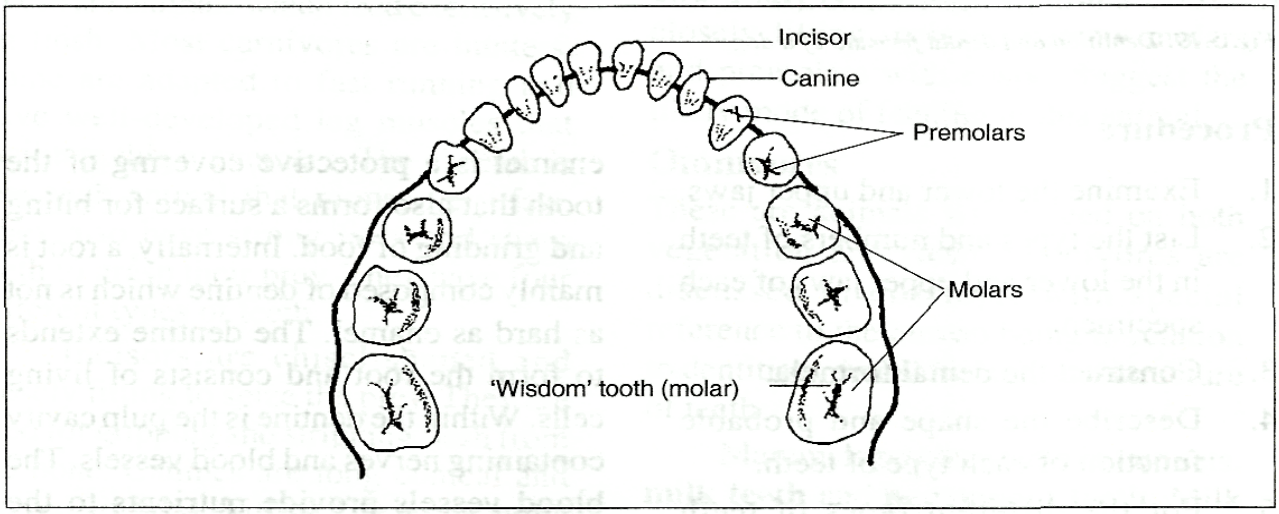


Figure 2.8 (b)

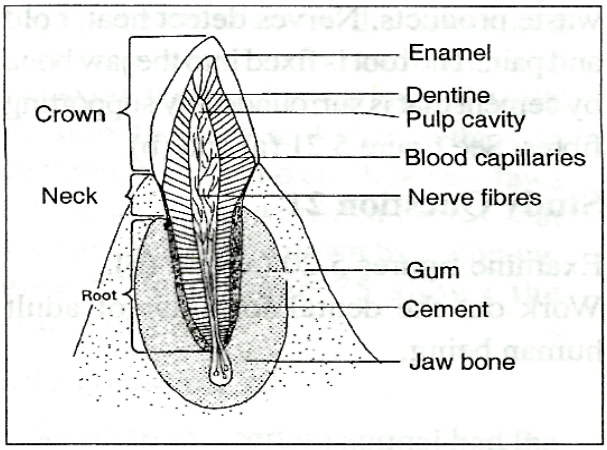


Figure 2.9 (a)

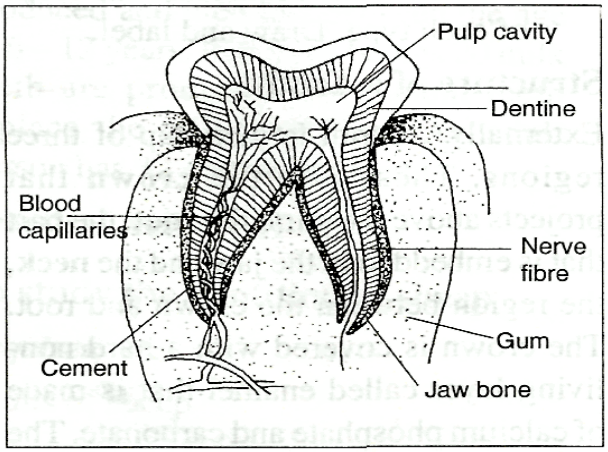


Figure 2.9 (b)

Dental Diseases

Tooth decay is on the increase. Dentists have been trying to discover what causes this decay. There are several possible causes. One possible cause, supported by a great deal of evidence, is that the sugars and starch we eat become logged between the teeth and teeth cavities where they are broken down by micro-organisms. The micro-organisms use up the sugars for their own food and produce acids as waste products. The acids react with the enamel and dentine of the teeth, causing them to dissolve. A hollow area of those decayed parts is formed. When the decaying process continues into the pulp cavity, the nerves are affected and therefore, a lot of pain is felt (toothache). In very serious cases, the pulp cavity may be destroyed and the infection spreads to the gums. There are two main dental diseases discussed below.

Dental carries and Periodontal diseases:

(i) **Dental carries** is caused by lack of hard food, too much sweet or sugary foods, lack of calcium in the diet, lack of vitamin D, lack of cleaning teeth and general ill-health. These have the effect of causing gradual tooth decay as shown in figure 2.10.

(ii) Periodontal disease is caused by lack of vitamins A and C, lack of massage of the gums and lack of proper cleaning of gums. This disease causes the gums to become soft and flabby so that they do not support the teeth. It is more common in adults than in children. There are two types of periodontal disease **pyorrhoea** and **gingivitis.** Gingivitis is characterised by the reddening of the gums, bleeding and the presence of pus in the gums. Pyorrhoea is a condition where teeth become loose due to infection of the fibres holding the teeth in the sockets. The diseases can be avoided by eating a balanced diet, brushing the gum regularly to encourage blood circulation and removing food particles through observing dental hygiene.

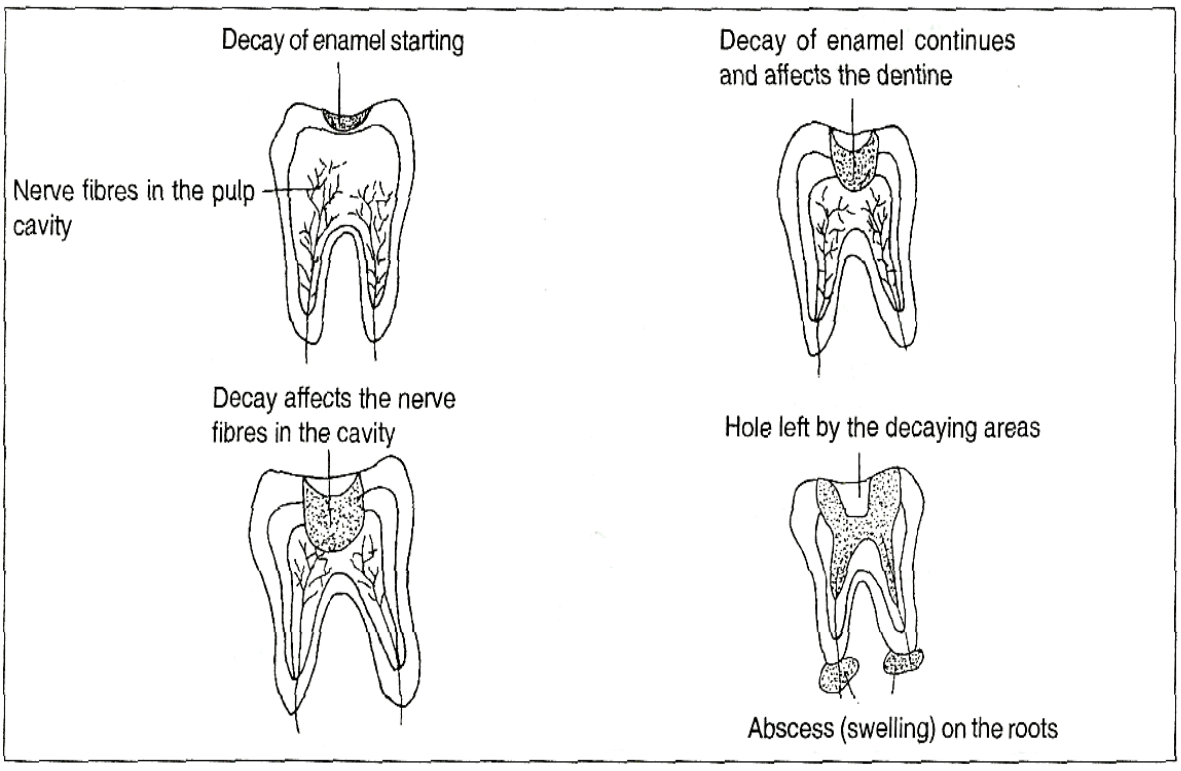


Figure 2.10

Dental Hygiene

Proper care of the teeth requires the following:

(i) Regular cleaning or brushing of teeth after every meal,
(ii) Avoid eating too much sugary foods.
(iii) Eating hard foods, for example raw carrots, cassava, yams and sugar cane.
(iv) This helps to remove the soft materials from the gums and teeth. It also helps to exercise the teeth.
(v) Eating diet rich in calcium, phosphate and vitamins A, C and D.
(vi) Teeth should be used for their proper purpose. They should not be used to open
(vii) beverage bottles or crack hard nuts.
(viii) A regular visit to the dentist is necessary.

Study these Question

(a) State four ways of keeping teeth healthy.
(b) Draw a neat well-labeled diagram of the internal structure of an incisor tooth.

2.7. The Digestive System

The digestive system is made up of the alimentary canal, and it is associated with organs such as the liver and pancreas. The main functions of the digestive system are digestion and absorption apart from others like ingestion and egestion.

The alimentary canal, also known as the digestive tract, is a tube leading from the mouth to anus. It consists of oesophagus, stomach, small intestines, (comprising duodenum and ileum) and the large intestines the caecum, appendix, colon and rectum. See figure 2.11.

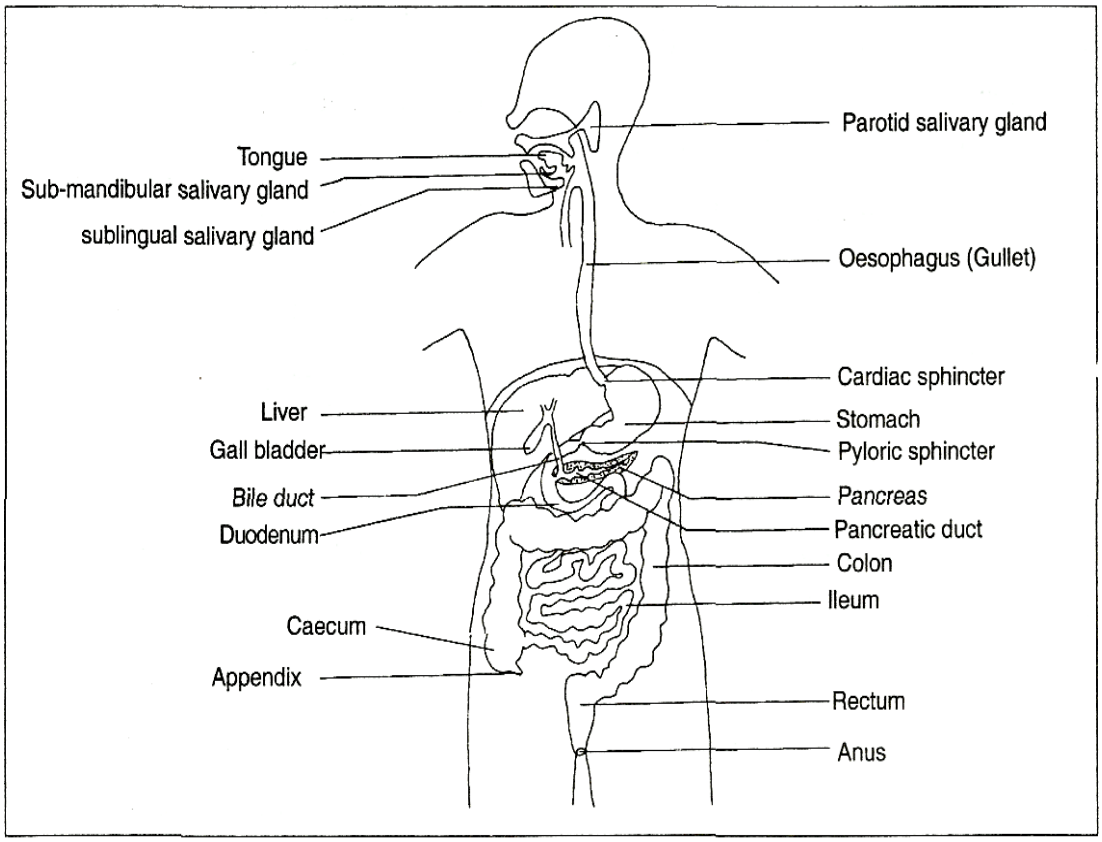


Figure 2.11

The alimentary canal is relatively long and greatly folded to increase the surface area for digestion and absorption of food. It is also wide and narrow in some parts and in others it is sac-like. Although each different portion of the mammalian digestive tract has its own adaptations in relation to function, all conform to a basic common structure

Also of interest to note is that although the digestive tracts of mammals show the basic fundamental plan, there exist slight variations which correlate to the kind of diet each animal eats, that is different eating habits. For example, carnivores have a relatively short digestive tract with very much reduced and functionless caecum and appendix. This is because the digestion of proteins which form the bulk of their diet is rapidly digested in the gut. However, some herbivores have a very long digestive tract with a single stomach and a large caecum and appendix particularly in non-ruminant ones such as the rat. But in ruminant herbivores such as cows, the stomach is four-chambered in order to increase the surface area for the digestion of cellulose which takes a long time.

2.8. Food Processing along the Digestive Tract

This is the treatment which food undergoes as it passes along the tract so that food nutrients are availed to the body tissues. Since much of the food an animal takes in (ingests) is made up of large complex molecules (for example carbohydrates, proteins and fats), it is first broken down to simpler and soluble molecules before they can be absorbed. The process of food breakdown is called **digestion.**

However, small molecules like those of vitamins, mineral salts and water are directly absorbed into the blood stream without undergoing digestion.
Along the digestive tract, food digestion occurs in the following regions: mouth, the stomach, the duodenum and the ileum. Each region is adapted to its functions in a variety of ways.

Digestion in the Mouth

The introduction of food into the mouth is called **ingestion.** In the mouth, food is mechanically broken down by the teeth in the process of chewing and grinding. This is also known as **mastication. Mastication** reduces food to small particles and also increases the surface for enzymatic action. During this process, the food is moistened and mixed with saliva secreted from the salivary glands. The glands are located in various places around the mouth region. There are three pairs of salivary glands;

(i) Sublingual salivary glands arebeneath the tongue.
(ii) Sub-mandibular salivary glands are under the jaw.
(iii) Parotid salivary glands are found in the cheeks in-front of the ears. All these glands have ducts that open into the mouth and through which saliva flows into the mouth. Saliva is a mixture of water, mucus and an enzyme called **salivary amylase** or **ptyalin.** The mixture is slightly alkaline and this provides a suitable medium for the function of the salivary amylase. Water acts as a solvent while mucus lubricates the food and the lining of the mouth.

The enzyme digests starch to maltose. The tongue rolls the food into small round masses called **boluses** (singular, bolus). The tongue then pushes the bolus into the pharynx (back of the mouth). This is the beginning of swallowing. The soft palate is raised to open the gullet and close the nasal cavity while the epiglottis relaxes to close the wind-pipe or trachea.

The food then passes down into the oesophagus or gullet. The gullet wall contains circular and longitudinal muscles. The passage of the bolus down the gullet is aided by a wave of muscle contractions known as **peristalsis.** This produces a series of constrictions that squeeze the bolus down the gullet and into the stomach as shown in figure 2.12.

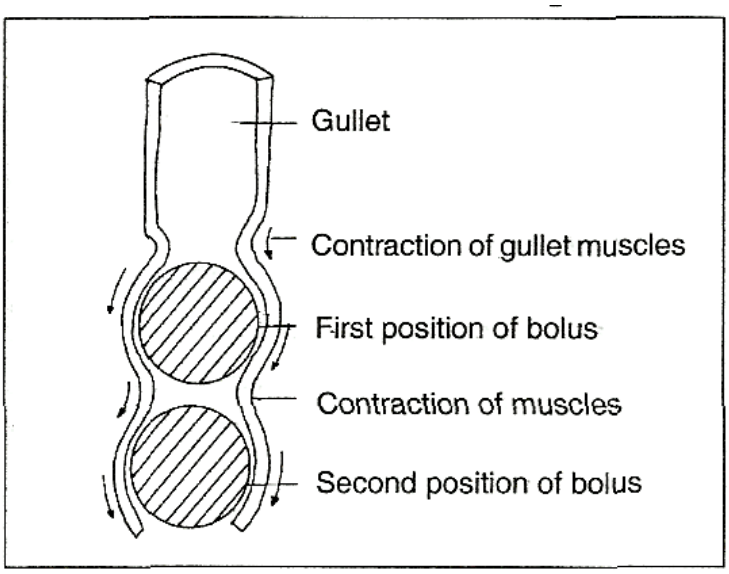


Figure: 2.12 *Diagrammatic representation of peristalsis*

Digestion in the stomach

The bolus enters the stomach through a muscular valve known as the **cardiac sphincter.** The stomach wall is made up of thick circular muscle and longitudinal muscle layers. These muscles contract and relax producing movements that mix the contents of the stomach. The mixing is known as **churning** and results in the formation of a fluid called **chyme.** The presence of food in the stomach stimulates the secretion of the hormone **gastrin** which in turn stimulates the production of **gastric juice** from the gastric glands embedded in the glandular layer of the stomach wall. Gastric juice contains:

(i) **Pepsinogen** which is activated to **pepsin** enzyme in the lumen of the stomach. Pepsin breaks down proteins into peptides.

(ii) **Renin** Enzyme which digests the protein caseinogen in milk to casein (curd). Renin is abundant in suckling young children, (iii) **Hydrochloric acid** which provides an acidic medium for the optimum activities of these enzymes. The acid also kills some bacteria that may be present in the food.

(iv) **Mucus** which forms a protective barrier to the stomach wall against corrosions by the hydrochloric acid.

Digestion in the Duodenum

The chyme is let out into the duodenum through the pyloric sphincter. The sphincter muscle allows small quantities of chyrne to pass through at a time. The duodenum is the first part of the small intestine where most of the digestion takes place.
The duodenum receives secretions from the following organs:

(i) The liver has specific cells which secrete bile into the gall bladder to be stored. The gall bladder releases the **bile** into the duodenum through bile duct.

(ii) The pancreas lies just below the stomach. It is a thin flat and cream-coloured gland. It plays two major roles; secretion of hormones and the secretion of digestive juices. The arrival of food into the duodenum stimulates secretion of the hormone secretin from the pancrease and **cholecystokinm** from the duodenal wall. Secretin stimulates the secretion of **pancreatic juice** into the duodenum whereas cholecystokinin stimulates the secretion of **bile** from the gall bladder.

The pancreatic juice is alkaline and contains three digestive enzymes:

(i) **Pancreatic amylase** which speeds up the breakdown of the remaining starch into maltose.
(ii) **Trypsin** digests proteins into peptides. This enzyme is secreted in its inactive form trypsinogen.
(iii) **Pancreatic lipase** digests lipids intofatty acids and glycerol.
(iv) Also produced by the pancreas is the **sodium hydrogen carbonate** which neutralises the acidic chyme and creates a suitable alkaline medium for pancreatic and intestinal enzymes.

The bile contains bile salts that include **sodium glycocholate and sodium taurocholate.** These two salts aid in the breakdown of fats into tiny fat droplets to increase their surface area for digestion. This breakdown is known as **emulsification.** The salts also provide an alkaline medium in which the enzymes listed above work best. They also neutralise the acidic chyme from the stomach. Figure 2.13 illustrates emulsification.

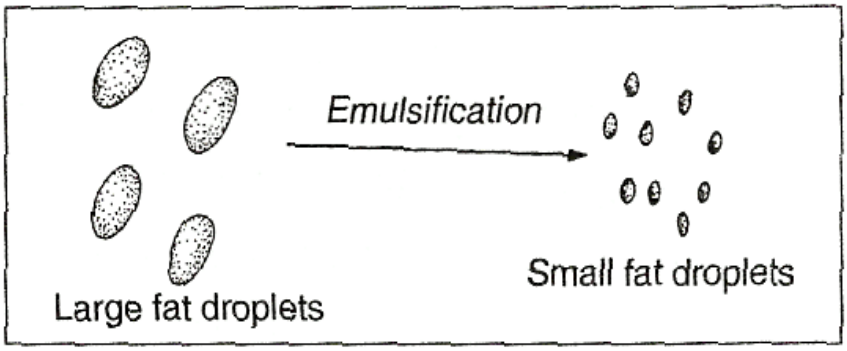


Figure 2.13

Digestion in the Ileum

The ileum is the lower part of the small intestine and the longest section of the alimentary canal. It is largely coiled to fit in the limited abdominal space. The inner walls of the ileum contain secretory cells, some of which secrete mucus and others secrete an alkaline fluid known as intestinal juice or **succus entericus.**

The arrival of chyme in the ileum stimulates the secretion of intestinal juice. The juice contains four enzymes that carry out digestive functions as follows:

(i) **Maltase** - speeds up breakdown of maltose to glucose.
(ii) **Sucrase** - speeds up breakdown of sucrose into glucose and fructose. Maltase and sucrase complete the digestion of the carbohydrates.
(iii) **Peptidase** - breaks down peptides into amino acids.
(iv) **Lipase** - breaks down lipids into fatty acids and glycerols.

The process of digestion is thus completed in the ileum. The resulting watery emulsion of food is called **chyle** and contains soluble products of digestion ready to be absorbed. The entire canal is lined with an epithelial membrane that contains **goblet cells** which secrete mucus. The mucus allows smooth movement of food materials and also coats the wall of the alimentary canal, thus protecting it from being digested by the enzymes. By the time food is fully digested, most of the enzymes on table 2.1 will have acted on the food and broken it to the end-products summarised as shown in the table 2.1.

Table 2.1: Summary of digestion

Part of the alimentary canal	*Gland*	*Secretion*	*Enzymes*	*Substrate (food acted upon)*	*Products*
Mouth	Salivary	Saliva	Ptyalin or salivary amyiase	Starch	Maltose
Stomach	Gastric	Gastric juice	Pepsin Renin	Protein Milk protein	Peptides Clotted casein
Duodenum	Pancreas Liver	Pancreatic juice Bile	Pancreatic amyiase	Starch	Maltose
			Trypsin	Protein	Peptides
			Peptidase	Peptides	Amino acids
			Lipase	Lipids	Fatty acids and glycerol
			No enzymes	Fats	Small fat droplets
			(bile salts only)		
Ileum	Crypts of Lieberkuhn (secretory cells)	Succus entericus	Maltase	Maltose	Glucose
			Sucrase	Sucrose	Glucose and fructose
			Lactase	Lactose	Glucose and galactose
			Peptidase	Peptides	Amino acids
			Polypeptidase	Polypeptides	Amino acids
			Lipase	Fats and oils	Fatty acids and glycerol

Study these Question

(a) List down the pH under which enzymes in each of the following parts of the alimentary canal work:

(i) Mouth
(ii) Stomach
(iii) Duodenum
(iv) Ileum.

(b) What are the final products of digestion for:
  (i) Carbohydrates?
  (ii) Proteins?
  (iii) Fats and Lipids?

Absorption

This is the process by which the soluble products of digestion diffuse into the cellular lining of the **villi.** Diffusion of these products continues through the thin walls of the capillary network and into the bloodstream. Absorption of alcohol, some water, water soluble vitamins B and C and water soluble salts takes place in the stomach.

Most absorption of final products of digestion occurs in the small intestines. The ileum is where absorption of digested food substances occurs and it is adapted to its function in the following ways:

(i) It is **long** and therefore provide a **large surface area** for absorption in addition, it is narrow so as to bring digested food into **close contact** with the walls of the ileum for easier absorption,

(ii) The ileum is **highly coiled** in order to **slow down movement of food** and thus **allowing more time** for digestion and absorption to take place. It also **increases the surface** area for digestion and absorption.

(iii) The inner-surface of the ileum has **large numbers of villi** and **microvilli** which **increases the surface area** for absorption of end-products of digestion. Figure 2.14 shows such a villus.

(iv) The presence of a **thin layer** of cells

(v) through which digested food diffuses,

(vi) The presence of a **dense network** of **blood capillaries** in the villi into which amino acids, sugars, vitamins, mineral salts, some fatty acids and glycerol are absorbed. This helps to maintain a steep diffusion gradient, (v) Presence of **lacteals** in the villi for the absorption of fatty acids and glycerol.

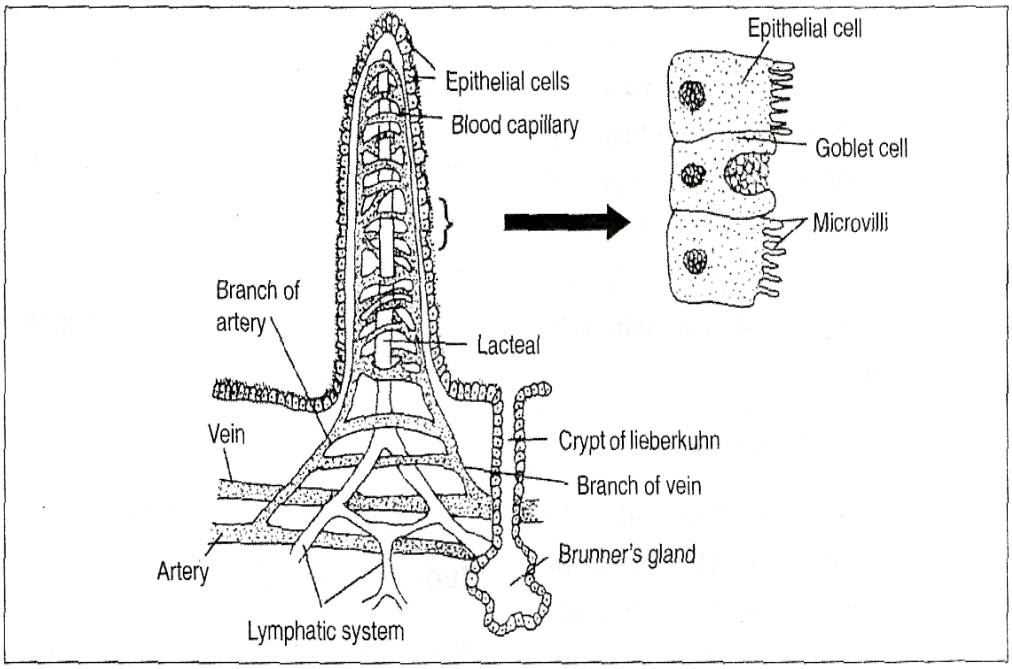


Figure 2.14

The molecules of amino acids and glucose pass through the epithelia of the villi and the capillary walls into the blood system by active transport. The capillaries drain into the hepatic portal vein where the amino acids and glucose are carried to the liver before being allowed to join general body circulation. The fatty acids and glycerol are absorbed into lacteals of the villi which drain into the lymphatic vessels. The lacteal contents join the general lymphatic system which ultimately finds its way into the blood circulatory system. The fatty acids and glycerol are then distributed to all parts of the body.

Egestion

The undigested and indigestible food substances reach the large intestine by the process of peristalsis. As these materials pass through the colon, water is extensively absorbed. The remaining semi-solid waste material is then passed to the rectum where it is eventually eliminated from the body as feaces through the anus as the anal sphincter muscle relaxes.

The Caecum and Appendix

The caecum and the appendix have no function in humans. However, in nerbivores, they contain a large number of bacteria which secrete **enzyme cellulase** that digests cellulose, breaking it down into glucose. The bacteria are in a symbiotic relationship with the herbivores. Some of the glucose is used by the bacteria but most of it is assimilated by the herbivores.

Assimilation

The absorbed products of digestion are carried in the blood stream to the rest of the body. From the blood, the body cells are able to obtain these substances and use them in their metabolism. The incorporation of these products of digestion into the cell metabolism is known as **assimilation.** The different food types are assimilated or utilised as follows:

a. **Glucose** is oxidised to release chemical energy during respiration and the excess is stored in the body as fats underneath the skin or in the form of glycosen in liver or muscle cells.
b. **Fatty acids and glycerol** are also oxidised to release energy but most of the fatty acids and glycerol combine into neutral fats which are stored underneath the skin to insulate the body against cold.
c. **Amino acids** are used in the synthesis of proteins for general body growth and repair of worn out tissues. In absence of fats and glucose, they may be used to release energy through oxidation.

2.9. Importance of vitamins and salts

Vitamins

Vitamins are organic chemical compounds that are essential for a healthy body. They are obtained from fresh fruits and vegetables. Some are synthesised in the body by the activity of microorganisms present in the gut. An example of this is vitamin K.

Vitamins are destroyed when the food is excessively cooked. Although vitamins are required in small quantities, they play an important role in **metabolic reactions.** Some act as **co-enzymes** in enzyme activities while others **influence intakes** of certain substances into the body. For example, vitamin D influences absorption of calcium ions in the gut Such vitamins are not affected by the reactions they influence hence they can be used repeatedly. Lack of vitamins in the diet results in a breakdown of normal body activities

and produce deficiency diseases. The breakdown can be corrected by including the necessary vitamins in the diet. Table 2.2 gives some of those important vitamins, their major food sources and deficiency symptoms, which allows smooth movement of food in the alimentary canal. Lack of roughage in the diet leads to constipation.

Table 2.2: Vitamins; Sources, Uses And Deficiency Symptoms

Vitamin	*Main food .source*	*Uses in the body*	*Deficiency disease symptoms*
VITAMIN A (Retinol)	Liver, milk, eggs, cod liver oil, carrots, fresh green vegetables, e.g. spinach and *sukitma wikii.e.* kale	For vision especially in the night. Protects skin and cornea from drying and becoming scaly.	Poor night vision and sore eyes, dry, scaly skin and cornea, reduced resistance to diseases, cold and bronchitis.
VITAMIN B, (Thiamine)	Groundnuts, bean, unpolished cereals, egg-yolk, milk, liver and kidney	For cell respiration and for proper growth in children	General weakness, retarded growth in children. The disease, Beri-beri, characterised by wasting of muscles and swelling of feet and legs.
VITAMIN B^ (Riboflavine and nicotinic acid.)	As for B,, plus green vegetables and yeast extract.	For normal skin health and function, for cell respiration.	Skin disorders, sores and bleeding in the mouth and gum. These are symptoms of the disease pellagra.
VITAMIN B. (Pantothcnic acid)	Sources are those for B, and E_2, but especially in eggs-	For respiration, proper functioning of the nervous system and the alimentary canal.	Malfunctioning of the nervous system and digestive system.
VITAMIN B,, (Cobalamine)	Liver, beef and kidney.	For formation of blood cells.	Low red blood cell count due to pernicious anaemia.
VITAM1NC (Ascorbic acid)	Fresh citrus fruits such as lemons, oranges, grapes, green vegetables, mangoes, pawpaws and tomatoes.	For protection against infection.	Bleeding of mouth and Gum, anaemia, swellings on the skin, poor healing of wounds, reduced resistance to infection. These are symptoms of the disease scurvy.
VITAMIN D (Calciferol)	Milk, fish, liver, egg-yolk, formed in skin in the presence of sunlight.	For formation and hardening of bones for strong teeth. For absorption of calcium and phosphorus.	Abnormal bone formation in children, soft and brittle bones in adults. These are symptoms of the disease rickets.
VITAMIN E (Tocopherol)	Milk, egg-yolk, green vegetables and vegetable oils.	Necessary for normal fertility in some animals, necessary for cell metabolism.	Sterility in some animals.
VITAMIN K (Quinone)	Liver, egg-yolk, green vegetables e.g. cabbage and spinach, unpolished cereals.	Necessary for blood clotting.	Excessive bleeding

2.10.Mineral Salts

Mineral salts are important inorganic compounds containing elements which are essential for normal body metabolism. Some of these elements are required in large quantities and are therefore called **macro-nutrients** while others are required in small quantities hence are called **micro-nutrients** or trace elements. Animals obtain these elements from the foods they take in. Table 2.3 gives a summary of the elements, their sources and importance in the body.

Table 2.3: A summary of the elements, their sources and importance in the body

Element	*Source*	*Function in the body*	*Disease caused by deficiency*
Nitrogen	Meat, milk, eggs, fish and other protein foods	For synthesis of protein. For formation of cells, tissues and structures such as hair and nails.	
Phosphorus	Protein foods	Synthesis of proteins, formation of bones and teeth. Formation of ATP.	Rickets, disease characterised by poorly developed bones.
Calcium	Green vegetables, milk and cheese	For blood clotting and muscle contraction. Formation of bones and teeth.	Muscle cramps and rickets.
Iodine	Iodised table salt, cheese, sea fish such as cod and salmon	Formation of the hormone thyroxine	Goitre characterised by a swelling of the thyroid glands in the neck region.
Potassium	Liver, beef, vegetables, milk and eggs.	Transmission of nerve impulses	—
Iron	Liver, eggs, green vegetables, e.g. spinach and kale.	Formation of haemoglobin in red blood cells, role in respiration.	Anaemia.
Sodium	Table salt, green vegetables, fish, milk	Maintain osmotic balance of body fluids. Transmission of nerve impulses.	—
Chlorine	Table salt	Maintain osmotic balance of body fluids. Important in trans-mission of nerve impulses.	—
Sulphur	Protein foods	Protein synthesis. Formation of body tissues.	—

Roughage

It is composed of cellulose and plant fibres. Mammals do not produce any enzymes that can digest cellulose. Some mammals rely on micro-organisms which secrete cellulase that digests cellulose. The micro-organisms are present in their gut. In humans, these organisms are absent hence no digestion of roughage takes place. Roughage adds to the bulk of food and also promotes peristalsis,

Water

Water has a wide variety of functions in living cells. It is not therefore regarded simply as a nutrient. Water makes about 65-70% of the total body weight. The importance of water is clear from the fact that a human deprived of water will live for only a few days, whereas it is possible to survive for more than 60 days without food. The main functions of water are: activity as a solvent, cooling the organism, providing a media of transport and faciliting hydrolysis.

2.11. Factors determining energy requirements in human beings

Heat produced by the body comes from oxidation of food. This can be used to determine the energy content of foods. Heat energy is measured in units called kilojoules (kj). One gram of carbohydrates yields 17.1 kJ of energy. Fats release 31.8 kJ of energy while proteins release 22 kJ. These figures represent energy values of these foods. The amount of energy required depends on the following factors:

(i) Basal Metabolic Rate (B.M.R.)

This is the energy required to maintain normal body functions such as breathing, heartbeat, circulation and other basic body reactions. It is also used to maintain constant body temperature. This requires about 760kJ per day for a man at rest. This does not include any activity the man does for example walking,- eating and bathing.

(ii) **Occupation or Everyday Activity**

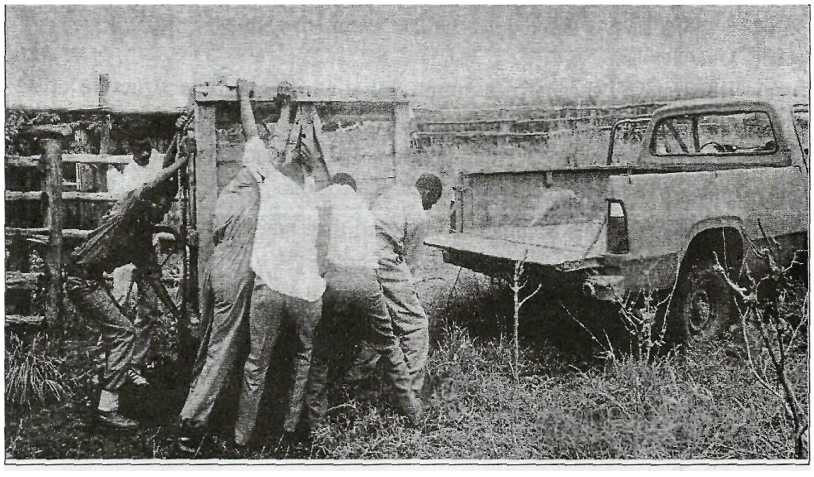
This involves activities one does every day. It determines the energy requirement of the person. For example, a labourer pulling a cart or digging or mixing concrete in a construction site requires more energy than an office worker, a doctor or a teacher. Manual workers should take more energy-giving foods to sustain their high energy demand.

(iii) Age

Young children have many actively dividing cells and they are physically more active than adults. Therefore, their basal metabolic rate is higher than that of adults. As they grow older, they become less active physically and their energy requirements decrease.

(iv) **Body** Size

Small-bodied people have a small volume which leads to a large surface area to volume ratio. Therefore, their bodies lose more heat energy to the surrounding. Such people require more energy-giving foods. On the other hand-big-bodied people have a small surface area to volume ratio. They lose less heat to the surrounding as compared to thin people.



Therefore, their energy requirement is low. Some big-bodied people may, however, eat a lot to maintain the high energy demands of their large bodies.

(v) **Sex**

Many males are more muscular than females. That means their bodies have more muscles than fat while females have a lot of fat as compared to the males. Hence males normally use more energy. See table 2.4 for this comparative case study.

Table 2.4: Energy use per day

Age (Years)	Male	Female
2	5 500__	5500
5	7000	7000
8	8800	8800
11	10 000	9200
14	12500	10500
18	14200	9600
25	12100	8800

Revision Questions

1. Name the elements that form :
    a) Carbohydrate
    b) Proteins
    c) lipids
2. State two properties of carbohydrate?
3. Write three differences between polysaccharide and monosaccharide?
4. What are the building blocks of proteins?
5. State two functions of lipids in the human body?
6. What do you understand by the term heterotrophism ? State the four heterotrophic modes of nutrition?
7. State the factors that determine energy requirements in human being?
8. Explain the following terms
    a) Peristalsis
    b) Emulsification
    c) Assimilation
9. Name two nutrients that do not require digestion before they are absorbed. Explain why this is so?
10. Describe parts o the alimentary canal and state the functions of each?
11. Name the four types of teeth and state their functions?
12. Pepsin, Trypsin, Amylase and lipase are enzymes. Discuss their role of digestion

CHAPTER THREE
THE CIRCULATORY SYSTEM

Large and complex animals have circulatory systems that consist of tubes, a transport fluid and some means of pumping the fluid or air within the tubes. A circulatory system transports the substances and maintains a steep concentration gradient at the surfaces where diffusion takes place. Such surfaces include the lungs and gills. Two types of circulatory systems exist in animals: open and closed.

In an **opencirculatory system** the transport fluid is contained in the general body cavity or **coelom.** This type of system is common in invertebrates especially arthropods. The transporting fluid in the body cavity is known as **haemocoel. A closed circulatory system** on the other hand, is found in vertebrates and annelids where the transporting fluid (blood) is conveyed in special tubes referred to as **blood vessels.**

3.1 Comparison between Open and Closed Circulatory System

In closed circulatory system, blood is pumped into closed vessels, hence generation of high pressure which causes the blood to flow faster. Tissues receive their requirements at a faster rate and removal of metabolic waste, is also faster. As a result, organisms with closed circulatory system are more active than those with open circulatory where blood is pumped into the haemocoel thus loosing its pressure. In a closed circulatory system, blood is not in direct contact with the tissues as is the case in an open circulatory blood system.

Transport in Insects

Insects have an open circulatory systems where blood is contained in haemocoel and within a dorsal tubular heart. See figure 3.1. The blood contains suspended leucocytes (white blood cells) and some pigments but it is not largely involved in the transport of oxygen and carbon dioxide. Transport of gases in insects is principally by diffusion in the tubes called tracheal system.
In a cockroach (a typical insect) there is a tubular heart just above the alimentary canal. The heart has thirteen chambers, three in the thorax and ten in the abdominal segments. The anterior segment is joined to

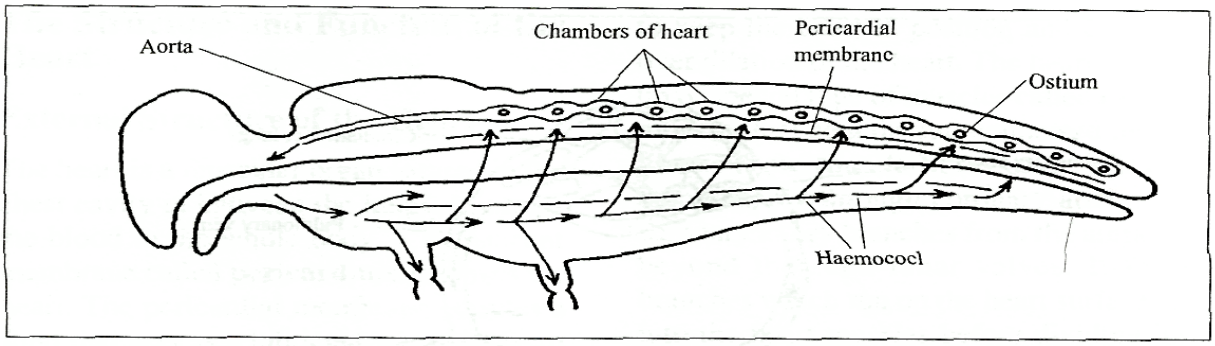


Figure 3.1

The aorta that empties the blood into **sinuses** of the head. Each chamber contains a pair of valves at the anterior part, which prevent back flow of the blood. Each chamber has a pair of lateral openings called **ostia** which are closed by valves. The valves allow blood to flow into the heart through the ostia but not out of it.

3.2.The Mammalian Circulatory System

A closed circulatory system is found in all vertebrates but is most developed in mammals where a powerful muscular heart pumps blood into the **arteries.** The arteries divide into much smaller vessels called arterioles which in turn divide into even much smaller vessels called **capillaries.** Capillaries spread out in a network fashion in the tissues. The capillaries eventually re-unite to form venules that in turn form larger vessels called **veins.** The veins take blood back to the heart. See figure 3.2.

Practical Activity

In this activity you will use figure 3.2. Trace the path followed by blood from any one point until it returns to the same point e.g.

(i) Kidneys
(ii) Liver
(iii) Right arm.

From the above activity you notice that blood flows into the heart twice for every complete circulation. This is called the **double circulation.**

Blood from the body tissues is pumped to the lungs and then back to the heart. This is called **pulmonary circulation.** From the heart, blood is then pumped to the rest of the body organs. This is called **systemic circulation.**

Mammals and birds have a four-chambered heart. The right two chambers deal with deoxygenated blood while the left two chambers deal with oxygenated blood. Hence deoxygenated and oxygenated blood do not mix.

Furthermore, blood is at a **higher pressure** since the heart pumps it twice. This enables the blood to flow faster to the tissues. These two advantages enable the birds and mammals to be more active.

In some other animals e.g. fish, blood flows only once through the heart for every complete circuit. This is called single circulatory system. In such a circulator., the heart has only one atrium and ventricle.

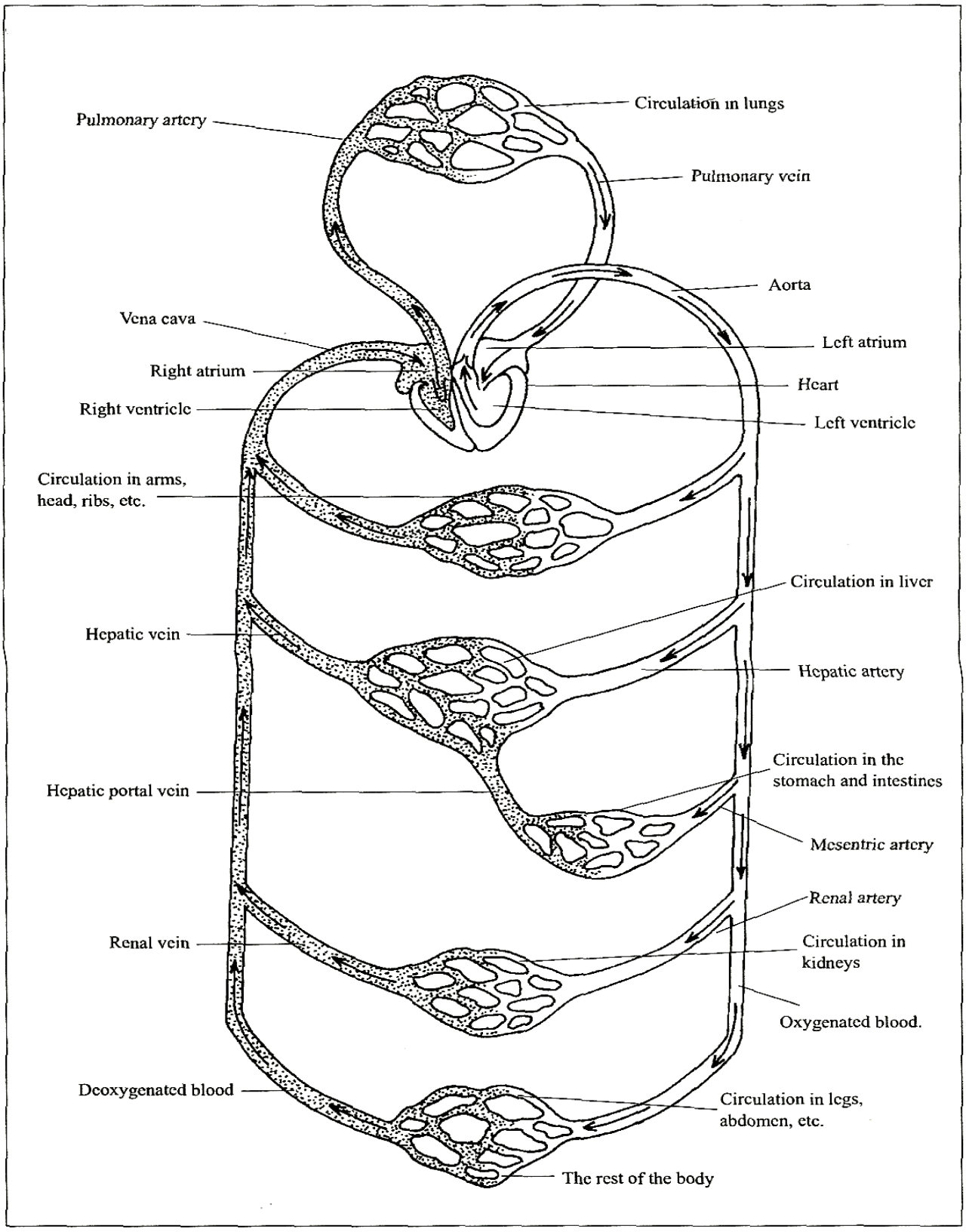

Pulmonary artery
Circulation in lungs
Pulmonary vein
Aorta
Vena cava
Left atrium
Right atrium
Heart
Right ventricle
Left ventricle
Circulation in arms, head, ribs, etc.
Circulation in liver
Hepatic vein
Hepatic artery
Circulation in the stomach and intestines
Hepatic portal vein
Mesentric artery
Renal artery
Renal vein
Circulation in kidneys
Oxygenated blood.
Deoxygenated blood
Circulation in legs, abdomen, etc.
The rest of the body

Figure 3.2

3.3. **The Structure and Function of the Heart**

External Structure of the Heart

The heart is a muscular organ located in the chest cavity in between the lungs. It pumps the blood to the whole body. A translucent membrane called **pericardium** encloses the heart. The pericardia! membrane secretes a fluid that acts as a lubricant when the heart is working. The outer part of the membrane is covered with a layer of fat that act as a shock absorber. This membrane also helps to keep the heart in position and check on over dilation of the heart. The heart is made up of special type of muscles called **cardiac muscles** that contain interconnected muscle fibres. These muscle fibres have their own blood supply through coronary artery. The coronary artery branches from the aorta just beyond the semi-lunar valves. It forms branches which run on the heart surface and into the heart muscles before dividing into capillaries. The capillaries join up to form coronary vein which conveys blood to the right atrium. See figure 3.3.

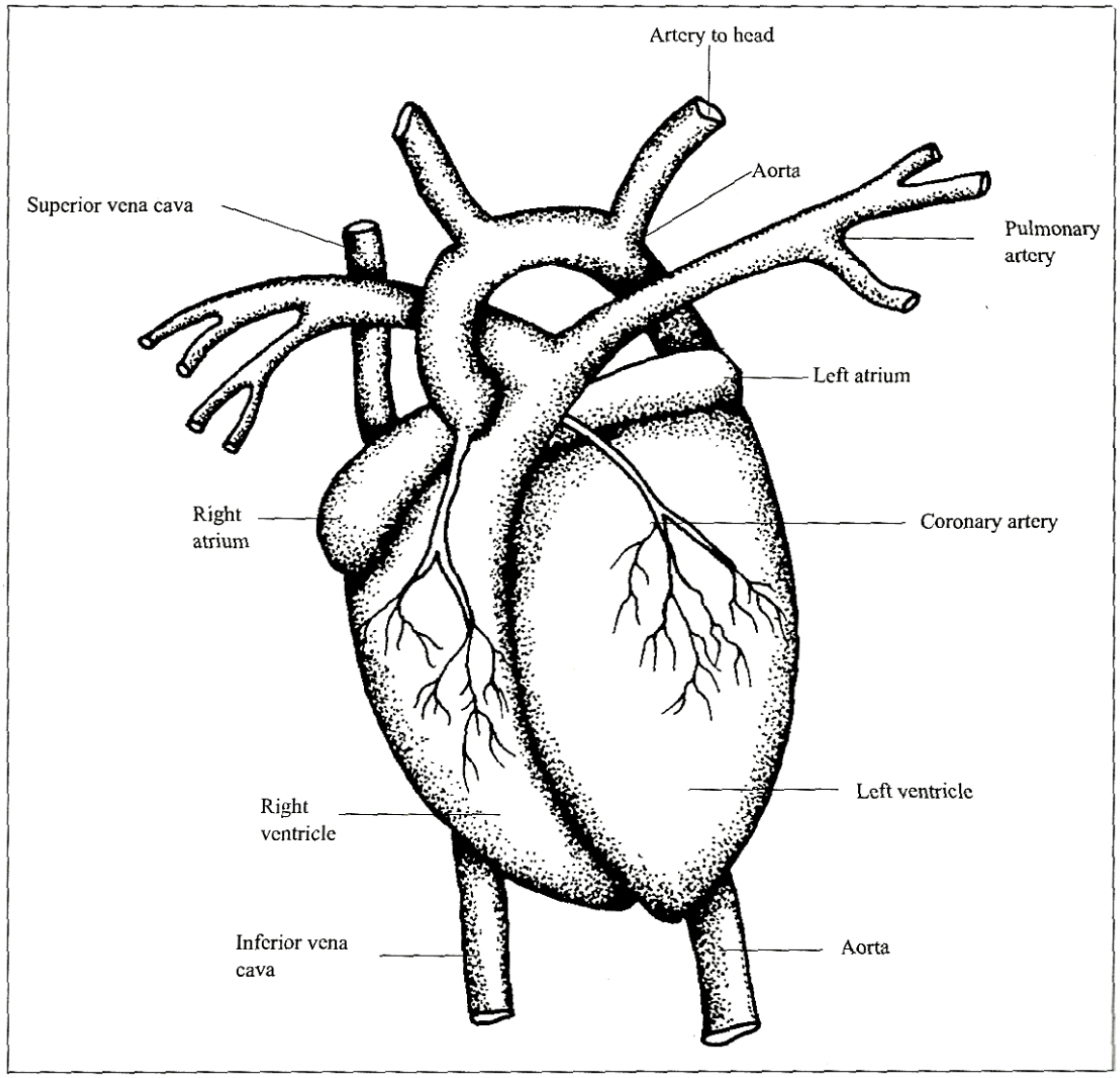


Figure 3.3: External structure of the mammalian heart

Internal Structure of the Heart

The mammalian heart is composed of four chambers. Two auricles (atria) form the upper chambers. They are thin-walled and smaller in volume than the lower chambers. The right auricle receive deoxygenated blood from the body organs except the lungs while left auricle receives oxygenated blood from the lungs through the pulmonary vein.

The lower chambers are called **ventricles** and are composed of thick cardiac muscles. The left ventricle has thicker cardiac muscles than the right ventricle. The volume of the left ventricle is smaller than that of the right ventricle. A thick muscular wall called the interventricular septum separates the two ventricles. Between the atria and the ventricles are **atrio-ventricular valves** which prevent the blood from flowing back into the auricles when ventricle muscles contract. These are right atrio-ventricular valve or **tricuspid** valve and left atrio-ventricular valve or bicuspid valve. These valves are supported by tendons (cordae tendinae) which are attached to the wall of the ventricles on each side. The tendons prevent the atrio-ventricular valves from turning inside out when underpressure as the ventricles contract.

At the base of pulmonary artery and aorta are cup like valves called **semilunar valves.** The valves are opened by the force of the blood generated by contraction of the ventricles. The valves prevent backward flow of blood when the ventricles relax. See figure 3.4.

Circulation in the Heart

Deoxygenated blood from the body tissues except the lungs enters the right auricle through the vena cava. It then flows to right ventricle via the tricuspid valve. When the right ventricle contracts, blood from the right ventricle is forced via the semilunar valves through the pulmonary artery into the lungs. Blood from the left ventricle is forced to flow via the semilunar valves through the aorta to the body tissues. Oxygenated blood from the lungs flow through the pulmonary vein to the left auricle via the bicuspid valve to the left auricle.

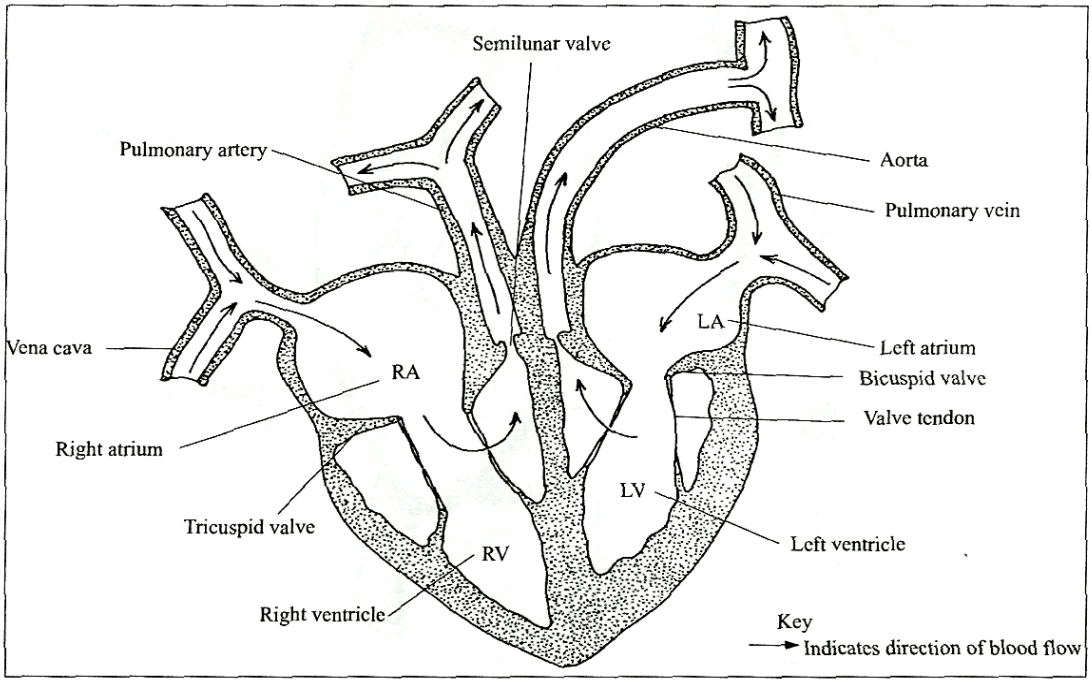


Figure 3.4: The internal structure of the mammalian heart

Pumping Mechanism of the Heart

The heart undergoes contraction (systole) and relaxation (diastole) rhythmically throughout the animal's life.

Diastole (Relaxation)

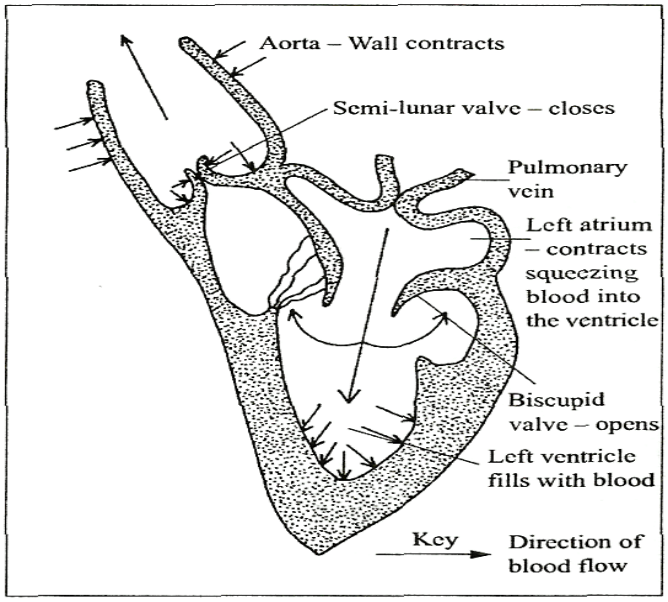


Figure: 3.5 (a) Diastole - Ventricle relaxes

When ventricular muscles relax, the volume of each ventricle increases, while pressure decreases. The atrio-ventricular valve or cuspid valve opens allowing deoxygenated blood from the body tissues to flow into the right ventricle while oxygenated blood flows from the left atrium into the left ventricle. The semilunar valves close preventing the blood from flowing back into the ventricles. The slight contractions of the auricles force the blood to flow into the ventricles. Refer to figure 3.5 (a) which shows diastole on the left side of heart.

Systole (contraction)

When the ventricular muscles contract, the atrio-ventricular or cuspid valves close preventing the blood from flowing back into the auricles. The volume of the ventricles decreases while pressure increases, to force blood out of the heart to the: (i) Lungs via the semilunar valve through the pulmonary artery, (ii) Body tissues except the lungs via the semilunar valve through the aorta.

The thick cardiac muscles of the left ventricle generate high pressure which forces the blood to the furthest tissue. A systole is always followed by a diastole and the two make a complete heart beat. See figure 3.5 (b).

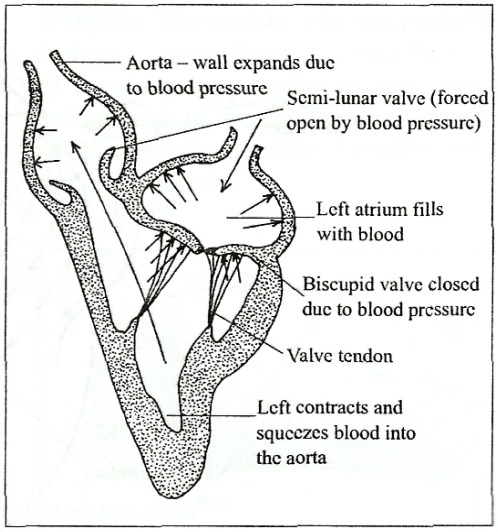


Figure: 3.5 (b) Systole - Ventricle contracts

The heart contracts at an average of about 60 to 70 times per minute. High temperature and emotions can result in an increased rate of the heartbeat. The heartbeat is faster in a child than in an adult. Heartbeats may be felt as pulse by placing a finger on a fairly large artery, such as that at the wrist, against a bone.

Heartbeat

The heart is capable of contracting and relaxing rhythmically without fatigue due to its special muscles called cardiac muscles. The cardiac muscle fibres are interconnected as shown in figure 3.6 so that waves of contraction can travel throughout the mass of the muscle.

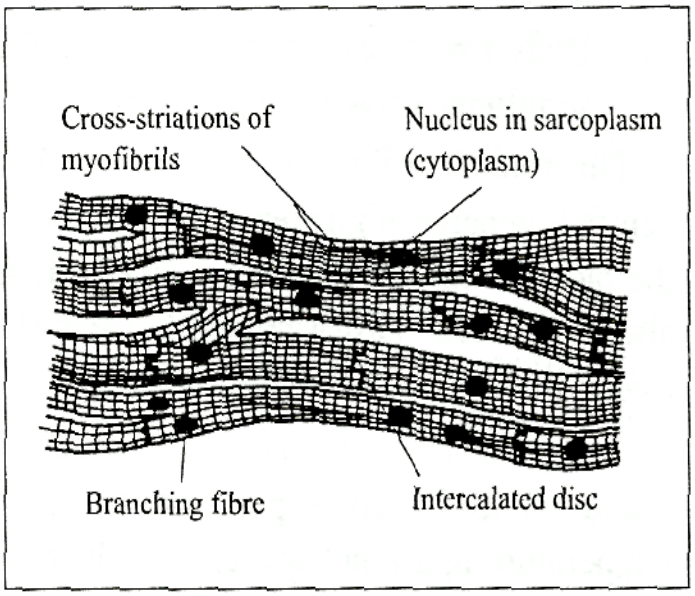


Figure: 3.6 Structure of the cardiac muscle

The rhythmic contraction of the heart arise from within the heart muscles without nervous stimulation. The contraction is therefore said to be **myogenic.**

However, the heartbeat is initiated by the **pacemaker or sino artrio node** (SA). This is a small area of specialised cardiac muscle fibres in the wall of right auricle. Its spontaneous rhythmical electrical activity initiates and maintains contractions of the heart (heartbeat). However the rate of heartbeat is under nervous control. The vagus nerve slows down the heartbeat where as the sympathetic nerve speeds up the heart beat. See figure 3.7.

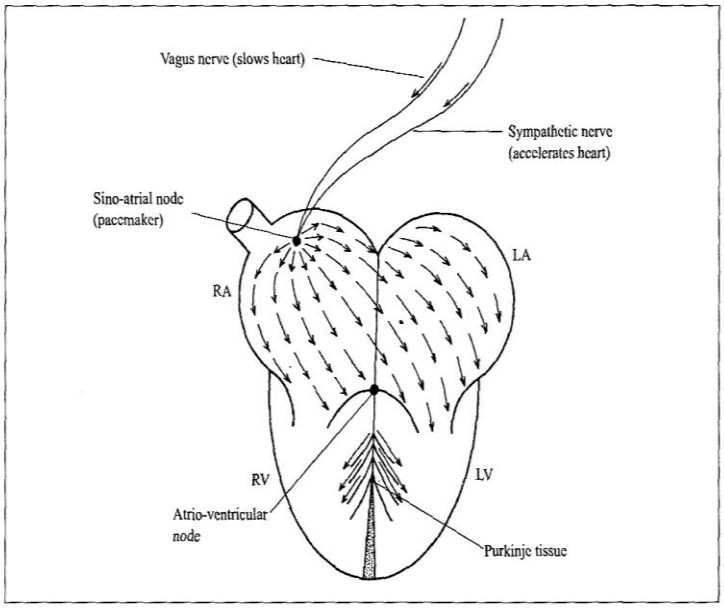


Figure: 3.7 The electrical excitation that follows the contraction of the heart

3.4 .Structure and Function of Arteries, Capillaries and Veins

The main blood vessels are arteries, veins and capillaries.

Arteries

They originate from the heart and carry blood away from the heart e.g. aorta carry oxygenated blood from the heart to all parts of the body except the lungs while pulmonary artery carry deoxygenated blood to the lungs. Arteries carry blood at high pressure and have a thick muscular wall to resist the pressure of the blood inside them. The innermost layer of the artery is called **endothelium** which is composed of a single layer of cells. This layer is found in all blood vessels. It provides a smooth lining which offers the least possible frictional resistance to blood flow. The middle layer is composed of elastic fibres and smooth muscles. The outer layer is formed of elastic muscular fibres (collagen fibres) as shown in figure 3.8 (a).

When ventricles contract (systole), the muscular layer of arteries relaxes stretching outwards to allow blood into the arteries. When ventricle muscles relax (diastole), the muscular layer contracts, pressing inwards forcing the blood to flow forwards. This produces the **pulsating action** in arteries.

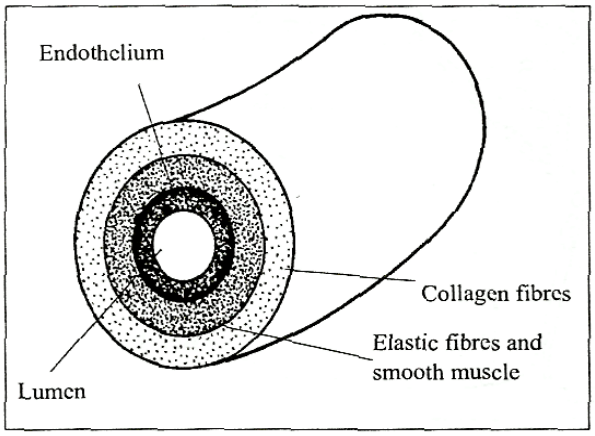


Figure: 3.8 Structure of the artery

The muscular wall of the arteries is under the control of nerves and hormones which alter the diameter of the arteries. This plays a major role in regulating blood flow to the body organs.

The aorta forms branches which supply blood to major organs of the body. These branches divide to form small blood vessels called **arterioles.** The arterioles divide further to form the blood **capillaries.**

Capillaries

They form one of the most important parts of the circulatory system. Capillaries are numerous and very close to the tissues in such a way that each cell is near a blood capillary. Exchange of substances between the tissues and the blood takes place across the capillary wall. This is possible due to the fact that the walls of capillaries are made up of endothelial cells only that are only one cell thick. Thus provides the least distance for exchange of substances within cells. Figure 3.8(b) shows the structure of a capillary.

Exchange of substances occurs by **ultra filtration.** The exchange occurs in capillary beds as shown in figure 3.9 (c). Branching of arterioles into capillaries increases the surface area of the capillaries and pressure of blood in them. This forces small molecules out of the blood within the capillaries to form part of the **tissue fluid.** The tissue fluid formed is

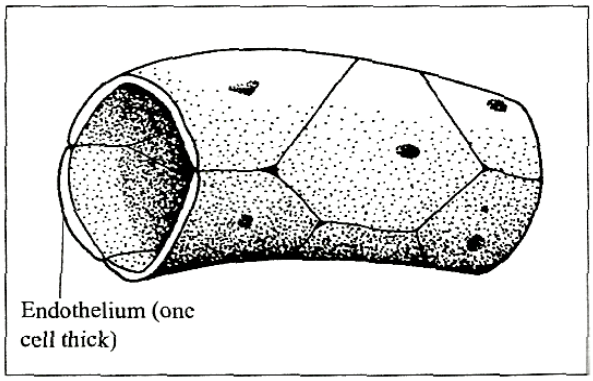


Figure: 3.9 (b) Portion of a capillary blood vessels

similar to plasma in composition except it lacks protein, red blood cells and some leucocytes. Phagocytic leucocytes squeeze in between the cells of the capillary wall and pass into the tissue fluid. From the tissue fluid, cells extract substances such as glucose, oxygen, amino acids, vitamins, hormones and mineral ions. **Ultra filtration** results to a drop in pressure so that at the venules and in the capillary bed, blood pressure is less than that of the tissue fluid. Substances from the tissue fluid pass back into the capillaries by diffusion while water passes back by osmosis since the blood is more concentrated than the tissue fluid. Carbon (IV) oxide passes into the blood through diffusion. More tissue fluid passes into lacteal of the lymphatic system as shown in figure 3.9 (c).

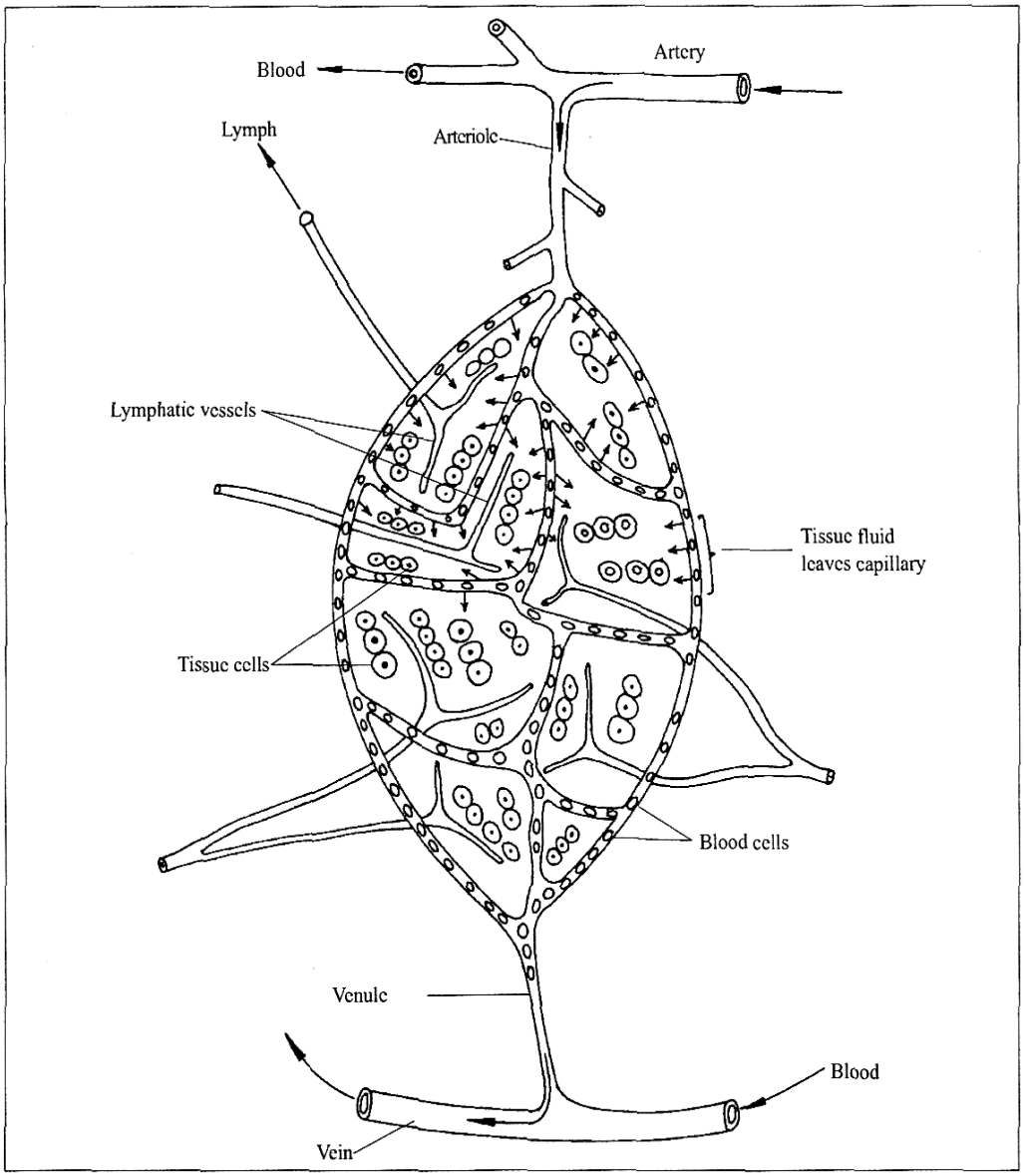


Figure: 3.9 (c) Relationship between capillaries, cells and lymphatics

The **venules** join up to form large vessels called **veins.**

Veins

Veins carry blood from all parts of the body back to the heart. Blood pressure in the veins is very low hence the blood flows smoothly. The veins have relatively larger lumen as compared to the arteries. This offers minimum resistance to blood flow. The walls of the veins are made up of thin muscles as shown in figure 3.10.

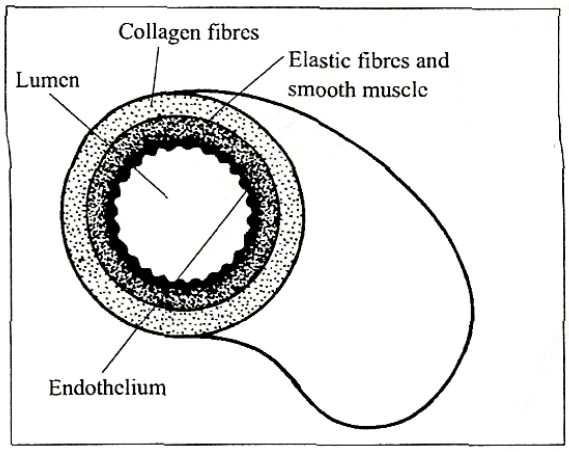


Figure: 3.10 Veins

Veins have valves as shown in figure 3.10 (e) throughout their length, which prevent back flow of blood thus ensuring that blood flows only towards the heart. Forward flow of blood in veins is assisted by contraction of skeletal muscles. Large veins are located in between the skeletal muscles. When the muscles contract they press the veins forcing the blood flow towards the heart. This explains the need for physical exercises. All veins carry deoxygenated blood with fewer nutrients but more nitrogenous waste and other metabolic wastes except:

a. Renal vein that carries blood from the kidney where nitrogenous waste, some water and salts has been removed.
b. Hepatic portal vein that carries blood rich in dissolved food substances from the gut to the liver.
c. Pulmonary vein that carries oxygenated blood from the lungs to the left auricle of the heart.

Major Blood Vessels of the Body

Figure 3.11 illustrates major arteries which supph blood to some organs of the body and major veins which collect blood from the organs.

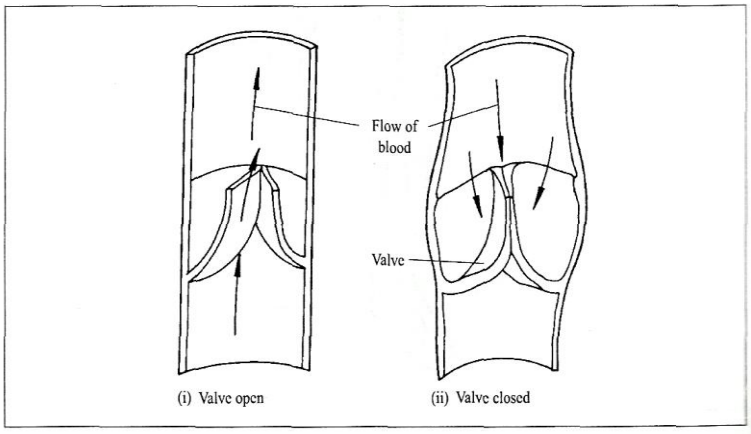


Figure: 3.11 Valves in veins

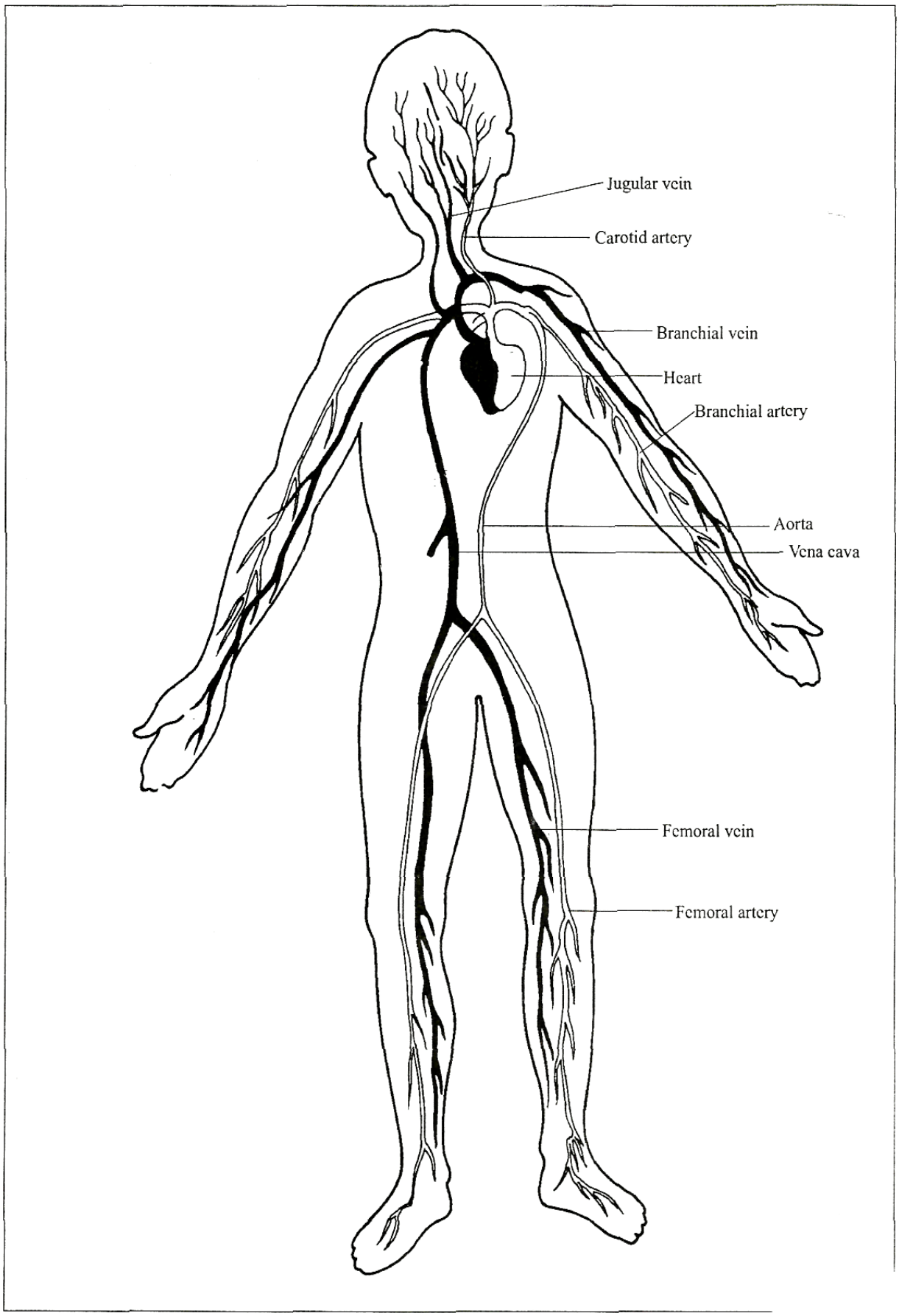


Figure: 3.12 Major blood vessels of the human body

Table 3.1: Differences between arteries and veins

Arteries	Veins
1. Walls are thick muscular and elastic.	1. Walls thin (less muscular and elastic).
2. Have no valves except at the base of large arteries leaving the heart.	2. Have valves at intervals throughout their length.
3. Blood flows rapidly in pulses.	3. Blood flows smoothly.
4. Blood flows rapidly under pressure.	4. Biood flows slowly under low pressure.
5. Tend to lie deeper in the body.	5. Tend to lie near the body surface.
6. Transport oxygenated blood except pulmonary artery.	6. Transport deoxygenated blood except pulmonary vein.
7. Narrow lumen.	7. Wider lumen.

Study these questions

1. Draw and label the external structures of the heart.
2. Draw and label the internal structures of the heart. Show with arrows the direction of blood flow through the heart.

3.5. Diseases and Defects of Circulatory System

Thrombosis

This refers to formation of a clot in the blood vessels. The most common of all is the **coronary thrombosis** that leads to blockage of coronary artery which supplies blood to the heart.

The blockage may be due to arteries becoming increasingly fibrous or accumulation of fatty materials on the artery walls. The subsequent narrowing of coronary artery results in less blood flowing to the heart. Insufficient oxygen therefore, reaches the heavy oxygen dependent heart muscles. A serious blockage of the artery can result into fatal heart attack. Coronary thrombosis may be caused by heavy intake of fat which results to high amount of cholesterol in the blood. Cholesterol accumulates in the coronary arteries blocking the associated blood vessels thus causing less oxygen to reach the heart muscles. Other causes may be heavy intake of alcoholic drinks, smoking, overweight, psychological and emotional stress. Practicing healthy lifestyles can control coronary thrombosis.

Arteriosclerosis

Arteriosclerosis refers to the deposition of calcium in the walls of the blood vessels. It leads to hardening of the arteries which result to permanent change in arterial wall. This leads to thickening and loss of elasticity of the vessel wall. The most common type of arteriosclerosis is characterised by excessive growth of fibrous connective tissue in the wall of the arteries. The cause of the disease is not clearly known, however medicai scientists have established some relationship between the disease and overweight, lack of exercise and emotional stress.

Taking drugs that reduce cholesterol in the blood can control arteriosclerosis. Physical exercises can also reduce chances of arteriosclerosis since the excess fat will be broken down while the heart is kept active and strong.

Varicose Veins

It is a condition in which the superficial veins especially at the back of the legs become swollen and flabby due to failure of some valves to function properly. This results in the retention of tissue fluid. The disease can be controlled by regular physical exercises of the body.

Hypertension or High Blood Pressure

Normal blood pressure varies between 90/60 and 140/90 mm of mercury. The numerator refers to systolic pressure during contraction and the denominator refers to diastolic pressure during relaxation. High blood pressure is a disorder that is associated with heavy drinking, smoking, taking of large quantities of salt in the food and general body stress. High blood pressure may also be caused by arteriosclerosis which causes the heart to generate high pressure that force the blood through the less elastic vessels.

The heart of a hypertensive person is therefore overworked and the person is prone to heart failure. Hypertension may lead to bursting of arteries and capillaries. If the blood vessels in the brain bursts, a stroke results and the brain cells die in the affected areas. Paralysis at least for some parts of the body, usually accompanies a stroke. Some strokes are fatal.
This disorder is more common in individuals aged above 40 years.
Hypertension can be controlled by:

(i) Having regular exercises.
(ii) Intake of less salt.
(iii) Avoiding excessive drinking of alcoholic beverages,
(iv) Not smoking cigarettes and other related drugs
(v) Avoiding general body stress by practicing healthy life styles that give individuals peace of the mind.

3.6. The Structure and Functions of Blood

Composition of Blood

The mammalian blood consists of fluid medium called plasma with cellular components suspended in it. These cellular components are **erythrocytes** (red blood cells), **leucocytes** (white blood cells) and non-nucleated **thrombocytes** (platelets).

The Plasma

Plasma is a pale yellow fluid consisting mainly of 90 per cent water in which a variety of substances are suspended and others dissolved. Substances in plasma include glucose, mineral salts, hormones, some enzymes, amino acids and lipids. Also found in the plasma are plasma proteins such as anti-bodies, albumin, fibrinogen and waste products of metabolism such as carbon (IV) oxide and urea. Blood plasma from which fibrinogen and cells have been removed is called serum.

The main functions of plasma are:

(i) Transports red blood cells which contain oxy haemoglobin to the tissues hence facilitate transport of oxygen.
(ii) Forms the main medium in which dissolved food substances are transported to the liver and then to the other body tissues.
(iii) Transports metabolic wastes such as urea carbon (IV) oxide and other nitrogenous wastes to the excretory organs where they are eliminated from the body such organs include kidneys, lungs and the skin.

(iv) Transportation of hormones.
(v) Oxygen and carbon (IV) oxide are slightly soluble in water. Hence the plasma transports small amount of these gases.
(vi) Regulation of pH of the body fluids.
(vii) Distributes heat around the body hence regulate body temperature.

Red Blood Cells (Erythrocytes)

In an adult the red blood cells are made in the bone marrow of the short bones such as the sternum, ribs and the vertebrate. In the embryo they are made in the liver and spleen. Mature red blood cells have no nuclei but have a sunken centre that makes the cell resemble a biconcave disc as shown in figure 3.13 (a) and (b). The absence of a nucleus leaves room for more haemoglobin to be packed in the cell to enable it to carry more oxygen. Haemoglobin is a protein which contains iron and readily combines with oxygen to form an unstable compound known as oxy haemoglobin. Red blood cells carry oxygen in the form of oxy haemoglobin.

The haemoglobin has high affinity for oxygen. It readily picks up oxygen in the lungs where the concentration is high and easily releases oxygen in the tissues where the concentration is low.

In the tissues, oxyhaemoglobin readily breaks down (dissociates) into haemoglobin and oxygen. The oxygen diffuses out of the red blood cells and through the capillary walls into the tissues. The haemoglobin is then free to pick up more oxygen molecules from the lungs.

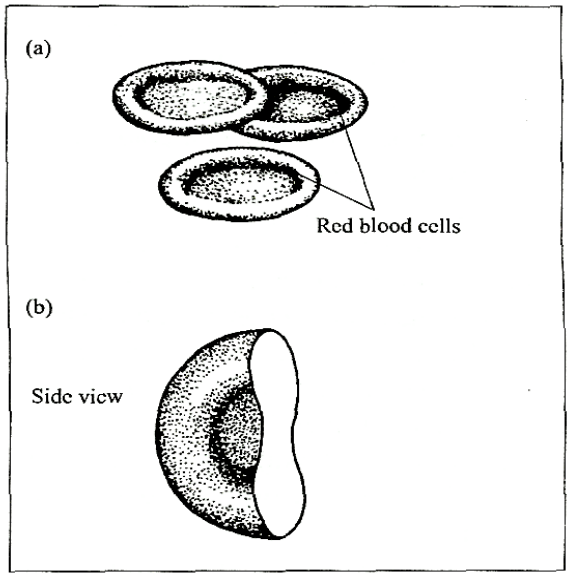


Figure: 3.13 Red blood cells

Red blood cells are about five million per cubic millimetre of blood. Due to their ability to change their shape, they are capable of squeezing through the narrow capillaries. Their large numbers and shape make them suitable for their function. The biconcave shape increases their surface area over which gaseous exchange can take place.

Red blood cells have a life span of about four months after which they break down and disintegrate in the liver and the spleen. The iron released from the breakdown of the old red blood cells is used in the manufacture of new cells. Although one per cent of all the red blood cells is used in the manufacture of new ones daily, their number per cubic millimetre

remains fairly constant in the blood of a healthy person. In the case of people living in high altitudes, the body responds to the low oxygen concentration by increasing the total number of red blood cells and the haemoglobin content in them. This response increases the oxygen carrying capacity of the red blood cells.
Besides oxygen, haemoglobin can readily combine with carbon (II) oxide (carbon monoxide) to form carboxyhaemoglobin. This compound does not readily dissociate and therefore reduces the capacity of haemoglobin to transport oxygen to the tissues. Carbon (II) oxide is therefore a respiratory poison which can be fatal if breathed in for a considerable length of time. Burning charcoal stoves, *(jikos)* in a poorly ventilated room produces carbon (II) oxide. Exhaust fumes from vehicles also contain carbon (II) oxide. It is important therefore that charcoal stoves are not allowed to burn in poorly ventilated rooms because carbon (II) oxide can accumulate to levels dangerous to life.

In addition to transport of oxygen red blood cells also transport about 95 percent of carbon (IV) oxide. Here the enzyme **carbonic anhydrase** speeds up the conversion of carbon (IV) oxide to weak carbonic acid. The carbonic acid dissociates into hydrogen carbonate and hydrogen ions. The hydrogen carbonate ions diffuse out of the red blood cells into the plasma in which it is then transported to the lungs. The remaining 5 percent of carbon (IV) oxide is transported as dissolved carbon (IV) oxide in the plasma.

White Blood cells (Leucocytes)

Unlike red blood cells, white blood cells are nucleated, they lack haemoglobin and hence their cytoplasm is colourless. They are fewer in number than the red blood cells. There are about 7,000 leucocytes per cubic millimetre of blood. In an average healthy man, there are about 600 red blood cells to every leucocyte cell. However their number increases greatly during infection. They are formed in the bone marrow of long bones and lymph nodes. Their function is to protect the body against pathogenic micro-organisms such as bacteria, protozoa, viruses and their secretions.

Leucocytes are of two main types: **granulocytes and agranulocyies.** Granulocytes are also called **phagocytes** or **polymorphs.** They have lobed nuclei and granulated cytoplasm. See figure 3.14.

Granulocytes use amoeboid movement to pass through the walls of the capillaries into the affected tissues. In the tissues and blood, the granulocytes engulf pathogenic micro-organisms by a process called phagocytosis hence the name phagocyte. Once ingested, the microorganism are digested. Some white blood cells may die in the course of phagocytosis. The dead phagocytes together with dead micro-organisms and damaged tissues form pus. The agranulocytes assist the phagocytes to destroy the pathogenic micro-organisms.
Agranulocytes on the other hand have rounded or bean-shaped nuclei and lack granules in their cytoplast. They consist of monocytes and lymphocytes.

The lymphocytes are formed in the lymph nodes and produce antibodies that protect the body from infection in the following ways:

(i) Antibodies which are antitoxins neutralise the toxins (antigens) produced by pathogenic microorganisms.

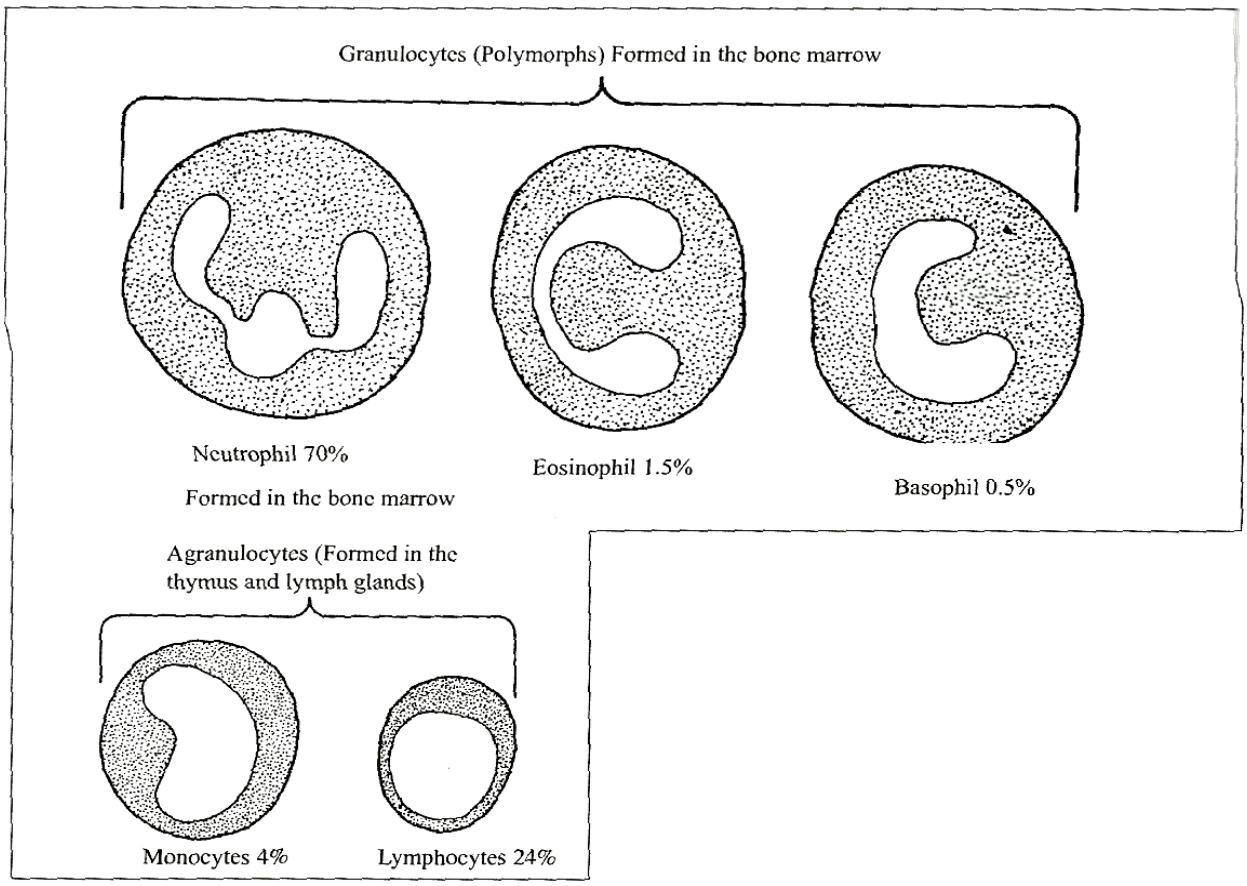
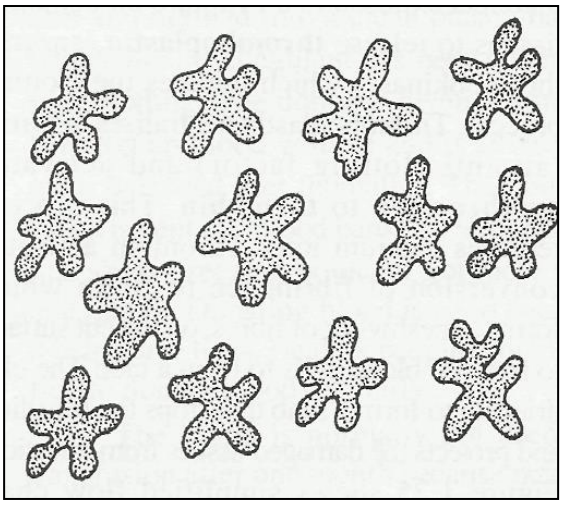


Figure: 3.14 Types of Leucocytes

Platelets (Thrombocytes)

Platelets are fragments from large cells in the bone marrow. They are discoid in shape and assume a star-shaped appearance in extracted blood. Their number is approximately 2.5 million per mm^3 of blood. They have no nucleu and play an important role in blood clotting when blood vessels are injured. See figure 3.15.



(ii) Some antibodies such as agglutinins cause clumping together of microorganisms. This stops the microorganisms from multiplying and eventually they die. In this way they are ingested by the phagocytes.
(iii) Lysins destroy micro-organisms by digesting their cell membranes or walls.
(iv) Opsonins are antibodies which adhere to the outer surface of micro-organisms thus making it easier for phagocytes to ingest them. The antibodies are produced when micro-organisms invade the body. After recovery from infection the level of antibodies decreases gradually as they disintegrate. (See immune response).
A blood smear observed under a microscope reveals the various components of blood. See photomicrograph in plate 3.15.



Figure: 3.16 Human blood smear

Blood Clotting Process

The process of clotting involves a series of complex reactions where soluble blood protein is converted into a mass of tangled threads of insoluble protein. This process begins when blood vessels are damaged.

When blood vessels are injured, platelets exposed to air rupture on damaged tissues to release **thromboplastin** (enzyme thrombokinase) which initiates the clotting process. Thromboplastin neutralises **heparin** (an anti-clotting factor) and activates **prothrombin** to **thrombin.** This process requires calcium ions. Thrombin activates conversion of fibrinogen to fibrin which forms a meshwork of fibres, on the cut surface to trap red blood cells to form a clot. The clot dries up to form a scab that stops the bleeding and protects the damaged tissues from infection. Figure 3.17 shows simplified flow chart summarising the process of blood clotting.

Thus blood clotting reduces loss of blood when blood vessels are injured. Excessive loss of blood especially more than 2 litres can lead to severe anaemia unless corrected immediately by blood transfusion.

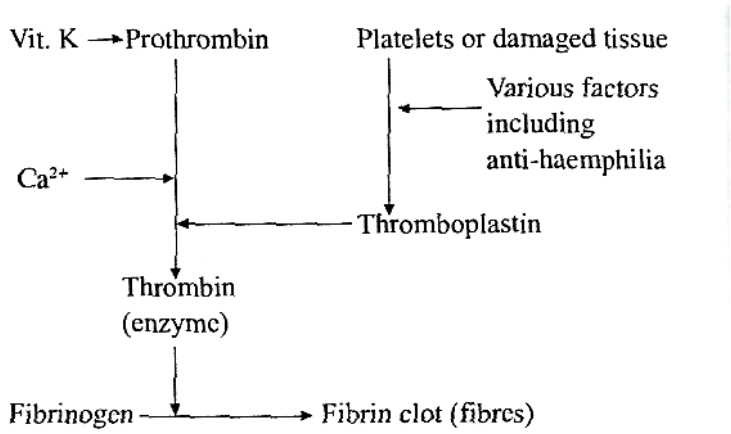


Figure: 3.17 The process of blood clotting

It is important to note that fibrinogen is only changed to fibrin when blood vessels are injured. Otherwise if this happens in vessels that are not injured, it would block up the blood vessels leading to death. However, this does not happen because fibrinogen is not changed to fibrin by the enzyme called thrombin. In undamaged vessels, blood does not contain thrombin but its inactive form called prothrombin. Formation of prothrombin requires vitamin K. Undamaged vessels contain heparin which prevents conversion of prothrombin to thrombin and neutralises any thrombin which may be formed accidentally.

Blood Groups

Red blood cells have certain proteins called antigens on their plasma membrane. There are two of these antigens, designated A and B. Blood groups are determined by the type of antigen present in an individual's red blood cell. Thus an individual whose red blood cells have antigen A is grouped as A. Antigen B is grouped as B. Antigen A and B is grouped as AB while that without antigens is grouped as O type.

The plasma too has proteins called antibodies. There are two types of antibodies designated a and b. If an individual has antigen A (blood group A) on his/her red blood cells, he/she cannot have antibody 'a'

In his/her plasma, but will bave antibody 'b'. Similarly an individual with antigen B (blood group B) has antibody 'a' in his/her plasma. This is due to the fact that agglutination or clumping of red blood cells takes place if antibodies corresponding to the antigen come into contact. See table 3.3.

Table 3.3: Blood groups, antigens and antibodies

Blood group	Antigen in red biood cells	Antibody in plasma
A	A	b
B	B	a
AB	AandB	None
O	None (neither A nor B)	Both a and b

Blood transfusion

Blood transfusion is the transfer of blood from a **donor** to the circulatory system of the **recipient.** A recipient will receive blood from a donor if the recipient cannot produce antibodies corresponding to the donor's antigens. Otherwise agglutination (clumping together) of the recipient's red blood cells will take place. Table 3.4 gives a summary of blood types and reactions of the blood types.

Table 4.4: Reactions of blood types

		DONOR			
		Ab	Ba	AB	Oa,b
RECIPIENT	Ab	V	X	X	V
	Ba	A.	V	X	V
	AB	V	V	V	V
	Oa,b	X	V	V	V

Key:
Capital letter: Antigens (blood groups)
Small letter: Antibodies
√ = Compatible (no agglutination)
X = Not compatible (agglutination)
Note: Blood group AB has neither antibody a nor b. Indviduals with blood group AB can receive blood from all others. They are therefore refered to as **universal recipient.** On the other hand, individuals with blood group O can donate blood to all others. This characteristic leads to individuals with this blood group being called **universal donor.**
A doctor must ensure that before one donates blood he/she is healthy and is between 18 and 65 years of age. A drop of the donor's blood is first tested to find out what group he/she belongs to. Haifa litre of the donor's blood is taken from a vein in the arm and drained into a clean plastic bag to which an anti-coagulant has been added, to stop clotting. The donor is given a drink to help top up blood volume and is advised to eat a balanced diet thereafter. The donated blood is kept in a blood bank at a temperature just above freezing point for not more than one month. Donating blood is good because it helps save lives. Healthy people should feel free to donate blood regularly.

The blood is normally not used for transfusion after one month because most of the red blood cells will have died. Before blood transfusion is carried out, it is important that the blood is screened for pathogens such as Human Immunodeficiency Virus/Acquired Immuno-Deficiency Syndrome (HIV/AIDS) and compatibility.

In addition to the A and B antigens, there is another antigen on the red blood cells known as the **Rhesus factor.** People whose blood contains this antigen are described as rhesus positive (Rh ^ve) while those who lack it are referred to as rhesus negative (Rh ^ve). If Rh $^{+}$ve blood is given Rh ~ve recipient, the latter responds by producing the corresponding rhesus antibodies and nothing further happens. But if the same recipient is given another dose of Rh $^{+}$ve blood in a period of less than two weeks agglutination of red blood cells occurs.

In a case where a Rh ~ve mother bears a Rh $^{+}$ve baby, fragments of the foetus' red blood cells containing the rhesus antigen pass across the placenta and get into the mother's blood stream. The mother's red blood cells respond by producing rhesus antibodies that in turn pass across the placenta into the blood of the foetus' red blood cells before the foetus' birth. This reaction is common after the first born and affects the foetus of the subsequent pregnancies. This is as a result of the antigen-antibody reaction taking place on the surface of the red blood cells. This condition is referred to as **haemolytic disease of the new-born** (Erythroblastosis foetalis). The new born baby can be saved by replacing its blood with Rh -ve blood. With every successive pregnancy the antibody level increases in the blood stream of the mother and subsequent foetuses, if the baby is also Rh +ve he/she will suffer from serious haemolytic disease of the new bom. With the advancement in technology, it is possible to transfuse blood to the foetus when still in the mother's womb and save the child.

In recent years, it has also been found that the haemolytic disease of the new-bora can be prevented by treating the mother with an anti-rhesus globulin which coats the surfaces of red blood cells thus preventing the antigen-antibody reactions.

3.7. Lymphatic System

Animals particularly vertebrates have an additional transport system besides the blood system. This is known as **lymphatic system** and it supplies all the regions of the body just like blood system. The lymphatic system is made of narrow, thin walled tubes known as **lymph vessels** which branch to form **lymph capillaries** in which a fluid known as **lymph** is transported. See figure 3.18.

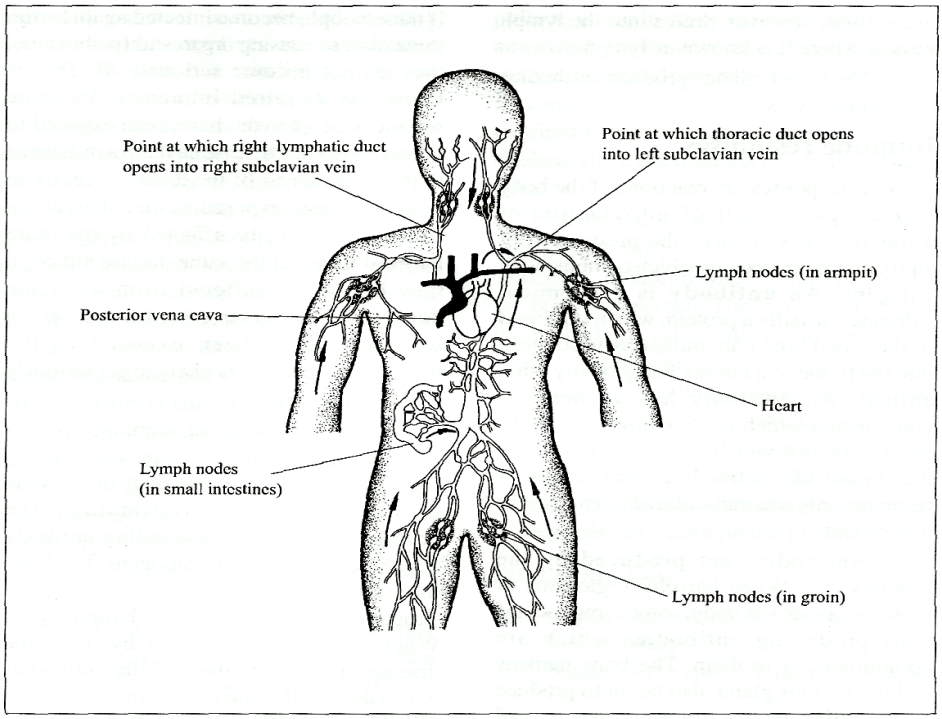


Figure: 3.18 Human lymphatic system

Lymph

This is a fluid similar to blood plasma except that it contains less proteins. It is formed as a result of ultra-filtration of blood from the narrow blood capillaries. As blood circulates it reaches the body tissues through the blood capillaries that form a network throughout the tissues. The pumping force from the heart together with the narrow lumens of the capillaries exert a high pressure that forces the fluid part of the blood to filter out of the capillary walls into the surrounding tissues. This filtrate consists of all the constituents of blood plasma except the blood cells and the proteins. This is because the blood cells and proteins are too large to filter out of the capillary walls. The fluid is known as **tissue fluid** or **intercellular fluid.** Once formed the tissue fluid bathes the cells of the tissues supplying them with oxygen, food and other useful substances.

The cells absorb these substances and pass out carbon (IV) oxide and other waste products in exchange. Most of the tissue fluid then returns to the blood system through the venule end of the capillaries. This is due to the lower hydrostatic pressure of the blood at the venule and compared to that at the arteriole end of the capillary. The excess tissue fluid, however, drains into the lymph vessels where it is known as lymph.
The lymph glands produce antibodies and lymphocytes.

3.8.Immune responses

Immune responses are reactions of the body that are as a result of introduction of **antigens.** They involve the production of antibodies or leucocytes which combine with antigens. An **antibody** is a chemical substance, usually a protein, which is formed in the blood when an antigen is introduced into the tissue of a human being or any other animal. An antibody has a chemical composition which is complimentary to the antigen against which it reacts. This means that a particular antibody combines with or responds only to a particular antigen to make it harmless.

Antibodies are produced by the lymphocytes. When harmful organisms or proteins invade the body, some lymphocytes start producing antibodies which are complimentary to them. The bone marrow and the thymus gland also begin to produce more polymorphs (phagocytes) and lymphocytes respectively.

Types of Immunity

Natural Immunity (Innate Immunity)
Natural immunity is inherited and controlled. This trait can be transmitted from parent to offsprings.

Acquired Immunity or Artificial Immunity

Acquired immunity can either be naturally or artificially induced. When attacked by diseases like small pox, chicken pox, measles, poliomyelitis, and mumps the people who recover completely from these diseases develop resistance to any subsequent infections from the same diseases. If these people become infected again by the same disease causing organisms (pathogens), they do not become seriously ill. This is known as acquired immunity. In some instances people who have been exposed to milder forms of a disease develop a resistance to the acute forms of the disease, e.g. those who have been exposed to the tuberculosis bacteria may not be affected by the more harmful forms of the same disease although they had never suffered from the acute disease before. On the other hand, a person who has never been exposed to the tuberculosis bacteria is likely to get seriously ill with the disease.

Artificial acquired immunity occurs when a mild form of a disease-causing organism is injected into the body of a healthy person. The infection stimulates the production of the corresponding antibody which then destroys the pathogens. The body thereafter retains the "memory" of the structure of this antigen in its lymphocytes. When the body is attacked by the same disease, it produces the specific antibodies which destroy the disease causing organisms. This type of immunity is called **artificial acquired immunity.** What happens is that, on coming into contact with specific antigens a group of B lymphocytes (called "committed" cells) in the lymph nodes undergo cell division to produce a group of large plasma cells. The plasma cells synthesise the antibodies which are released into the lymph and eventually reach the blood. In the blood the antibodies destroy the invading organisms. A small number of plasma cells remain in the lymph nodes for years, even after the antibodies have eliminated the original infection and are removed from the blood. This system provides a very rapid response to any subsequent infection by similar antigens.

These methods of artificially inducing immunity has now been adopted in many countries and many lives are saved from various diseases like smallpox, measles, poliomyelitis and tuberculosis. The first work on immunisation was by a British doctor called Edward Jenner in 1797 who used a vaccine to prevent a smallpox attack. He had observed that most milkmaids did not suffer from smallpox after they had suffered from cowpox. He carried out an experiment by first making some scratches on a healthy boy and introducing some pus from a pox vesicle of a woman suffering from cowpox. Later he introduced some pus taken from a woman suffering from smallpox into the boy's body.

Doctor Jenner observed that the boy did not contract smallpox, though he only developed mild symptoms of the disease. Thus the boy had been immunised against the deadly disease because a mild antigen (cowpox virus) produced antibodies against the smallpox.
Currently, the method of producing vaccines involves the treatment of the disease causing organisms so that they are weakened. This treatment of pathogens is called **attenuation.** The attenuated bacteria or viruses are then introduced into the body of a healthy person or animal by either vaccination or inoculation. The attenuated bacteria or viruses stimulate the production of specific antibodies by the body such that next time the body gets infected by the pathogens, there will be no serious illness caused. Vaccines generally contain attenuated disease causing organisms. These vaccines are currently produced commercially. The reaction of the body to cowpox vaccine is an example of active immunisation. Similarly, the body actively makes its own antibodies against some antigens e.g. measles, whooping cough and poliomyelitis. In some cases the artificially acquired immunity is permanent and immunisation is done only once in a lifetime. In some cases a "booster" vaccination is required to maintain immunity e.g. against cholera, since the immunity lasts for a short time.

Artificial passive acquired immunity is achieved when antibodies from another source e.g. serum, are directly introduced into the body of a person. The serum containing the antibodies is called **antiserum,** and it may be effective for only a few weeks. This type of immunity is called **passive** because the body is not activated to produce its own antibodies. In newly born babies antibodies pass from milk produced by the mother, so providing the babies with passive immunity to some diseases for a period of time.

Study These Questions

1) Explain how immunity is achieved in human beings.
2) Name two types of immunity you know.
3) List three diseases that are effectively controlled through vaccination.

The Role of Vaccination

Vaccination protects individuals from infections of many diseases such as smallpox, tuberculosis and poliomyelitis and it prevents the spread of the diseases. Diseases like smallpox, tuberculosis and tetanus used to be killer diseases but now, due to the development of vaccines, individuals can be protected from them. It is now believed that smallpox has been eliminated from the world since 1977. Pregnant mothers should be immunised against tetanus at least once before giving birth.

Table 3.5: Immunisation for children

Name of disease	*Causative agent*	*Age of baby when administered*	*Method of vaccination*
Tuberculosis	Bacterium	At birth	Injection
Poliomyelitis (Polio)	Virus	At birth 6 weeks 10 weeks 14 weeks	Oral inoculation
Diphtheria	Bacterium	6 weeks 10 weeks 14 weeks	Injection with vaccine
Whooping cough	Bacterium	6 weeks 14 weeks	Injection with vaccine
Measles	Virus	9 months	Injection with virus (Weakened)



***Vaccination** against various **diseases** is done*

In children, vaccination against certain diseases is done at different times. Immediately after birth, the baby should be immunised against tuberculosis and polio. The baby should then receive a compound vaccine against whooping cough and tetanus. The compound vaccination should be repeated after 10-14 weeks. At the age of nine months, the child should be vaccinated against measles. Measles is a major child-killer disease. Vaccinations should be given at regular intervals (see table 3.5). For example, booster injections of vaccines against polio in babies have to be given regularly after every four weeks, for the first 16 weeks. It is also recommended that healthy children should be exposed to chickenpox when young for the attack is severe when the children mature.

Immunisation against other diseases should be done as advised by the health officers. Usually, people of all ages are vaccinated if there is an outbreak of diseases like cholera.

Apart from immunisation the control of diseases can also be done by restricting movement of people into and out of infected areas. This method is called **quarantine.** It can be done at international, national or local levels.

Facilities like water wells, should not be shared as long as the quarantine is in force. Internationally, before one enters another country, one must be vaccinated against various diseases, and certificates of vaccination obtained. In schools and homes, people suffering from infectious diseases should be isolated to avoid infection of healthy people. This minimises the spread of disease.

Allergic reactions

An allergy is a hypersensitive reaction to an antigen by the body. This occurs when the combination of an antibody with an antigen produces a violent reaction or severe damage to the body. Allergic people are hypersensitive to materials like dust, pollen grains, some foods, some drugs and certain air pollutants.
The allergy manifests itself in various ways. In some people, on eating certain foods, rashes appear on the skin. Some drugs e.g. penicillin, chloroquine and aspirin can also cause rashes on the skin. Other allergic reactions are itching, sneezing, vomiting or difficulties in breathing.

The allergic conditions are brought about when the body reacts by overproducing antibodies against harmless antigens. The antibody-antigen reaction takes place on the surface of cells that burst open, releasing a chemical substance called **histamine,** Histamine increases the permeability of the epithelial cells thus making them take in fluid and swell up. The intercellular spaces too become filled with fluid, and swell. Histamine also causes inflammation and pain. A severe condition called **anaphylaxis** sometimes occurs, in which blood vessels get dilated and this lowers the blood pressure to the extent of causing death. This is how bee stings can cause death. Avoiding the allergens (allergy causing substances) or administration of the antihistamine drugs can control this.

Organ Transplants

Currently, a lot research is being done on organ and tissue regeneration and human immune system. Surgeons can replace damaged tissues of organs using similar organs from other persons or animals e.g. the pig, in transplant operations. It has also been possible to transplant kidneys, liver, spleen, reproduction organs, parts of skin and limbs. Parts of organs or tissues transplanted on to larger parts of (recipient) are called **grafts.** It is known that although two organisms belong to the same species, their immune systems may be so different that grafts may be rejected by the recipient. In most cases grafts involving identical twins or those from same individual are not rejected.

The grafts may be rejected because the body of the host recognises the new tissue or organ as foreign to it. The donor tissue has antigens to which the host's leucocytes produce antibodies and the tissue may be rejected; if not, the graft will "take" or be accepted. Some transplants of hearts, kidneys, cornea of the eye, lungs and bone marrow have been carried out by using drugs that suppress the immune response of the host. A substance called interferon is also used to suppress rejection of grafts. In organ transplants, sophisticated machines are used to keep the organs to be transplanted and the patient alive.

Revision Questions

1. Distinguish between:
   (a) Open and closed circulation.
   (b) Single and double circulation.
2. If the nerve supply to the heart of a mammal is severed, the rhythmic heart movements will still go on and the heart continues to beat. Explain why is this so. (b) With the aid of a labelled diagram describe the heartbeat. What is the importance of the heartbeat to blood circulation?
3. Make a table of comparison between the structure and functioning of the arteries and veins of a mammal.
4. A doctor performing an operation cuts two blood vessels by mistake. He notices that from one of the blood vessels blood spurts out, while from the other, blood flows out steadily. Identify, with a reason, the type of each of the blood vessels cut.
5. Excessive blood loss can be rectified by blood transfusion in which blood from one person, the donor, is transferred into the patient's blood system.

   (i) Complete the table below:

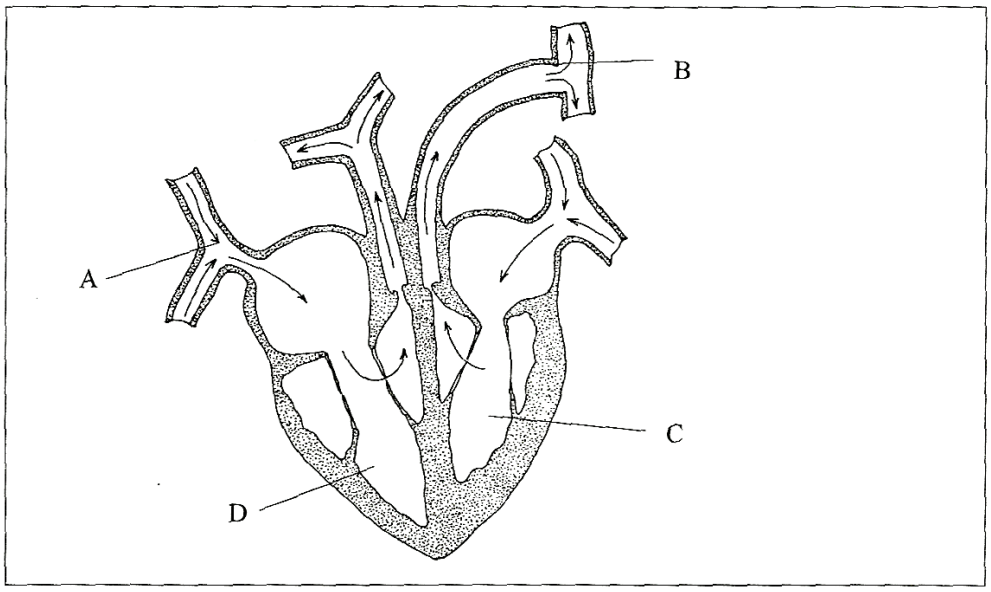
Table

Group	*Can donate blood to*	*Can receive from*
A		A,O
B	B and AB	
AB|		A,AB,B, O
O	A,B,ABand O	

   (ii) What are the advantages and disadvantages of having blood group O?
   (iii) What is the advantage of having blood group AB?
   (iv) A transmission of Rh $^{+}$ve blood was given to a patient with Rh ~ve Wood. After one week a similar transfusion was given to the same patient. What was likely to be the effect of the second transfusion?

6. (a) State two functions of mammalian blood other than transport of substances.
   (b) Name one group of organisms that has:
      (i) an open circulatory system.
      (ii) a closed circulatory system.

7. The following Figure represents a section through a mammalian heart.



(a) Label the parts marked A, B, C and D.
(b) Using arrows, indicate the direction of blood flow in and out of the heart.
(c) State the structural differences between blood vessels labelled A and *B.*
(d) Explain why chamber C has thicker walls than the chamber labelled D.

8. In a blood test, a few drops of antiserum were added to two samples of blood. No agglutination occurred. What were the blood groups of the two samples?
9. People can die when they inhale gases from burning charcoal in poorly ventilated rooms. Explain how this death comes about.
10. (a) State two proteins in the blood which are responsible for determining the blood group of a person.
    (b) Give two reasons why a transport system is necessary in higher animals.
11. State any two adaptations of red cells to their functions.
12. What do you understand by the term double circulation?
13. (a) Explain the differences between:
        (i) blood plasma and serum,
        (ii) blood and lymph.
        (iii) tissue fluid and blood plasma,
    (b) State the functions of the plasma.
14. (a) Draw a large labelled diagram of internal structure of a mammalian heart
    (b) Describe the circulation in the heart.
    (c) Describe the working of the heart.
15. Describe two diseases and two disorders of blood vessels. Identify the causes of the disorders in
    (a) above and list their symptoms and treatment,
    (b) In a certain person, blood took a long time to clot after a cut. What vitamin deficiency was the person likely to have been suffering from?
16. (a) What do you understand by the term immunity?
    (b) State and discuss the two types of immunity.
    (c) What is a vaccination? State the role of vaccination in providing immunity.
    (d) What causes allergies?

CHAPTER FOUR
THE RESPIRATORY SYSTEM AND RESPIRATION

Introduction

The process by which the respiratory gases (Oxygen and Carbondioxide) are passed across the respiratory surface is known as **gaseous exchange**. This is brought about by a concentration gradient that exists between the body of living organisms and surrounding medium. In simple organisms, oxegen is absorbed by the exposed surface of the body by simple diffusion.

In more complex organisms, there special organs such as lungs which absorb oxygen and remove carbondioxide from the body.

The importance of gaseous exchange in the living organisms is to promote oxygen intake for respiration and facilitate carbondioxide removal from the body as a waste product of metabolism

4.1. The structure and function of the Respiratory System

Breathing system In humans consists of the following structures: lungs, trachea, chest cavity made of ribs and intercostal muscles, diaphragm and nostrils or nose as shown in figure 4.1.

Nose

The nose has two openings called nostrils which let in air into the air passages. As air moves in the passages, it is warmed and moistened. The lining of nasal cavity of the nose also houses the sense organs for smell.

The Larynx

The larynx is also the voice box. It is located on top of the trachea. Its muscle fibres and the vocal cords control the pitch of the voice.

Trachea

The trachea is a tube made up of rings of cartilage which ensure that it does not collapse during breathing. The lumens of the trachea are lined with ciliated epithelium. The cilia beat in waves and move the mucus and foreign particles towards the pharynx away from the lungs. As the trachea enters the lungs, it divides into two branches called bronchi (singular bronchus).

Lungs

Lungs are found in the chest cavity. They are enclosed in a double membrane known as pleural membrane. One part of the membrane adheres tightly to the lungs and the other covers the inside of the thoracic cavity. The space between these membranes is known as the pleural cavity. It is filled with pleural fluid which reduces friction and therefore make the lungs move freely in the chest cavity during breathing.

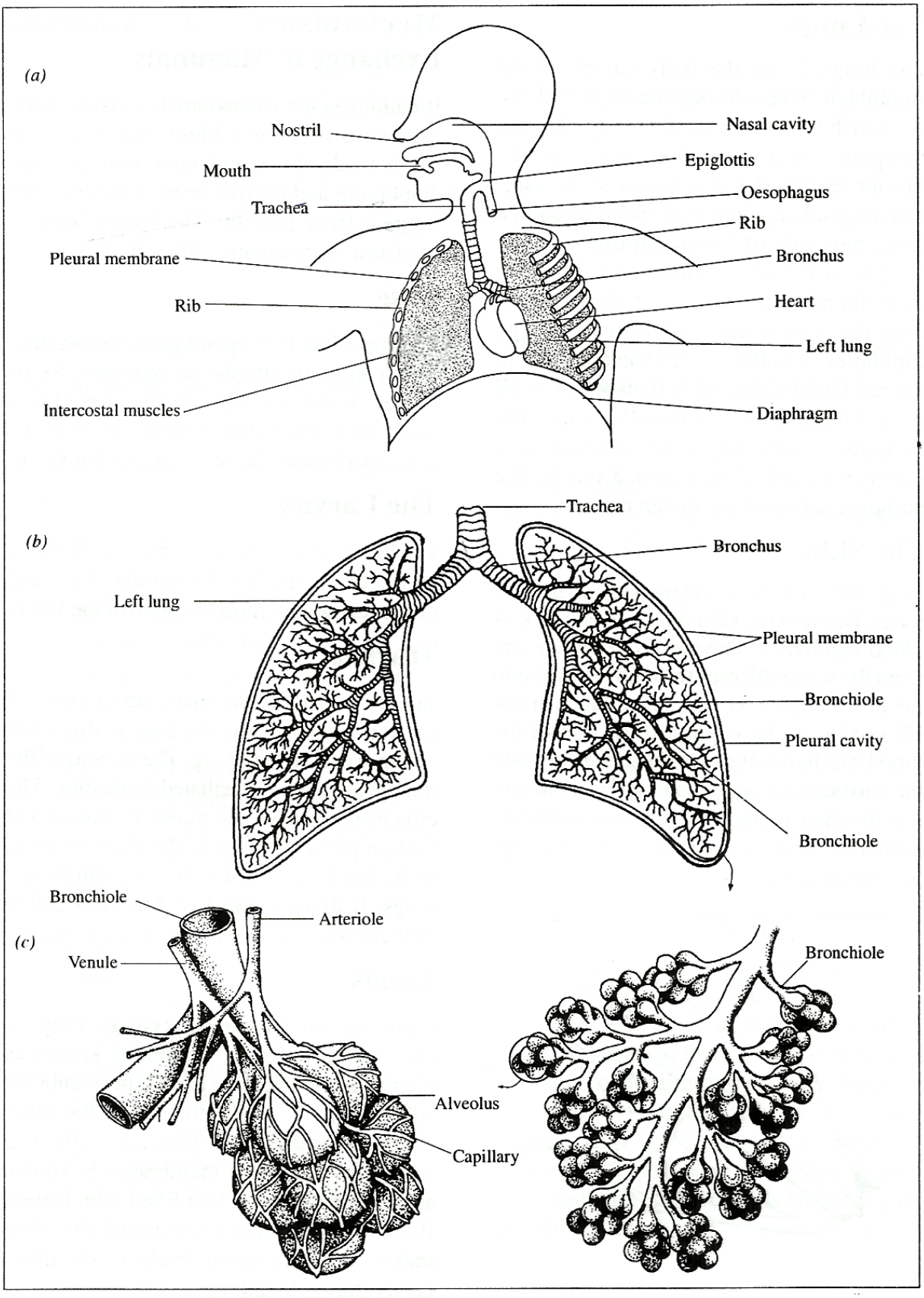


Figure: 4.1 The structure of the lung of the human being

Within the lungs, each bronchus divides into small tubes called bronchioles. The bronchioles branch and terminate in groups of tiny air sacs called alveoli (singular alveolus) hence the spongy nature of the lungs. The alveolus is covered by a fine network of blood capillaries as shown in figure 4.1 (c).

4.2. The Mechanism of Breathing

Breathing is accomplished by changes in volume and air pressure of the thoracic cavity. The thoracic cavity is enclosed by ribs which are attached to the vertebral column at the back and sternum in front. The ribs are covered by intercostal muscles, and below the cavity is the diaphragm. The diaphragm is a muscular sheet of tissue extending across the floor of the cavity between the thoracic cavity and abdomen. It curves upwards to form a dome shape.

Breathing mechanism involves two processes: inspiration (inhalation), and expiration (exhalation). Inspiration is breathing in, and expiration is breathing out. These two processes are brought about by movement of the ribs and diaphragm. See figure 4.2.

Inspiration/Inhalation

This process occurs when the thoracic cavity increases in volume and therefore decreases in pressure. A number of movements are involved during the enlargement of the thoracic cavity. During inspiration the external intercostal muscles contract -white the internal intercostal muscles relax. This movement pulls the ribs upwards and outwards. The diaphragm, which is dome-shaped flattens by the contraction of its muscles. The flattening of the diaphragm together with the outward movement of the ribs increases the volume of the thoracic cavity and decreases the pressure inside it. Atmospheric pressure being higher than pressure inside the thoracic cavity, forces air to rush into the lungs through the nose and trachea hence inflating the lungs. Figure 4.2 (a) summarises these movements.

Expiration/Exhalation

This process occurs when the volume of the thoracic cavity decreases and the pressure inside it increases. This is brought about by the following: the external intercostal muscles relax while the internal intercostal muscles contract bringing the ribs down to their original position. At the same time the muscles of the diaphragm relax and it regains its original shape. These movements decrease the volume of the thoracic cavity and increase the pressure inside it. Thus air is forced out of the lungs through the air passages into the atmosphere. See figure 4.2 (b) for the summary.

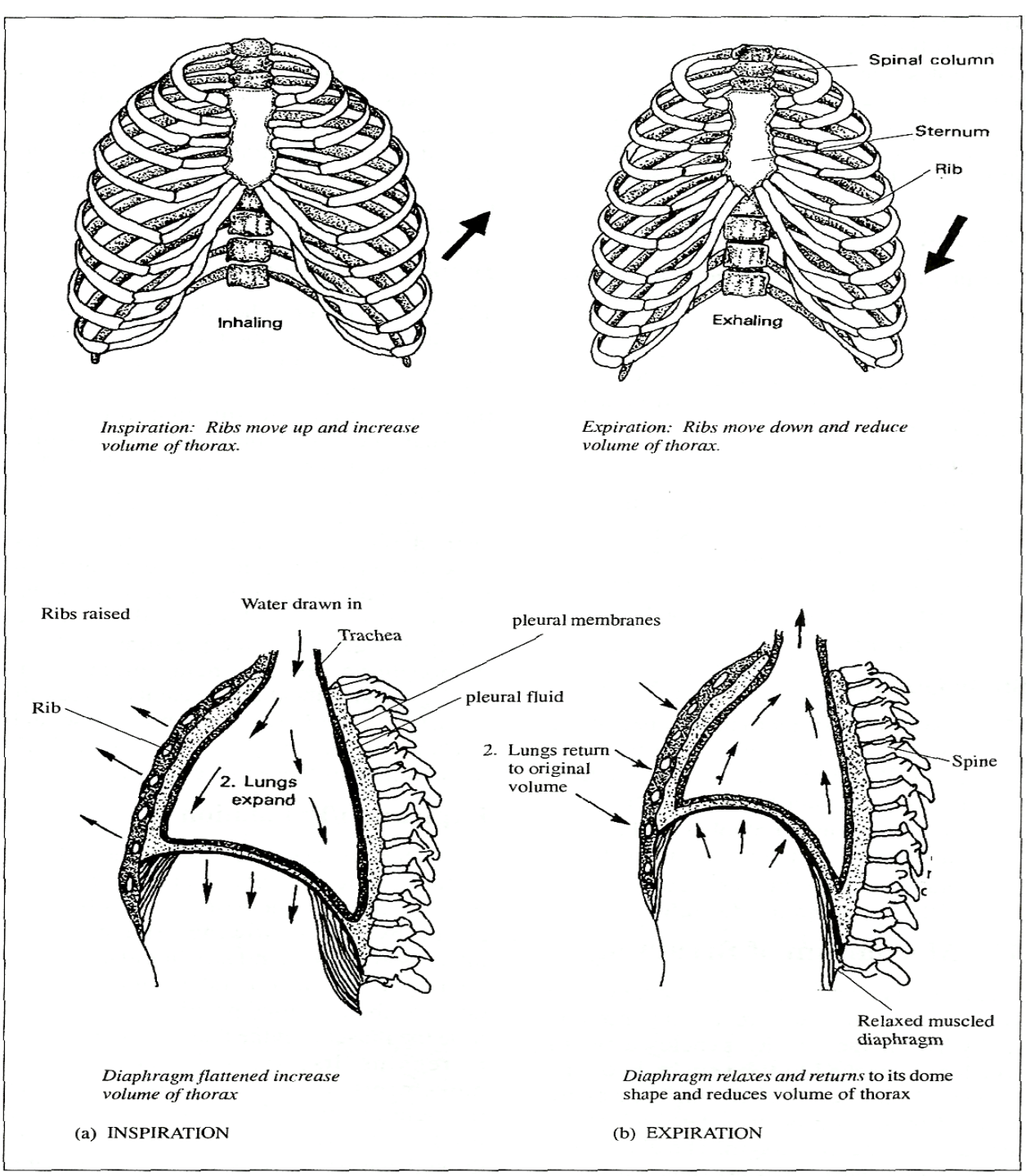


Figure: 4.2 Movement of the ribs during breathing

Practical Activity

To investigate the movement of the lungs and diaphragm in a model thoracic cavity

Requirements

Two balloons, bell jar, rubber stopper with a hole, y-shaped connector and rubber sheet.

Procedure

1. Set up the apparatus as shown i n figure 2.18.
2. Pull down the rubber sheet at the base of the bell jar.
3. Observe what happens to the balloons.
4. Release the rubber sheet slowly and observe what happens to the balloons.

Study this Question

In what ways is this model similar or dissimilar to the working of the thorax of a living mammal?

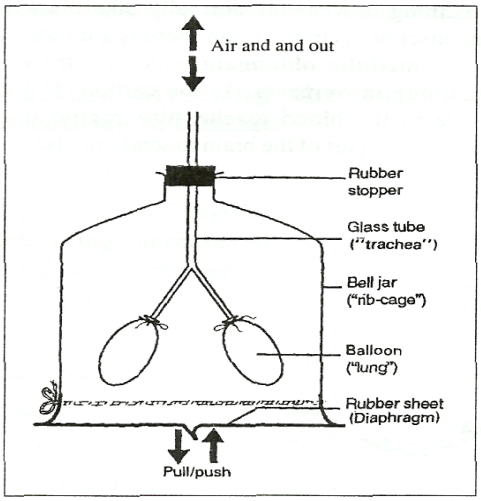


Figure: 4.3 To investigate the rib action during breathing using a model

Exchange of Gases in the Alveolus

The alveoli and the blood capillaries are made of very thin walls. The wall of the alveolus is covered by a film of moisture which dissolves oxygen in the inhaled air. Since oxygen concentration in the blood is lower than in the alveolus, it diffuses through the epithelium, the capillary wall, the plasma and into the red blood cells where it combines with haemoglobin. Carbon (IV) oxide in the capillaries surrounding the alveoli is at a higher concentration than inside the alveoli. Hence it diffuses into the alveoli. See figure 4.4. Water vapour passes out of the blood by the same process. Table 4.1 shows the estimated percentage of different gases in inhaled and exhaled air.

Table 4.1: **Percentage composition of gases in inhaled and exhaled air**

Gas	*% in inhaled air*	*% in exhaled air*
Oxygen	20	16.9
Carbon (IV) dioxide	0.03	4.0
Nitrogen and other gases	79.97	79.97

Regulation of Breathing

Breathing movements normally take place unconsciously. In the brain there is a region called **medulla oblongata** which controls breathing movements. As the carbon (IV) oxide in the blood reaches this region it triggers this part of the brain to send impulses to the rib muscles and the diaphragm, which in turn respond appropriately. This makes breathing to continue on and on.

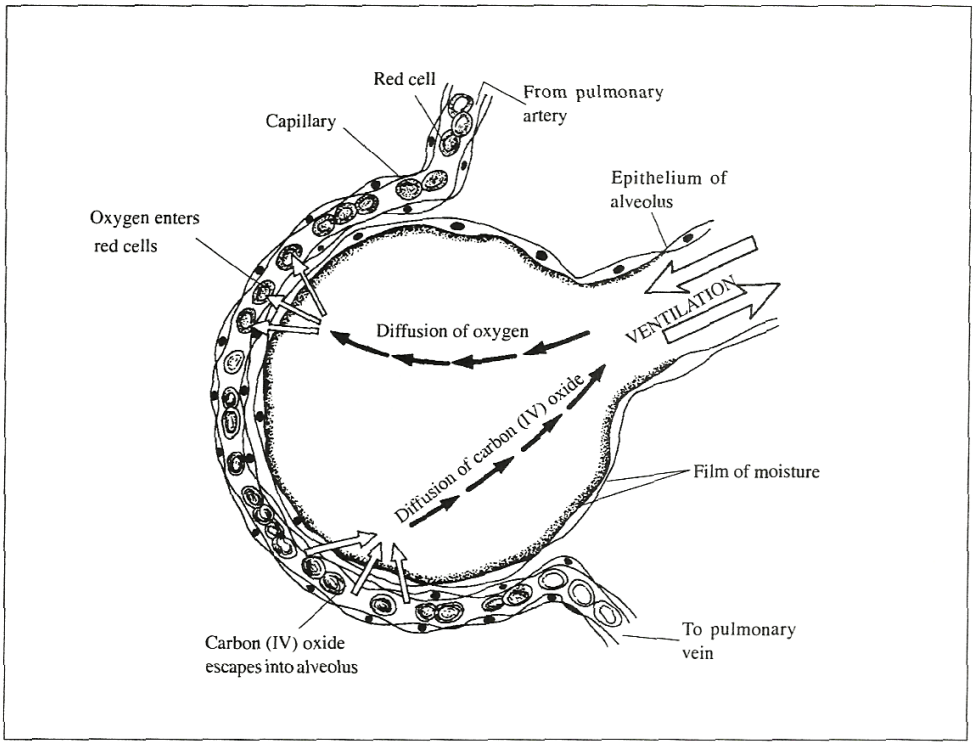


Figure: 4.4 Gaseous exchange in the alveolus

During vigorous activity the concentration of carbon (IV) oxide increases in the body tissues. As a result of this, more carbon (IV) oxide diffuses into the blood and reaches the medulla oblongata. The high concentration of carbon (IV) oxide in blood triggers the medulla oblongata to increase the rate of breathing. Increased rate of breathing helps to increase the amount of oxygen in the blood thereby meeting the demands of the increased tissue respiration.

4.3.Factors affecting the rate of breathing in humans

1. Exercise

During vigorous physical activity the rate of breathing increases so as to meet the increased oxygen demand. Faster breathing also eliminates the extra carbon (IV) oxide produced by increased respiration.

2. Age

Younger people have a higher demand for oxygen. They therefore have faster breathing rate.

3. Emotions

Generally the body emotions affect the production of hormone adrenaline which increases the general metabolism and hence increased rate of breathing. Examples include
fear, anxiety and fright.

4. Temperature

Generally when the temperature is high there is a tendency in the rate of gaseous exchange to increase. However, if the temperature is too high the breathing rate will reduce.

5. Health

One effect of illness is fever. The temperature of the body tends to increase hence increased metabolic rate, which leads to higher rate of breathing. Some respiratory diseases block the respiratory tract making breathing difficult.

Study Question

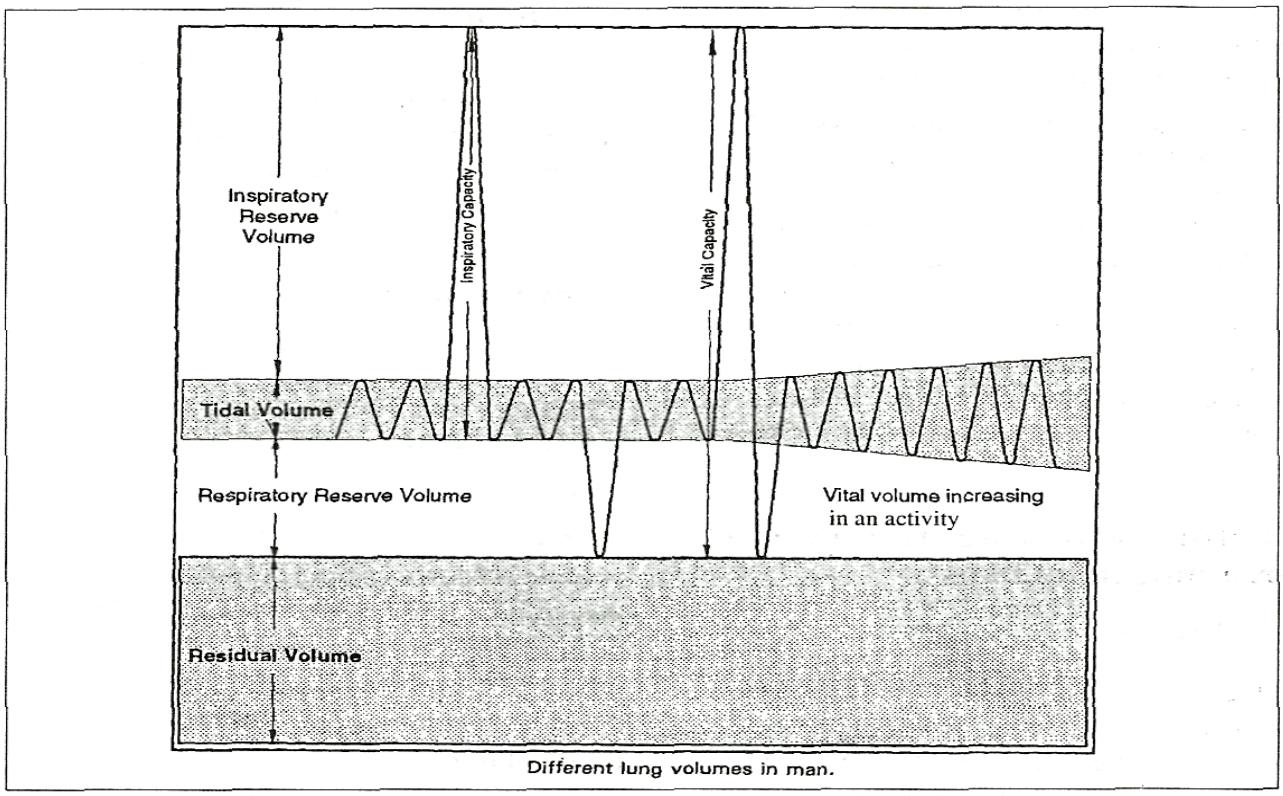
Suggest how altitude may affect the rate of breathing.

Lung volumes

Lungs of an adult can hold approximately 5 500 cm^3 of air when completely filled. This volume is known as **lung capacity.** However this volume is not reached normally. During normal breathing, a small volume of air (about 500 cm^3) is taken in and out of the lungs. This volume of air is referred to as the **tidal volume.**

A person is capable of having a forced inhalation in addition to the tidal volume. This additional volume is called inspiratory **reserve volume** and reaches about 2 000 cm^3. The tidal volume plus inspiratory reserve volume forms what is referred to as **inspiratory capacity.** After normal exhalation, it is possible to force out extra volume of air. This volume is referred to as **expiratory reserve volume** and can be up **to** 1 300 cm^3. It is also possible to have the deepest possible exhalation. Such a volume of air, which can only be forcibly pushed out of the lungs, is called the **vital capacity.**

However, it is not possible to force all air out of the lungs even after the deepest exhalation. The air that normally remains **in** lungs is referred to as the **residual volume** and is about I 500 cm^3. See figure 4.5 for a graphical representation.



Different lung volumes in man.

4.4. Diseases of the Respiratory System

Respiratory diseases are those which affect the breathing structures and make gaseous exchange in animals difficult. They include:

1. Asthma

Asthma is a common respiratory disease caused by:

(i) Allergy to the respiratory structure due to pollen grains, atmospheric dust, animal's fur, scents from certain drugs, foods and flowers.

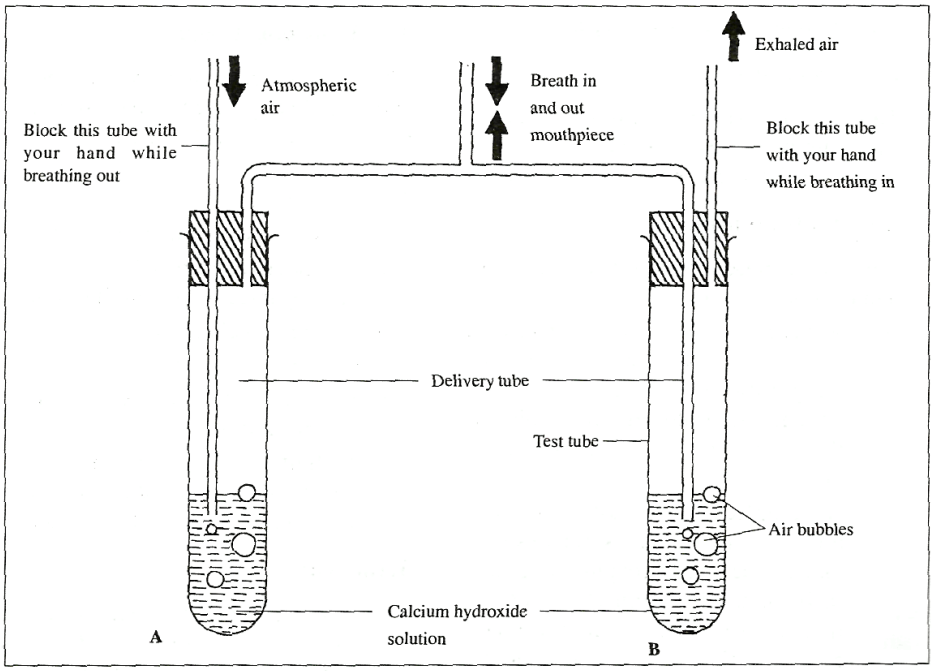


Figure: 4.6 Set-up for comparing amounts of carbon dioxide taken in and out

(ii) Lung or bronchial infections by bacteria or viruses. The respiratory problem comes in form of attacks which are mild or severe.

When the weather is cloudy and chilly, or exposure to the causative agents listed in (i) above, the attacks are more frequent. The patient may have difficulty in breathing because of the constriction of air channels caused by muscular contractions. The patient, therefore, produces a characteristic "wheezing" sound accompanied by the feeling of suffocation.

Treatment and Control

Treatment and control of asthma consist of:

(i) The spraying of a muscle-relaxant directly into the bronchial tubes,
(ii) Injection of drugs or oral application of pills prescribed by a health physician,
(iii) Avoiding the causative agents.

2. Bronchitis

This is an inflamation of the bronchial tubes. There are two types of bronchitis, namely; acute bronchitis and chronic bronchitis.

(a) Acute bronchitis

This is widespread illness in children and frail adults. It is caused by:

(i) A complication of the common cold when one is exposed to low temperatures especially in high attitudes. It results into the chilling of the body, giving way to bacterial infection.

(ii) A complication resulting from a previous disease attack for example measles, dengue, whooping cough and influenza. The clinical symptoms include: headache, mild fever and coughing that are accompanied by uncomfortable feelings behind the sternum. The illness may clear in a few days or may persist for several months.

(b) **Chronic Bronchitis**

Chronic bronchitis develops after several repeated attacks of acute bronchitis. It is a fatal condition which makes the sufferer disabled and unfit to work.

Its symptoms are:

(i) Production of **phlegm** (thick sputum) that is greenish or yellow in colour due to pus from respiratory surface.

(ii) The patient has difficulty in breathing and finds it difficult to walk or sleep unless propped up in bed to ensure that the bronchial tubes are not clogged.

Treatment and Control

Patients should seek early medical assistance when the illness is still in its early stage.

3. Whooping Cough

Whooping cough results from acute infection of the respiratory tract by a bacterium called *Bordetella pertussis*

The symptoms are:

(i) Prolonged coughing and vomiting.

(ii) Conjunctival haemorrhage accompanied by peri-orbital oedema,

(iii) Severe bronchopneumonia.

(iv) Convulsions and coma.

(v) Ulcers and cardiac failure orcomplications.

(vi) Malnutrition signs for protein and energy deficiency due to repeated vomiting with difficulty in feeding.

Treatment

(i) Complicated cases should be admitted to hospital for specialised care and administration of antibiotics.

(ii) Lung or bronchial infections by bacteria or viruses. The respiratory problem comes in form of attacks which are mild or severe.

When the weather is cloudy and chilly, or exposure to the causative agents listed in (i) above, the attacks are more frequent. The patient may have difficulty in breathing because of the constriction of air channels caused by muscular contractions. The patient, therefore, produces a characteristic "wheezing" sound accompanied by the feeling of suffocation.

4.Pneumonia

Pneumonia is an inflammation of the lungs by micro-organisms. There are several types of pneumonia caused by different bacteria. Common ones include: (i) Lobarpneumonia caused by attacks of *Streptococcus **pneumonias.***Symptoms of attack of pneumonia occur after a short incubation period followed by:

(a) coughing (b) fevers (c) chest pains and
(d) deposits of fluid in the lungs.

The invasion proceeds from the throat spreading to other parts of the body. This sets on when the patient's body is completely weakened.

Treatment and Control

The patient should use antibiotics which include penicillin and sulphonamides,

(i) Avoid overcrowded places,
(ii) Provide good ventilation in living premises.

5.Pulmonary Tuberculosis

Tuberculosis is a respiratory disease caused by a bacterium called *Mycobacterium tuberculosis.* It is airborne, but occasionally it is spread through infected cow's milk or other fluids taken as a meal. The symptoms include:

(i) General weight loss
(ii) Coughing, sometimes with sputum containing blood
(iii) Slight afternoon fever.

The bacterium destroys lung tissues making it hard for the patient to breathe. It may eventually result into death. Treatment involves use of antibiotics especially, streptomycin,

Control

(i) Detection of the disease in its early stages by radiographical method.
(ii) Pasteurisation of milk.
(iii) Vaccination of the population using BCG (BacilleCalmette Guerin).

6. Lung Cancer

Cancer is an uncontrolled cell growth in the body resulting into tissue tumour or enlargement. The tumour can be benign (which affects cells at a single point) or malignant (when affected cells break away and spread to other parts of the body).

There are no specific causes for lung cancer but it may result from:

(i) Smoking, in which the mucal walls of the bronchial tubes are blocked with deposits of tar from the cigarette smoke. Tar contains **cancer-causing** (carcinogenic) substances that can trigger uncontrollable growth of the Jung cells.

(ii) Inhalation of cancer-causing substances such as asbestos dusts or exposure to:

(a) radiation e.g. X-ray, gamma rays, cosmic rays.
(b) Radio-active substances e.g. uranium.
(c) Substances that alter the genetic composition of a cell e.g. mustard gas, sulphur dioxide used as a preservative in foodstuff.

Lung cancer destroys the lung cells and tissues and as a result this interferes with free exchange of respiratory gases, which may eventually lead to death.

Treatment

(i) Surgery to remove the tumour
(ii) Radiotherapy to destroy cancerous cells.
(iii) Chemotherapy to relieve the patient of pain and to destroy the cancer cells
(iv) The combination of several drugs each toxic to cancer cells enhances the treatment programme
(a) and
(b) above.
(c) By not smoking actively and passively and in food preservatives.

4.5. Respiration
3.1 Introduction

Respiration is the process by which food substances are chemically broken down in all living cells to release energy, carbon (IV) oxide, water or alcohol. Respiration takes place slowly and is controlled by many different types of respiratory enzymes so that energy is produced continuously and in small amounts.

Respiration should not be confused with gaseous exchange. Note that whereas respiration is a chemical process taking place inside tissue cells, gaseous exchange is a purely physical process which takes place at respiration surfaces. The term respiration as described in this chapter is sometimes referred to as **tissue respiration** or **internal respiration.**

4.6 .Significance of Respiration

All living organisms require energy all the time. The energy is obtained from food substances which are either taken in or manufactured during photosynthesis. Examples of foods which can provide large amounts of energy are carbohydrates (like starch and glucose) and fats. The energy derived from these food substances as a result of respiration is used for such activities as muscular contraction, conduction of nerve impulses, secretion of enzymes, growth, repair of worn out tissues, functioning of body organs such as kidneys, heart and brain. However, some of the energy is also lost in form of heat.
Tissue respiration takes place mainly in cell organelles called mitochondria.

Structure and Function of a mitochondrion

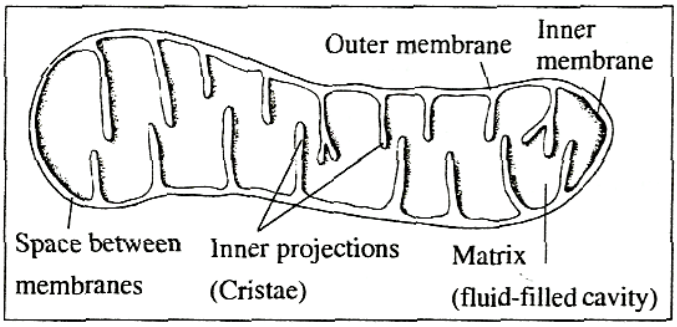


Figure: 4.7 The structure of the mitochondrion

Mitochondria are small round or rod shaped cell organelles found in cells and provide sites for respiratory activity. Living cells such as the kidney cells, the flight muscle of insects and birds, the sperm cells and muscle cells have high energy requirements and consequently possess large numbers of mitochondria.

The structure of mitochondria is shown in figure 4.7. It has two membranes, the outer and inner membranes that are separated by fluid filled spaces. The inner membrane folds into projections inside the matrix called **cristae.** The cristae provide a large surface area for respiratory activities. Enzymes are bound to the cristae.

4.7. Types of Respiration

There are two types of respiration namely aerobic and anaerobic.

Aerobic Respiration

Aerobic respiration is the process in which food substances such as glucose are broken down in the presence of oxygen in tissue cells to release energy, water and carbon (IV) oxide. The total energy released at the end of respiration (oxidation) is very high. If all the energy were released at once in the form of heat, it would burn the body cells. To protect the cells from burning the heat energy is released in small quantities in stages.

This energy is used to bring about a chemical reaction in which a compound in the cell called adenosine diphosphate (ADP) combines with an inorganic phosphate molecule to form another compound called adenosine triphosphate (ATP). This reaction is summarized as follows:

Adenosine + Inorganic + Energy $\longrightarrow$ Adenosine triphosphate (high energy molecule)

ADP + $(PO_4)'$ + Energy $\longrightarrow$ ATP

The following equation summarizes the process of aerobic respiration in plants and animals.

$$C6H12O6 + 60 \xrightarrow[\text{enzymes}]{\text{Respiration}} 6CO + H2O + \text{Energy (ATP)}$$

(glucose) (oxygen) (carbon (IV) oxide) + (water)

Molecules of adenosine trisphosphate (ATP) store the energy released in respiration in their bonds and avails it to cells readily when required.

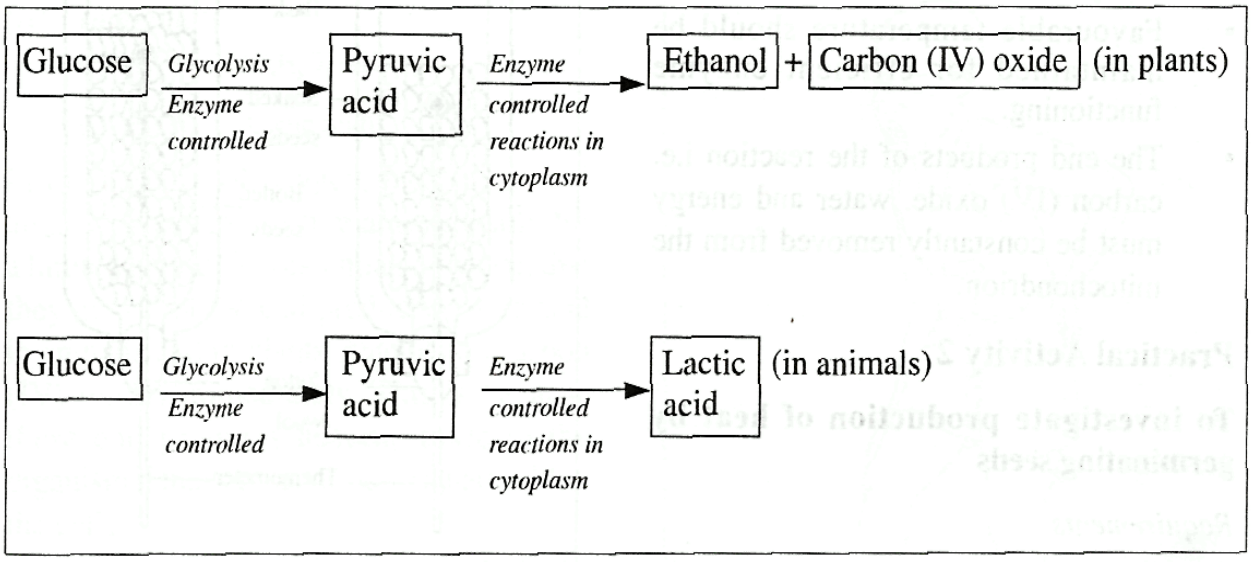
The chemical equation as represented above gives the false impression that respiration involves only one chemical reaction. The whole process in fact involves a series of many reactions. A specific enzyme catalyses each of these reactions. In broad terms, respiration takes place in two major phases and each phase consist of a series of reactions.

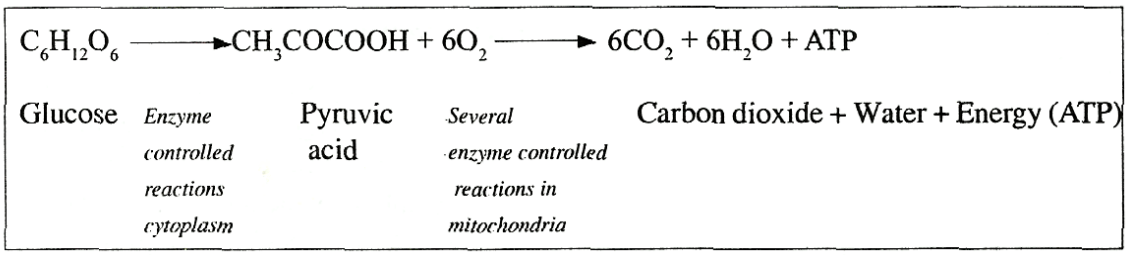
First phase

The earliest stages of respiration take place without using oxygen. These stages involves a series of chemical reactions which occur in the cytoplasm of the cell. Acompound with a three-carbon molecule called pyruvic acid is formed from glucose.

The breakdown of glucose is called glycolysis. What happens after pyruvic acid is formed depends on whether oxygen is available for use or not. If oxygen is not supplied to the cell, then pyruvic acid is then partially broken down to lactic acid in animals or to ethyl alcohol (ethanol) and carbon (IV) oxide in plants. See chart below.

In glycolysis, one molecule of glucose yields two molecules of ATP. Alcohol production occurs in plant tissues and during fermentation by yeasts and many bacteria. The alcohol accumulates in these organisms provided oxygen is excluded.





Second phase

This phase takes place in the matrix of the mitochondria. It involves a series of enzyme-controlled reactions that require oxygen. The pyruvic acid formed in the first phase is further oxidised by oxygen in a series of enzymatic reactions (Kreb's cycle) into carbon (IV) oxide, energy and water as the end products.

In this reaction shown above, one molecule of glucose yields 38 molecules of ATP. For the above process to be maintained in the living cells, the following conditions are necessary:

- The cells must be provided with glucose or food.
- Oxygen must be taken in and react with the glucose.
- There must be respiratory enzymes to catalyse the reaction.
- Favourable temperature should be maintained for efficient enzyme functioning.
- The end products of the reaction i.e. carbon (IV) oxide, water and energy must be constantly removed from the mitochondrion.

Anaerobic Respiration in Plants and Animals

Anaerobic respiration is the process by which food substances such as glucose are broken down without using oxygen. It takes place in the cytoplasm. The glucose is not broken down completely into carbon (IV) oxide and water to release energy, as is the case of aerobic respiration. Instead, an intermediate compound, alcohol in plants and lactic acid in animals, is produced. The incomplete breakdown of glucose result into production of less energy than in case of aerobic respiration breakdown of glucose is complete. The process of anaerobic respiration is summarised as shown below.

(i) In plants

$C_6H_{12}0_6 \longrightarrow 2CH_5OH + CO_2 + Energy$

Glucose → Ethanol + Carbon (IV) oxide + Energy

(ii)In animals

$C_6H_{12}O_6 \longrightarrow 2C_3H_60_3 + Energy$

(Glucose) (Lactic acid)

In the absence of oxygen, most plant and animal tissues can respire anaerobically for a limited period. It is essential, however, that they get rid of the end products (lactic acid in animals and in plants ethanol and carbon (IV) oxide) immediately. This is because these end products become toxic to the organism if they are left to accumulate within the cells.
Anaerobic respiration that results in the accumulation of alcohol is referred to as **fermentation.** Fermentation occurs when bacteria or yeast break down simple sugars into energy, carbon (IV) oxide and alcohol Some bacteria break down alcohol into ethanoic acid through anaerobic respiration.. Similarly the break down of sugar in milk by bacteria results in the production of energy and lactic acid which causes milk to become sour.

'Oxygen Debt'

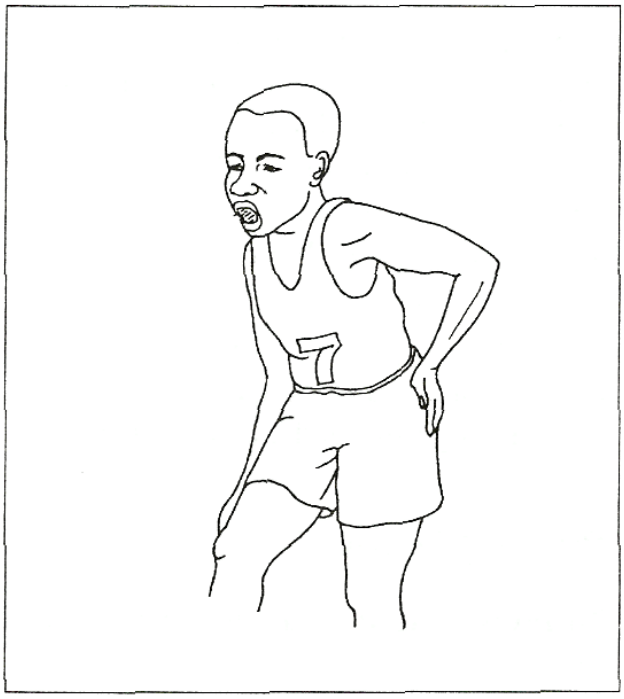


Figure: 4.8 Oxygen debt in a painting athlete

This is the oxygen required to get rid of the lactic acid that accumulates in the body tissues when the supply of oxygen is less than the demand. Under these conditions, the animal tissues respire through anaerobic respiration and this causes lactic acid to accumulate in the muscles. The lactic acid might cause fatigue and result in muscle crumps. Another example of anaerobic respiration in animals is when a short distance runner or diver holds his or her breath while running or diving. The oxygen debt incurred here is "paid" back by the person breathing more quickly and more deeply in order to increase the supply of oxygen during the recovery period after the race. Figure 3.4 shows a panting athelete.\

During the process of paying back the oxygen debt, the lactic acid is oxidised to carbon (IV) oxide, water and energy when oxygen is available or it is taken to the liver and converted into glycogen.

Application of Anaerobic Respiration in Industries and at home

Man has applied the knowledge of anaerobic respiration in his everyday life for a long time with limited understanding of the physiology of the process. Products of fermentation such as alcohol, wines, yoghurt and cheese are some of the examples. In Kenya, bread baking industry uses yeast and so is the beer brewing and distillery industry. Power alcohol used as a substitute for petrol is produced through fermentation. The production of vinegar (ethanoic acid) citric acid, oxalic acid, butyric acids and some drugs also depends on fermentation. These chemicals are of great commercial value. The type of alcoholic drink produced by fermentation depends largely on the nature of the sugar solution used. For example, fermentation of apple juice produces cider, grape juice produces wine, and malt extract from germinating barley produces beer. Distillation of some of the products of fermentation gives rise to stronger alcoholic drinks called spirits. For example, distilling wine makes brandy.

Other applications of anaerobic respiration include biogas production for cooking, lighting and making of compost manure.

Comparison between Aerobic and Anaerobic

Aerobic Respiration	*Anaerobic Respiration*
(i) Oxygen is necessary for the process to take place. The use of oxygen ensures a complete combustion or oxidation of the substrate. (ii) High amounts of energy are released hence an efficient way of obtaining energy. The amount of energy released from one molecule of sugar is 2880 KJ. (38 ATP (molecules). (iii) The substrate is completely broken down to carbon (IV) oxide and water. (iv) The end products are water and carbon (IV) oxide which diffuses out of the cells and is excreted before it accumulates in the body to toxic levels. (v) Water molecules are produced. (vi) Over a short period of time, energy is not released faster.	(i) Oxygen is not required hence the substrate is not broken down completely. (ii) Low amounts of energy are released hence it is an inefficient method of obtaining energy. The amount of energy released from one molecule of sugar is 2IOKJ. (2ATP molecules). (iii) The substrate is not completely broken down and as a result lactic acid or alcohol is produced. (iv) The end products are alcohol in plants and lactic acid in animals. Both of these end-products are toxic to cells accumulate in the body. (v) Water molecules are not produced. (vi) Over a short period of time, energy is released faster.

Respiratory Substrates

Respiratory substrates are energy-rich food substances which when oxidised release energy e.g. carbohydrates, fats and proteins. Carbohydrates are the main source of energy in respiration. These are mainly in the form of simple sugars such as glucose, fructose and galactose.

They provide about 17 KJ per gram or 2 898 KJ/Mole when completely oxidised. Whereas plants synthesise their own food substances (cellulose, starch and sugars), animals obtain most of these food substances by feeding on plants. Some of the plant organs rich in these food substances include maize, cassava, rice, fruits, yams, bananas, sweet potatoes, sugar cane and sorghum! Fats produce more energy than carbohydrates or proteins. When one gram of fat is completely oxidised it produces about 38 KJ of energy. Plants synthesise fats and oils and store them in seeds, leaves and fruits. Some animals obtain them by feeding on other animals or animal products. Plants that are rich in fats and oils include sesame, groundnuts, sunflower, coconut, cashew nuts and castor oil seeds. Some of the animal products rich in fats include fatty meat, milk, ghee, cheese and butter. Fats are not the main substrates of respiration because they are not very soluble and therefore are not easily transported to the sites of respiration. It will also require more oxygen to oxidise one gram of fat than one gram of glucose.

Proteins are not normally used in respiration. However, in extreme cases of starvation the cells may use proteins to obtain energy. Proteins are first broken into amino acids. Amino acids are then deaminated (broken down further) and oxidised. One gram of protein produces 22 KJ when completely oxidised. Proteins are mainly found in plant leaves, seeds and fruits. Some of the plants rich in proteins are beans, peas, sunflower, groundnuts, sesame and cashew nuts. Animals obtain proteins by feeding on plants rich in proteins or on other animals or animal products such as lean meat, milk, eggs and cheese.

Respiratory Quotient and its Significance

Respiratory quotient (RQ) is a ratio showing the relationship between the amount of carbon (IV) oxide used against the amount of oxygen used in respiration. Volume of carbon (IV) oxide produced Volume of oxygen consumed

Where carbohydrates such as sucrose and glucose are completely broken down to carbon (IV) oxide, water and energy, the amount of carbon (IV) oxide produced almost balances the amount of oxygen consumed. In this case of complete aerobic respiration of sugars, the RQ ratio is 1.0.

The value of RQ varies with the type of substrates and conditions under which they are respired. RQ can therefore range from less than one to more than one. The respiratory quotients give an indication of the type of substrate oxidised and whether aerobic respiration, anaerobic respiration or both are taking place.

For example, in respiration of fat the RQ is about 0.7. This would mean that the amount of carbon (IV) oxide produced is less than the amount of oxygen used. RQ values for carbohydrates and proteins are 1.0 and 0.9 respectively. A value of less than one indicates higher consumption of oxygen and lower production of carbon (IV) oxide. This would represent anaerobic respiration in which alcohol and carbon (IV) oxide are produced. Respiration quotient also depends on age, temperature of the surrounding and state of health of the organism.

4.8. Factors affecting the rate of respiration

Factors that affect the rate of respiration also affect the energy requirements in organisms. (Refer to chapter five of students' book one).

Study this Question

State five factors that affect energy requirements in organisms. Other factors include:

1. Oxygen Concentration

Respiration is affected by the amount of oxygen available in the tissues. When the amount of oxygen is low the rate of respiration slows down. When the amount of oxygen is high, the rate of respiration increases. In diving animals the oxygen concentration in their environment is low. Hence, soon after they dive, the cardiac frequency drastically decreases (bradycardia) and the arterioles of al 1 the vital body organs constrict so that oxygen can be delivered to the vital organs that cannot endure oxygen deprivation e.g. the brain and the heart.

As a result of this, less oxygen reaches other body tissues and organs hence their respiration rate reduces.

2. Substrate concentration

The. primary respiratory substrate in the tissues is sugar. When sugar concentration increases the rate of respiration also increases. The reverse is also true,

3. Hormones

Certain hormones in the body such as adrenaline and thyroxine are known to increase respiratory activities.

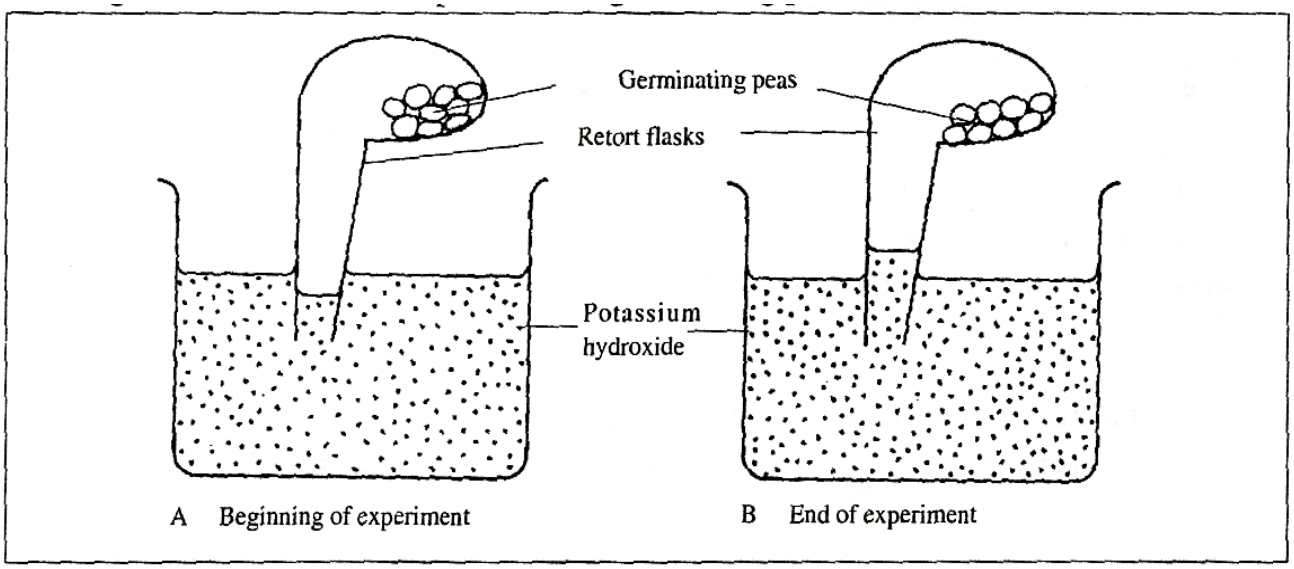
4. Surface area: Volume ratio ^Body size)

The surface area to volume ratio affects the rate of respiration. If the surface area to volume ratio is high, the organism would lose more heat energy. As more energy is lost to the surrounding more will be required to replace the lost energy hence higher rate of respiration.

Revision Questions

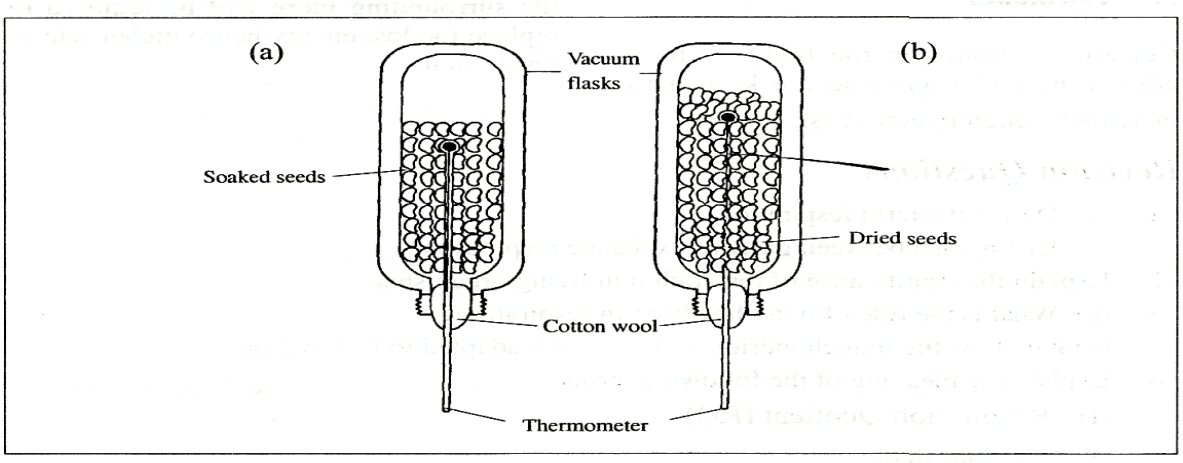
1. What is meant by the term gaseous exchange? Name the gas exchanged?
2. Explain why the respiratory surface has to be: (a) thin, (b) moist.
3. Describe the structure and function of respiratory organs?
4. Explain briefly the mechanism of breathing
5. State the factors affecting the rate of breathing in humans?
6. Name four diseases of the respiratory system? State their treatment and control?
   (a) Define the term respiration.
   (b) Distinguish between gaseous exchange and respiration.
8. Explain the significance of respiration in living organisms.
9. (a) What is the role of mitochondrion in respiration?
   (b)State how the mitochondrion is structurally adapted to its function.
10. Explain the meaning of the following terms:
    (i) Respiration Quotient (RQ).
    (ii) Oxygen debt.
    (iii) Basal metabolic rate (BMR).

11. Describe what happens in the two phases of aerobic and anaerobic respiration.
12. What is the economic importance of anaerobic respiration in industry?
13. (a) List the differences between aerobic and anaerobic respiration.
    (b) What is the significance of anaerobic respiration?
    (c) Give examples of food in your community which provides us with a lot of energy.
14. Figure 3.6 illustrate an experiment on germinating peas.



(a) (i) What changes are observable at the end of the experiment in figure 3.6 (b)? Explain the change,
(ii) What chemical change is taking place in the germinating peas?
(b) If water had been used instead of potassium hydroxide solution in the experiments, what would be observed?

15. A student set up an experiment using soaked and dry seeds as shown in figure 3.7.



(a) State the objective of this experiment and the observations made after 24 hours.
(b) Account for the observations made in (a) above.
(c) Suggest why vacuum flasks were used in the experiment.
(d) What alteration would you make in the set-up to make the results more reliable?

16. In an experiment on respiration, the rate of carbon (IV) oxide production in pea seedlings was recorded under different temperature, as shown in the table below.

Temperature			*Volume of CO produced (cm^3)*				
Time	Ohr	Ist hr	2nd hr	3rd hr	4^{Ih}hr	5th hr	6th hr
30^{D}C	0.0	9.0	13.0	20.0	21.5	23.0	24.5
35°C	0.0	8.0	16.5	25.0	25.5	26.5	27.0
40°C	0.0	12.0	23.5	30.0	26.0	18.5	10.0

a. Using the same axes, plot graphs to show carbon (IV) oxide production at each temperature against time. Let time be on the horizontal axis.
b. What is the optimum respiration temperature for this experiment? Explain how the answer is arrived at.
c. Suggest reasons for the shape of the graph when temperature was maintained at 40°C.

CHAPTER FIVE
EXCRETION AND HOMEOSTASIS

5.1 Introduction

Excretion is a process by which living organisms separate and eliminate waste products formed during metabolic processes, from their bodies. These waste products include carbon (IV) oxide, nitrogenous wastes, excess water, mineral salts, tannins, quinine and resins. If these substances were left to accumulate in the cells or in the tissue fluid surrounding the cells, they would become poisonous or toxic to the cells. This would also alter the conditions under which cells function efficiently, leading to their death. It is therefore necessary to remove these waste products as quickly as they are formed in order to provide a suitable working environment for the cells.

A suitable working environment for cells can be established if the waste products and excess substances are kept at very low and narrow ranges within and around the cells. Metabolic processes apart from producing these substances, release energy some of which is in form of heat and therefore alter body temperature. Others, such as acidic and alkaline substances alter the pH of body fluids. All these factors have adverse effects on the metabolism of the body. Organisms therefore, have a self-adjusting mechanism called **homeostasis** that functions to maintain a steady state in the internal environment of living organisms in order to provide optimum conditions for body metabolism.

Excretion, egestion and secretion are terms that denote processes of releasing substances in or from the bodies of living organisms and therefore require to be understood. **Egestion** is a process that results in the removal of undigested materials from food vacuoles or alimentary canals of animals. The undigested food materials which may not have entered into cells, to take part in metabolism may be released as solid remains from the body. However, the digested food materials which enter the body tissues are broken down. The waste products formed are removed from the body by excretion. On the other hand, secretion is the release of certain useful substances produced by cells. Such substances include hormones, enzymes, oxalates, sebum and mucus.

Plants and animals have various methods of disposing of waste products and those methods involve diffusion and evaporation from the body.

5.2. Excretion in Animals

Excretion in animals is carried out by elaborate systems made up of specialized tissues and organs. This is because their bodies are complex and have greater number of cells, such that simple diffusion would not suffice as a method of excretion. The excretory tissues and organs include **flame cells** of platyhelminthes, **ncphridia** of annelida, **malpighian tubules** of insects, **gills, lungs, liver** and **kidneys** of vertebrates. These organs are specialised to function in different environments such as aquatic (marine and fresh water) and terrestrial.

5.3. Excretion in Mammals

The main excretory organs in mammals such as human beings are lungs, kidneys, skin and liver. These organs are discussed in greater detail in the sub-topics that follow this.

5.4. Structure and function of mammalian skin

This is the largest body organ as it covers the whole body surface and even continues into many body openings like nostrils, mouth and ears. The main functions of the skin are:

a. Protection of the underlying tissues from entry of micro-organisms, physical damage and ultra violet rays from the sun.
b. Regulation of body temperature.
c. Excretion of salts, excess water and traces of urea.
d. Reception of stimuli of heat, cold, pain, touch and pressure.
e. Synthesis of vitamin D.
f. Storage of fat.

The skin is composed of two main layers. These are the upper layer called the **epidermis** and the inner layer called the **dermis.** See figure 5.1. The epidermis is made up of three other layers that are discussed later.

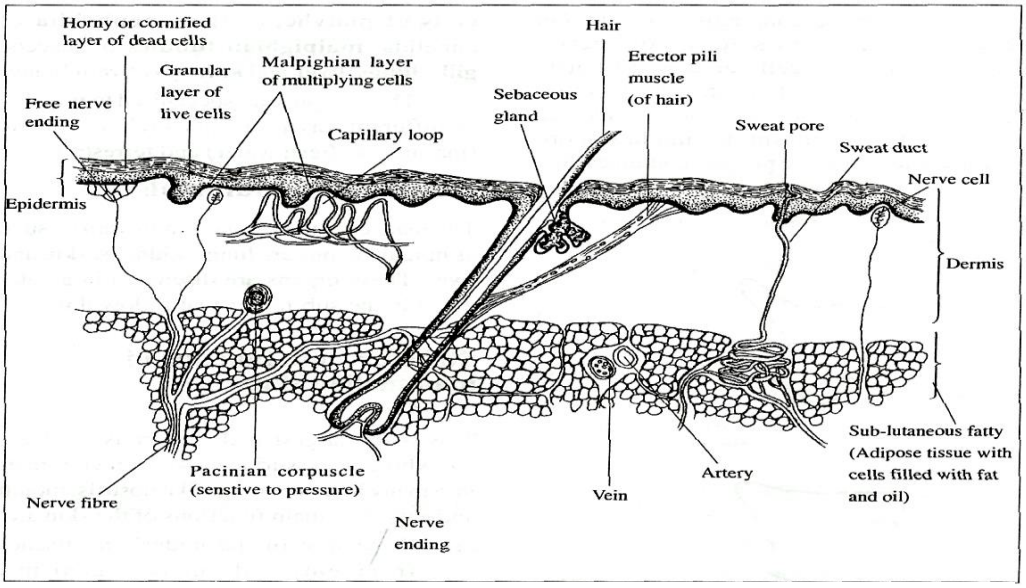


Figure: 5.1 Structure of mammalian skin

1. **The malpighian layer:** It is the innermost of the epidermal layers and is made up of actively dividing cells that give rise to a new epidermis. The cells have pigment granules called **melanin** that gives colour to skin and also give protection against harmful ultraviolet rays from the sun.
2. **Granular layer** is the middle layer of epidermis and consists of living cells that have granules. It gives rise to the cornified layer.
3. **Cornified layer** is the outermost layer. It is made up of flattened dead cells that become filled with a tough flexible substance called **keratin.** This layer is very important because it provides protection against mechanical damage and invasion of bacteria. It also reduces loss of water by evaporation. Cells of this layer are continuously lost through friction and replaced from beneath by granular layer. Its thickness varies in the body, for example, it is thickest in areas of high friction like palms of hands and soles of feet but thinnest on lips and eyeballs.The dermis is comparatively thicker than the epidermis. Many structures such as blood vessels, nerve endings, lymphatic vessels, sweat glands and hair follicle are found in the dermis.

4. **Blood vessels and lymphatic vessels:** Blood vessels contain blood that supplies nutrients and oxygen to skin tissues and remove waste products and carbon (IV) oxide. Blood also helps in temperature regulation. Lymphatic vessels drain excess tissue fluid.

5. **Nerve endings:** The nerve cells which detect changes from the external environment thus creating awareness within the body of changes in temperature (cold and heat), pressure and touch.

6. **Sweat glands** are made up of a coiled tubule of secretory cells which extend into long tubules that opens on the surface of the skins as sweat pores. The secretory cells in the coiled tubule absorb excess water, mineral salts, traces of urea, lactic acid and carbon (IV) oxide from the surrounding blood vessels and tissues. These substances are secreted into the tubule lumen to form sweat, which flow through the sweat duct to the skin surface. Sweat glands are involved in body temperature regulation through loss of excess heat by evaporation of water.

7. **Hair** originates from a deep infolding of the epidermis that forms **hair follicle.** The hair follicle is lined with granular and malpighian layers of epidermis. At the base of the hair is a dermal or hair papilla from which hair root develops. The hair follicle is supplied with sensory nerve to increase sensitivity of the skin and blood vessels for supply of nutrients and removal of waste products. Each hair is made up of a base called hair root and hair shaft which protrudes outwards. "Growth" of the hair is due to continuous addition of new dead cells at the base of the hair. Erector pili muscles are attached to the follicle at one end and on the other end to the epidermis. These muscles undergo contraction and relaxation to alter the angle between the hair shaft and skin and therefore vary the amount carbon (IV) oxide. Blood also helps in temperature regulation. Lymphatic vessels drain excess tissue fluid.

5.5. Structure and Function of the Kidney

The kidneys are important organs in the body whose functions are excretion, osmoregulation, ionic balance and regulation of PH. A mammal has a pair of kidneys located in the lumbar region of the dorsal part of the abdominal cavity. They are bean-shaped and dark red in colour. The right kidney is more anterior than the left. Above each Kidney are the adrenal glands that secrete hormones. A kidney is convex on one side and concave on the other side. The concave side has a depression called **hilum** through which enters a renal artery to supply blood and renal vein to remove blood. From the hilum also leaves a large thick walled tube called ureter that links the kidney to an elastic thin-walled urinary bladder. The ureter transports urine from the kidney to the bladder, which temporarily stores the urine. When the urinary bladder is full, sphincter muscles located at the base of the bladder relax and urine is released via the urethra. In males the urethra is long and is joined to the reproduction system unlike in females. See figure 5.2.

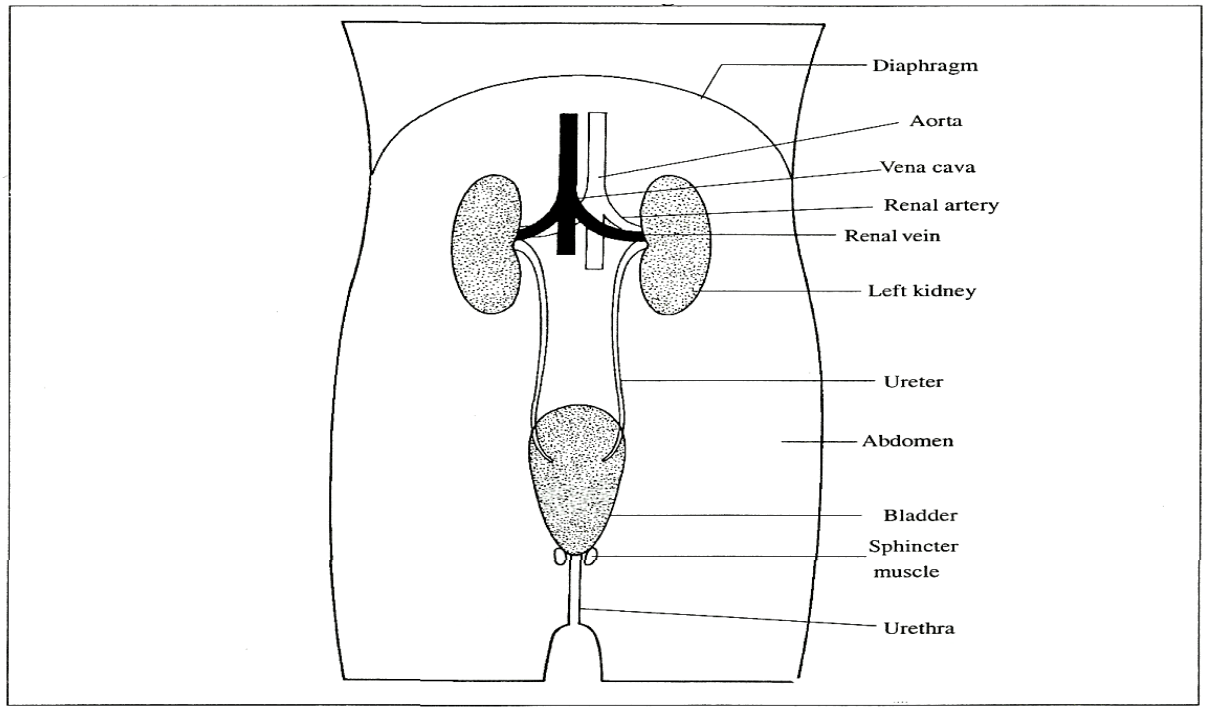


Figure: 5.2 A generalized urinary system of a mammal

A longitudinal section of mammalian kidney shows three distinct regions which include cortex, medulla and pelvis. The cortex which is dark red in colour is placed to the inner convex surface. The medulla which is red in colour, lies towards the centre of the kidney and extends, in form of conical structures called pyramids. These pyramids open into swollen cavity called pelvis. The pelvis, which is whitish in colour, narrows to form the ureter. The human kidney contains urinary tubules known as nephrons. A human kidney contains about five million nephrons. See figure 5.3 (a) and (b).

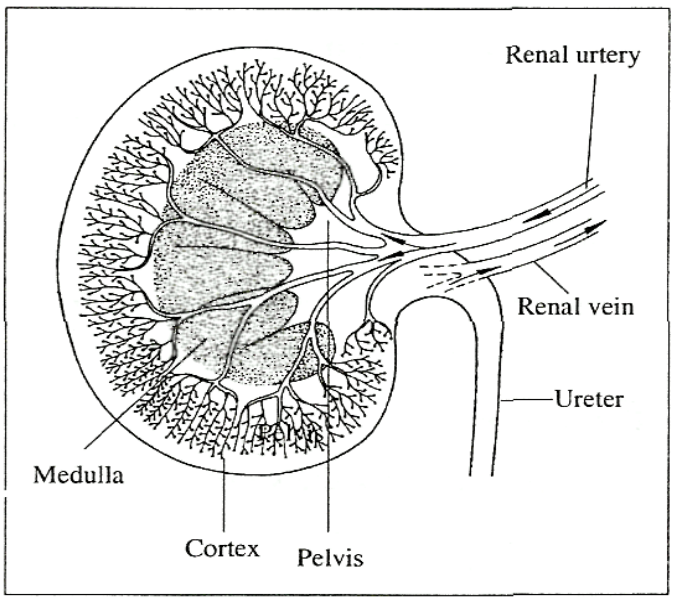


Figure: 5.3 (a) Longitudinal cross-section of a mammalian kidney

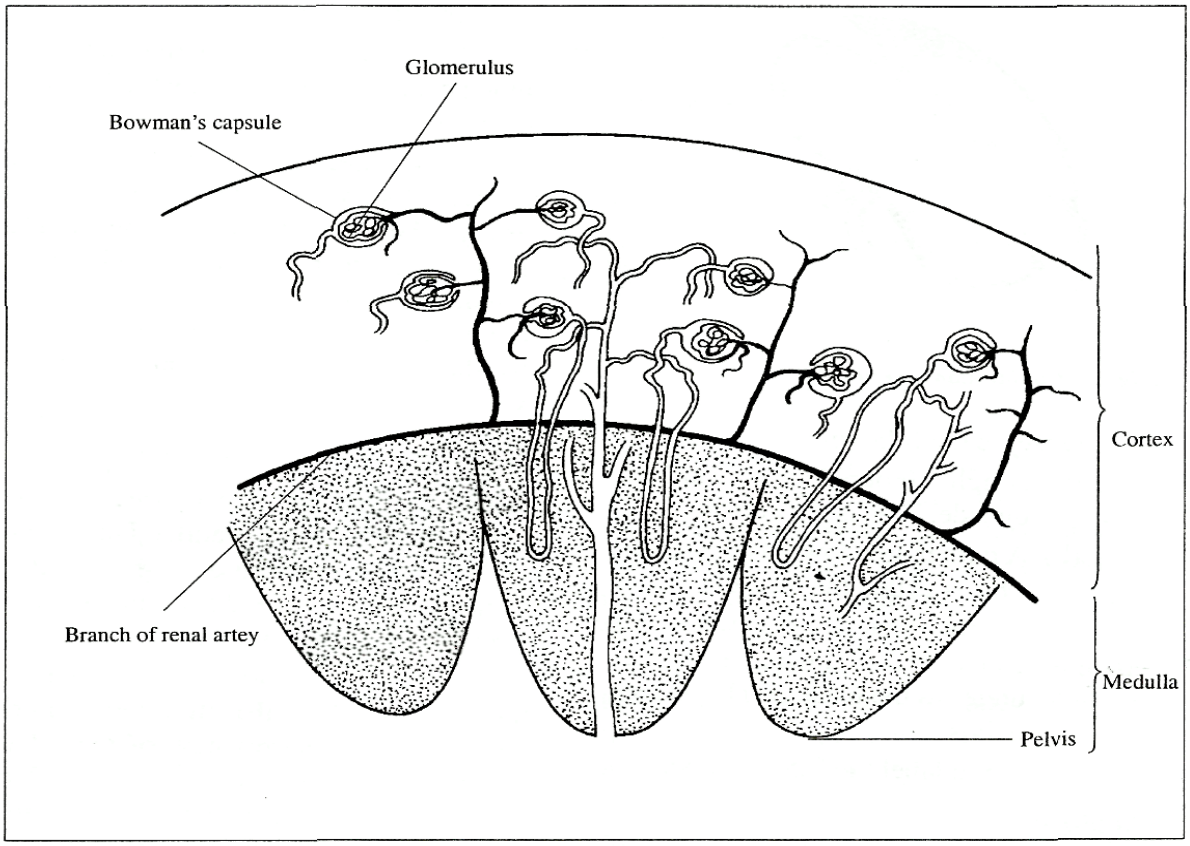


Figure: 5.3 (b) Section through cortex and medulla

Practical Activity

To observe the structure of a mammalian kidney

Requirements

A mammalian kidney e.g. goats' or any other available ones and a scalpel

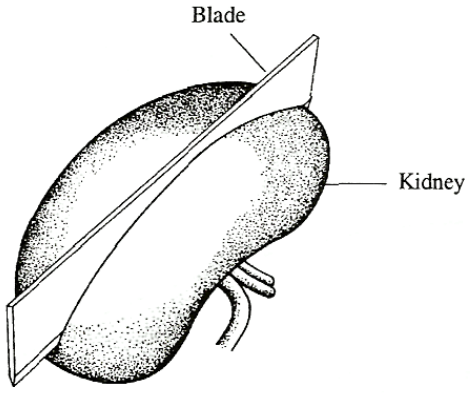


Figure: 5.4 Cutting kidney vertically

Procedure

1. Observe the kidney provided.

2. Draw and label the kidney showing external features.

3. Using a scalpel, slice through the kidney vertically as shown in figure4.5.

4. Observe the following:

   a. A light-coloured area towards the outside. This is the cortex.

   b. A darker area towards the inside. This is called the medulla.

   c. A light-coloured cavity where urine collect before flowing down the ureter to the bladder. This is the pelvis.

5. Draw and label the L.S of the kidney.

Nephron

A nephron is the basic functional unit of the kidney. See figure 5.5.

Each nephron is made up of two main parts namely a **renal tubule and glomerulus.** A renal tubule has five main parts whose structure and functions are different. These are:

(i) **Bowman's capsule,** a thin double walled and cup-shaped structure.
(ii) **Proximal convoluted tubule** that is coiled and extends into a U-shaped part.
(iii) **Loop of Henle.**
(iv) **Distal convoluted tubule,** which, is coiled and leads into a collecting tubule.
(v) **Collecting tubule** drains into a collecting duct into which collecting tubules from several nephrons drain thus forming an outlet of urine through a pyramid into the pelvis. The glomerulus is a fine network of blood capillaries enclosed by the Bowman's capsule.

A glomerulus is formed from the afferent blood vessel, a branch from the renal artery. The efferent arteriole collects blood from the glomerulus and extends to renal tubule where it divides into capillaries that ramify the tubule. This blood is then collected by the venules that join into the venous system.

Role of Nephron in Excretion

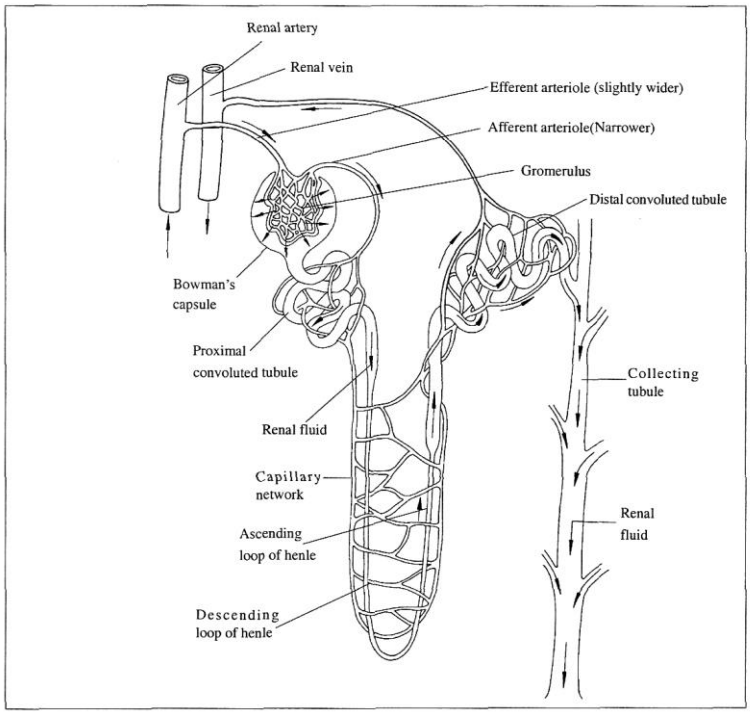


Figure: 5.5 The structure of the kidney nephron

Kidneys receive blood from the renal artery, a branch of the dorsal aorta. This blood is rich in nitrogenous wastes e.g. urea. It also contains dissolved food substances, plasma, proteins, mineral ions, hormones and oxygen. The afferent arteriole entering the glomerulus is wider than the efferent arteriole leaving it. The narrowness of the efferent arteriole produces both resistance to blood flow and back pressure which create extremely high pressure in the glomerulus. Secondly the renal artery branches directly from the dorsal aorta whose blood flow is at high pressure. These builds up high pressure within the glomerulus. Due to this pressure the liquid part of the blood and dissolved substances of low molecular sizes including urea, glucose, salts and amino acids are forced out of the glomerulus into the cavity of the Bowman's capsule. Large sized molecules in the plasma such as proteins and blood cells are not filtered out because the walls of capillaries of glomerulus and Bowman's capsule have very small pores. Hence the blood which remains is rich in plasma proteins and has little water. This process is known as **ultrafiltration** and the filtrate formed is called **glomerular filtrate.** The filtrate then flows from the capsular space into the proximal convoluted tubule of the nephron. As the filtrate flows along the renal tubules, most of the

filtered substances in the glomerular filtrate, useful to the body are selectively reabsorbed back into the blood. In the proximal convoluted tubule, all the glucose, amino acids, some water and mineral salts are actively reabsorbed against a concentration gradient - a process that requires energy. For efficient reabsorption the proximal convoluted tubule is adapted in the following ways:

(i) Cells lining the tubule have numerous mitochondria which provide the necessary energy in form of ATP.
(ii) Cells of the tubule have **microcilli** which increases the surface area,
(iii) The tubule is long and highly coiled to provide a large surface.
(iv) (iv) The coiling of the tubule reduces the speed of the flow of the filtrate thereby giving more time for efficient reabsorption.
(v) The tubule is well supplied with blood capillaries.

The **loop of Henle** forms an area where salts especially sodium chloride are reabsorbed into the blood. The U-shaped loop is generally longer and has a **counter current flow** established between the flow of filtrate and the large supply of blood in vessels. Active transport is involved in the reabsorption of sodium salts. To regulate the intake of sodium salt, a hormone called **aldosterone** is secreted by adrenal glands. Low content of salt in blood stimulates adrenal glands to secrete more aldosterone hormone and therefore more salt is reabsorbed from the filtrate and vice versa.

When the filtrate reaches the distal convoluted tubule, a controlled amount of water is reabsorbed into the blood by osmosis. This process is enhanced in two ways, first being due to the active intake of sodium salt into the blood at the loop of Henle which increases the osmotic potential of the blood. The second factor involves a hormone known as **antidiuretic hormone** (ADH). This hormone is secreted by the pituitary glands. Antidiuretic hormone increases the permeability of the tubule and blood capillaries to water. When there is excess water in the body for example, as a result of excessive intake of fluids, the osmotic potential of the blood falls causing the pituitary gland to reduce its secretion of ADH into the blood. Water reabsorption in the tubule is thereby reduced and results in the production of large amounts of dilute urine. If, for example, the body has lost excessive water through sweating, thereby raising the blood pressure, the pituitary gland will release more ADH which results in increased water reabsorption from the tubule into the blood. This results in the production of little amounts of concentrated urine.
It should also be noted that the distal convoluted tubule has some modifications similar to those found in the proximal convoluted tubule, that is, a large surface area, being surrounded by many blood capillaries and having a wall one cell thick.
The filtrate in the collecting tubule becomes urine and trickles down into the collecting duct where it joins urine from the collecting tubules of other nephrons. The urine then flows into the pelvis via the pyramid and is finally emptied into the urinary bladder through the ureter.

About 1 to 2 litres of urine trickles into the urinary bladder in a day. In the urinary bladder, about 250 millilitres of urine will initiate the urge to urinate. The sphincter muscles relax and the urine is passed out. The resultant urine composition of a healthy person may be as follows:

Water	95%
Urea	2%
Uric acid	0.030%
Creatinine	0.1%
Salts of Na^+, K^+, Cl~ $(PO_4)^3$	1.4%
Ammonia	0.04%
Proteins	0.0%
Glucose	0.0%

The quantity and concentration of urine in animals is affected by terrestrial, aquatic, desert conditions, the physiological and the structural adaptations of the animals. For instance, in a desert rat, water reabsorption is maximised by the development of a long loop of Henle.

Study these Questions

1. Explain why glucose and proteins are absent in urine.
2. Describe how to test for the presence of glucose and proteins in urine.
3. Explain the significance of the following with respect to habitats:
   (a) A long loop of Henle.
   (b) Presence of few glomeruli in mammalian kidney.

5.6. Kidney Diseases and Disorders

Nephritis

Nephritis is the inflammation of glomerulus of kidney caused by bacteria or associated infections such as small pox, measles, typhoid fever and sore throat.

Symptoms and signs

Headaches, fever, vomiting, oedema, general weakness, passing out of highly coloured and turbid urine due to presence of proteins.

Treatment and Control

(i) Dietary restrictions especially salts and proteins,
(ii) Administration of drugs.

Kidney Stones

There are various causes

(a) Improper balance of diet, lacking of certain vitamin and inadequate intake of water.
(b) Chemical salts in urine e.g. oxalates, phosphates, urates and uric acid. These may undergo precipitation and form hard deposits or stones in pelvis, ureter hence cause blockage of urine.

Symptoms

1. Increased frequency in passing out urine.
2. Pain and soreness in upper back side.
3. Pain, chills and fever.

Control and Treatment

a. Consult a physician.
b. Take balanced diet with plenty of water.
c. Take hot baths and massage the back with hot soft material,
d. Surgical treatment which may involve kidney transplant.
e. Dialysis or artificial washing out of the wastes.
f. Use of laser beams to disintegrate the stones.

Albuminuria (Protein in Urine)

This disorder is also known as **proteinuria.** It is a condition in which protein, mainly albumen is found in urine. This is due to increased permeability of glomerular capillaries which may be caused by bacterial infection.

Symptoms and signs

Fluid accumulation in tissues (oedema). It is fatal if not treated.

Kidney Failure

In situations where a kidney fails to function, the person can still lead a normal life using the other kidney. However, if both kidneys malfunction the individual will still survive if treated promptly. Such treatment can be administered in two forms. These are:

(a) Kidney dialysis.
(b) Kidney transplant.

5.7. The Liver and its Structure

The liver is the second largest organ after the skin and is a special organ of excretion because many excretory products are produced by it. It lies immediately beneath the diaphragm and is made up of several lobes. It receives more blood per unit time than any other part of the body other than the heart. It receives blood from two blood vessels, namely the hepatic portal vein and the hepatic artery. Blood flows out of the liver through the hepatic vein.

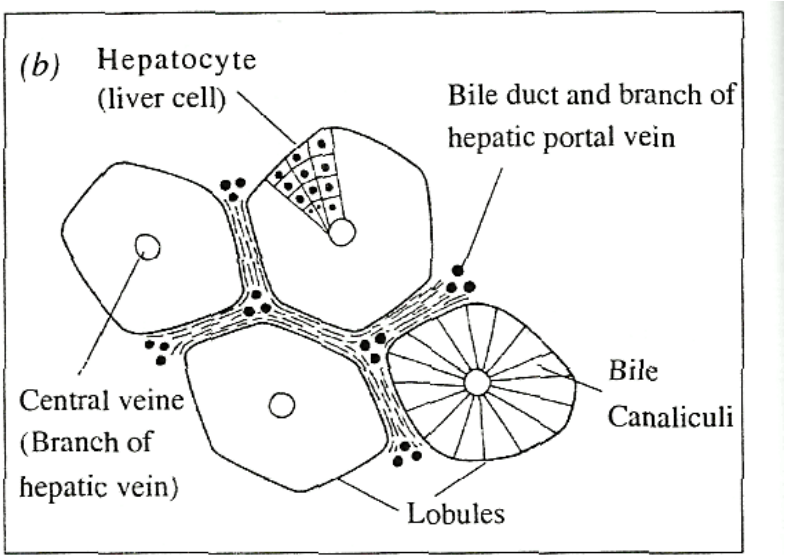


Figure: 5.6 (a) The liver lobules

The liver consists of a large number of **lobules.** Each lobule is made up of many liver cells. The cells are arranged radially around a central blood vessel which is a branch of the **hepatic vein.** The blood supply to each lobule is from two sources, the **hepatic artery** and the **hepatic portal vein.** These vessels branch between the liver lobules.

Between the plates of liver cells are channels called **canaliculi** which receive bile. The bile moves outwards to the periphery of the lobules where it collects into bile duct. See figure 5.7 (a) and (b).

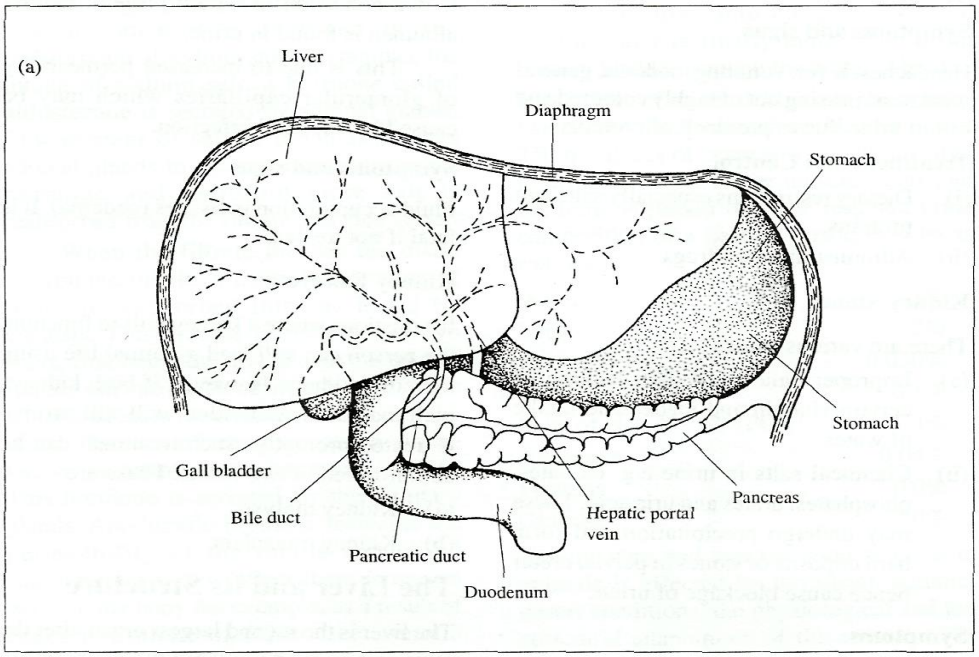


Figure: 5.7 (b) Structure of the liver

The Functions of the Liver

The liver performs many functions that contribute a lot to homeostasis. These are:

Deamination

Amino acids one absorbed from the gut, they are used in synthesis of proteins of the body. Excess amino acids or proteins cannot be stored in the body since the body does not have a mechanism for such storage. Excess amino acids not used, are broken down in a process **of deamination.** In this process the amino group (NH_2) of the amino acid is removed and used to form ammonia. The ammonia is taken into the omithine cycle which is a series of reactions resulting to the formation of urea, a less toxic substance than ammonia. The process is summarised as shown in the equation at the bottom of the page: The urea formed is released into the blood stream and is eventually passed out in the urine through the kidney.

Detoxification

Some of the metabolic activities of the liver result into the production of toxic substances which if left to accumulate, would destroy or harm the tissues of the body. The liver also receives harmful substances by way of drugs, food or drinks. It therefore makes these substances harmless and eliminate the substances in .harmless forms in a process called **detoxification.** The liver cells through oxidation, reduction, and combination with other substances carry out this process of detoxification. For example, hydrogen peroxide produced by actively respiring cells is broken down by enzyme **catalase** to form water and oxygen which are harmless. This enzyme is found in the liver. (You will investigate this aspect in Practical Activity 4).

Thermoregulation

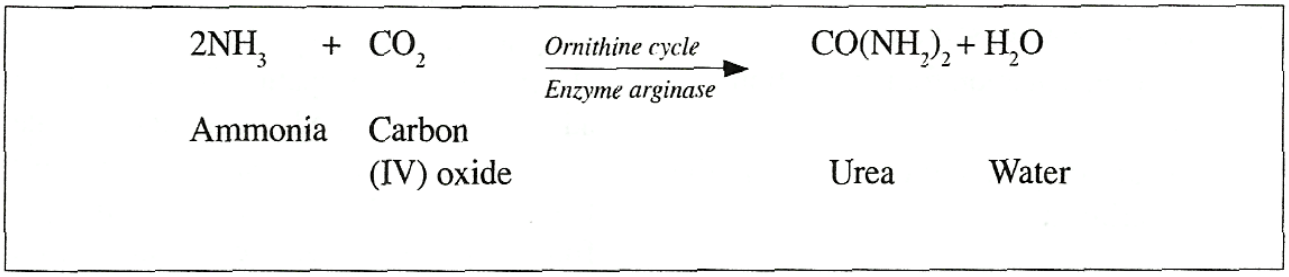
The liver carries out many metabolic reactions some being endothermic while others are exothermic. Under conditions of low temperature the hypothalamus sends impulses to liver to increase exothermic reactions producing more heat that is distributed throughout the body by the blood.

Haemoglobin Elimination

Haemoglobin from worn out red blood cells is also broken down in the liver and the residual pigments urochrome which give urine a yellow tinge is eliminated by the kidney, bilirubin excreted via bile juice into alimentary canal.

Regulation of Plasma Proteins

Plasma protein are important components of the body. Majority of them are synthesised from amino acids in the liver. These include albumin, fibrinogen, prothrombin and antibodies. Many of these are involved in regulatory mechanism of homeostasis. Digesting and deaminating excess proteins also regulate their quantities. Erythrocytes have a life span of about 120 days after which they are taken to the liver where they are broken down. Haemoglobin is broken into a haem group and globin. Globin is digested into amino acids and enters the amino acid pool while the haem group is changed in biliverdin and bilirubin and taken to gall bladder. These are later released into the gut
as bile and then passed out through faeces. These two substances give faeces its characteristic brown colour. Other functions of the liver include the manufacture of red blood cells during the foetus stage, formation and elimination of excess cholesterol which is an important component cell membrane, regulation of fat metabolism, storage of blood, storage of vitamins B, C, E, K and minerals.



The other major function of the liver is blood sugar regulation. This will be discussed under homeostasis.

5.8. Liver Diseases and Disorders Liver Cirrhosis

This is the contraction and hardening of the liver due to death of liver cells. A fibrous tissue replaces the dead cells. The disease is caused by ingestion of toxic chemicals such as alcohol, attack by either bacteria or virus and liver parasites.

Symptoms are slow in development and are normally seen when the disease is at advanced stages. These symptoms include body weakness, loss of weight, indigestion, poor appetite, pain in the upper right quarter of the abdomen and occasional vomiting of bloody material. If a large portion of liver is damaged, death may result.

Control and Treatment

(a) Avoid excess alcohol intake.
(b) Avoid fatty diet.
(c) Take adequate diet and varied easily digestible food.
(d) Have bed rest most of the time.
(e) Low salt intake.
(f) Consult a doctor.

Hepatitis

This is the inflammation of the liver. It is a viral disease and two types are known namely: Hepatitis A and B. Hepatitis A is more common among children and young adults.

It is infectious and is passed from one person to another through contact of body fluids, contaminated food, milk and water. The symptoms appear between two to six weeks. These include loss of appetite, nausea, fatigue, jaundice (yellow of skin) and abdominal pain. Hepatitis B is common in adults. It is transmitted through contaminated injections, instruments and other implements that pierce the skin and lead to exchange of fluids such as blood, semen and saliva.

Symptoms appear between three to four months. Hepatitis B is more serious than A because it is difficult to cure and cause more deaths.

Control

Proper disposal of sewage, vaccination, bed rest, and prescribed diet.

Jaundice

This is characterised by yellowing of the membranes and skin. It results from failure of the liver to excrete all the bile pigments from red blood cell haemoglobin breakdown. The bile pigment accumulates in blood and hence the yellowing of the skin. This happens due to blockage of bile duct or destruction of the liver as in cirrhosis and hepatitis or mass destruction of red blood cells in circulation as in erythroblastosis foetalis.

5.9.Homeostasis

An organism lives in an environment that keeps on changing in many of its factors, for example temperature, availability of water, food and fresh air. Similarly, changes occur in the body of the organism due to the different metabolic activities and the effects brought about by the changing factors in the environment. Many of these changes disrupt biological reactions being carried out in the organism and lead to adverse effects on the health of the organism. A process that adjusts these changes in the body of an organism to optimum standards or levels and therefore brings about a steady state is called **homeostasis.**

To understand the mechanism of homeostasis, there is need to distinguish two aspects of the environment to the organism that is, **internal** and **external** environments.

The external environment is the immediate surrounding of the organism. It may be aquatic or terrestrial. The internal environment is the immediate surrounding of the body cells. It is the tissue or interstitial fluid which surrounds cells in the body. It is formed from blood plasma in capillaries. There are also other factors in the intercellular fluid that tend to fluctuate. These include osmotic pressure, temperature, ionic concentration and pH. These factors that must be kept at steady state or equilibrium in order for the cells to function properly.

Principles of Homeostasis

Various body systems such as circulatory, excretory, endocrine (hormonal) and nervous, work in a co-ordinated way to bring about homeostasis. In order to maintain a state of balance in the internal environment, these systems work on a **feed back mechanism.**

There are two types of feedback mechanisms:

(a) Negative feedback

When a factor in the body such as temperature or blood sugar level drops below or shoots above the normal, it is detected and corrective action is taken. Such an action is either:

(i) An increase in the level if it was dropping or
(ii) A decrease in the level if it was increasing.

The response bringing about such corrective measures is called negative feedback. It restores the condition to normal.

(b) Positive feedback

In positive feedback, a change below or above the normal is not corrected. Instead, what is meant to be corrective action leads to further undesirable change from the normal as illustrated in the figure 4.8 above.

5.10.Role of Hypothalamus in Thermo-regulation

The hypothalamus is a small region between the cerebrum and cerebellum part of the brain. It acts as a thermo-regulatory centre. It has numerous temperature receptor cells which detect the slightest changes in body temperature. The external temperature affecting the body is determined by thermo-receptors in the skin. Thermo-receptors relay the impulse to the hypothalamus through the sensory nerves. The internal temperatures are detected by the hypothalamus as the blood flows in the brain.

The hypothalamus also controls other homeostatic processes e.g. osmoregulation and blood sugar regulation.

Skin and Thermo-regulation

The mammalian skin plays a very important role in thermoregulation. The parts of the skin that are concerned with thermo-regulation are:

Sweat Glands

Some animal possesses sweat glands on their skin. When the body temperature increases, the sweat glands increase the rate of sweat production. Water in the sweat evaporates by absorbing heat (latent heat of vaporisation) from the body and a cooling effect results.

Hair and Erector pili Muscles

When the body temperature lowers the erector pili muscles are stimulated to contract. This makes the hairs to stand erect on the body surface, thus trapping more air. Air, being a bad conductor of heat insulates the body against heat loss by radiation and convection. However, when it is hot the erector pili muscle relaxes, thus trapping little air hence heat can be lost from the body surface.

Blood Vessels

When body temperature lowers blood vessels in the skin constrict (vasoconstriction) and blood is diverted to a shunt system. This reduces blood flow to the skin and more blood is stored in the spleen as an adaptation to lose less heat. Dilation of blood vessels (vasodilation) increases blood flow to the skin encouraging heat loss when body temperature is too high. **Subcutaneous Fat:** Thick subcutaneous fat is a good insulator against heat loss. Animals in cold areas have thick subcutaneous fatty layers for this purpose. Organisms in warm areas have thin fatty layer to encourage more heat loss to environment.

Once the temperature changes are detected by the hypothalamus, the hypothalamus sends impulses to the appropriate responding tissues of the skin that responds as shown in figure 5.8.

One feature characteristic of mammals is that they are **homoiotherms** (endotherms). This refers to the fact their body temperature is maintained at a constant body temperature despite wide fluctuations in the temperature of the external environment. Lower vertebrates and invertebrates have a body temperature that depends much more on the external temperature. Their body.

Temperatures are within a few degrees of that of the environment. These animals are called **poikilotherms** (ectotherms). One major problem facing these animals is how to conserve this heat and maintain an optimum body temperature.

Homoiotherms and poikilotherms gain or lose heat through their body surfaces (skin) by physical processes that include radiation, conduction, convection and evaporation.
Animals regulate their body temperature by behavioural and physiological means.
Homoiotherms regulate their body temperature mainly by physiological activities. These includes, depending on internal sources of heat. Because of this, they are described as **endothermic.** Poikilotherms rely more on heat derived from the environment than metabolic heat in order to raise their body temperature and are described as **ectothermic.**

Metabolic activities of the body are increased to raise heat production when the body temperature is low. These metabolic activities are lowered when the body temperature is to be lowered. Shivering is an involuntary rhythm of contraction of muscles that serves to generate heat during low temperatures. It is initiated by the hypothalamus.

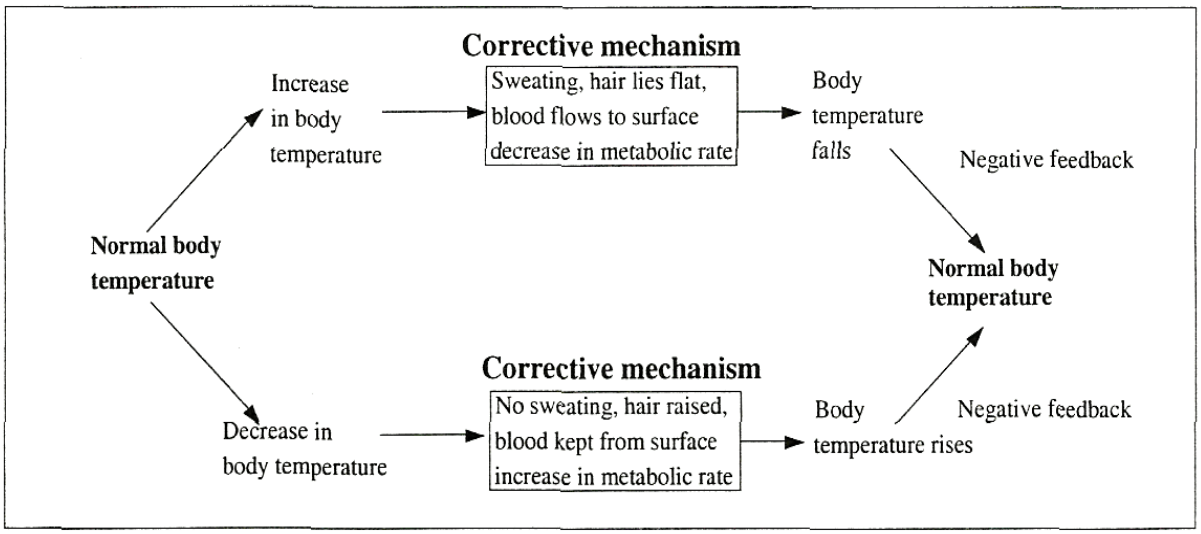


Figure: 5.8 A homeostatic control of body temperature in a mammal

Increased metabolic rate of the liver generates extra heat which is distributed throughout the body.
Insulatory mechanisms also control the extent of heat gain or heat loss through the physical processes of heat transfer. These include hair movements, sweating and dilation or constriction of superficial blood vessels as shown in the flow chart in figure 5.8.

There are many **behavioural activities** that organisms perform in order to regulate body temperature. These are clustering, coiling, putting on heavy clothes, burrowing, basking, migrating, hibernation and aestivation. Migration is seen in many homoitherrns and poikilotherms where there is a movement covering long distances by animals in order to avoid unfavourable climatic factors or food shortage. Other animals **hibernate** (go into deep sleep due to cold conditions) or aestivate (go into deep sleep due to dry and hot conditions) to avoid the harsh environmental conditions.

Ectotherms or poikilotherms have bodies that easily gain or lose heat from or to the enviroment. They will move to environments where temperature is close to their optimum. Lizards and snakes, bask on rocks in order to warm their bodies on cool, sunny mornings. Heat is gained through conduction and radiation. On hot days they move to cooler places in burrows or under shades.

Body size and heat loss

The amount of heat produced by metabolic reactions in an animal body is proportional to its mass. Large animals produce more heat than smaller ones. However, the rate of heat loss from the animal body is directly proportional to its surface area to volume ratio. Large animals have a smaller surface area to volume ratio compared to small animals e.g. the surface area to volume ratio of an adult elephant is about 70 times smaller than that of a rat. This means that each cubic unit of a rat's body has 70 times more area available for heat loss as compared to an elephant. A rat will therefore lose body heat much faster than an elephant.

It follows that in order to maintain a given body temperature, smaller animals will require to raise their metabolic rate to a much higher level than large animals. Therefore the smaller animals require a plentiful supply of food to provide the necessary respiratory substrates.

In addition to the mechanisms outlined above animals also have developed **adaptive features** that help in body temperature regulation. These are structural adaptations which control the extent of heat loss or gain on a long term basis. They include possession of fur or hair and large quantities subcutaneous fat layers as in the polar bear. Desert animals like the camel possess tissues tolerant to high temperatures.

Study Question

4. People in the tropics tend to be thin and tall compared to those in the arctic regions who tend to be short and plump. Account for these observations in relation to body temperature regulation.

5.11. Osmoregulation (Water and Salt Balance)

The relative amounts of water and solutes in the blood, tissue fluid and protoplasm determine their osmotic pressure. If the osmotic pressure of these fluids were to change, drastic events would occur such that metabolic activities of the cells would be hampered. For example, if the osmotic pressure of the tissue fluid falls below that of cells, the cells will take in water by osmosis, swell and may burst. On the other hand, cells would lose water and shrink if the osmotic pressure of tissue fluid was higher than that of the cells. Osmoregulation attempts to maintain an optimum osmotic pressure in the body tissues and fluids that is favourable to normal functioning of cells.

The body gains water through drinking, food taken in and metabolic water and loses through sweat, faeces, urine and exhaled air. These losses and gains produce corresponding changes in the quantities of salts and water. The balance is mainly carried out by the kidney and neuro-endocrine (hypothalamus and pituitary gland) system.

When the osmotic pressure of the blood rises as a result of dehydration, the hypothalamus is stimulated and sends impulses to the pituitary gland which releases a hormone called antidiuretic hormone (ADH) or vasopressin into the blood. On reaching the kidney, the distal convoluted tubules and collecting tubules become more permeable to water which is then reabsorbed into the blood stream. Consequently the osmotic pressure of the blood is lowered and concentrated urine is produced. When the osmotic pressure of the blood falls due to a large intake of water, the pituitary gland is less stimulated. This results to reduced release of ADH into the blood stream. The kidney tubules become less permeable to water and less reabsorption of water into blood stream takes place. The osmotic pressure of blood rises and dilute urine is produced.

5.12.Regulation of Ionic Content

Salts dissolve in water and then undergo dissociation to form ions. For example sodium chloride forms sodium (Na^+) and chloride (Cl~) ions. These ions and many others such as potassium (K*), magnesium (Mg^{2+}), calcium (Ca^{2+}) and phosphates (PO_4^{3}-) are important in body processes like protein synthesis, respiration, nervous co-ordination and muscle contraction. Their balance in body must be regulated within narrow ranges of their optimum concentrations for efficient functioning of these processes.

A hormone called aldosterone, which is produced by adrenal glands, regulates the level of sodium ions. When the level of sodium ions is low in the blood, adrenal glands are stimulated to release aldosterone into the blood which then stimulate loop of Henle of kidney and the gut to reabsorb sodium ion into the blood. If the sodium ions concentration in the blood rises above optimum level, adrenal glands produce less aldosterone into the blood and less amounts of sodium ions are absorbed. It should be realised that as sodium ions are absorbed in the blood, chloride ions follow in order to neutralise the charge on the sodium ions.

Diabetes Insipidus

When the pituitary gland is unable to produce antidiuretic hormone or produces it in inadequate amount, the kidney tubules are unable to reabsorb water from the glomerular filtrate. This leads to production of a large amount of dilute urine (a condition known as diuresis). The patient becomes dehydrated and has to compensate for the loss by drinking a lot of water.

5.13.The Role of the Skin in Salt and Water balance

Although the skin is not the main organ of osmoregulation, it has sweat glands which secrete waste products of metabolism such as water, mineral salts especially sodium chloride. These wastes are lost in form of sweat through the pores in the skin.

About 99% of the sweat is water while the remaining 1 % is mainly mineral salts. The water and mineral salts lost in the sweat contribute to osmotic changes of the body cells and fluids. On a hot day, the body loses a lot of water and some mineral salts, resulting in a sensation of thirst being felt due to tissue dehydration. The osmotic balance is, however, restored by drinking large volumes of water, and intake of mineral salts in the diet.

5.14.Regulation of Blood Sugar Level

All sugars, gaJactose and fructose taken to the liver from the alimentary canal by hepatic portal vein are converted to glucose. Glucose is then broken down to release energy and excess is converted to glycogen and stored in the liver or converted into fats and stored in adipose tissues. Some glucose flows in the general circulation of blood and is maintained within a narrow range of 90 to 100 mg per 100 cm^3 of blood. Fluctuations do occurdueto large supply or increased utilisation of glucose.

The liver carries out the control of these events through two hormones produced by the **pancreas. Insulin** and **glucagon** are the two pancreatic hormones produced by the interstitial cells of the pancreas in the **islets of langerhans**and released into the blood stream. Their effects are carried out in the liver. Functions of insulin in many cases are antagonistic to those of glucagon. For example, high concentration of insulin in the liver converts excess glucose to glycogen for storage, inhibits change of glycogen to glucose, converts glucose into fats and increases breakdown of glucose to release energy. Glucagon at high concentration increases breakdown of glycogen into glucose, also fats, proteins and amino acids to glucose. Generally insulin tends to lower glucose concentration in the blood while glucagon increases it. It also means that a low sugar content in the blood stream stimulates pancreas to release glycagon an

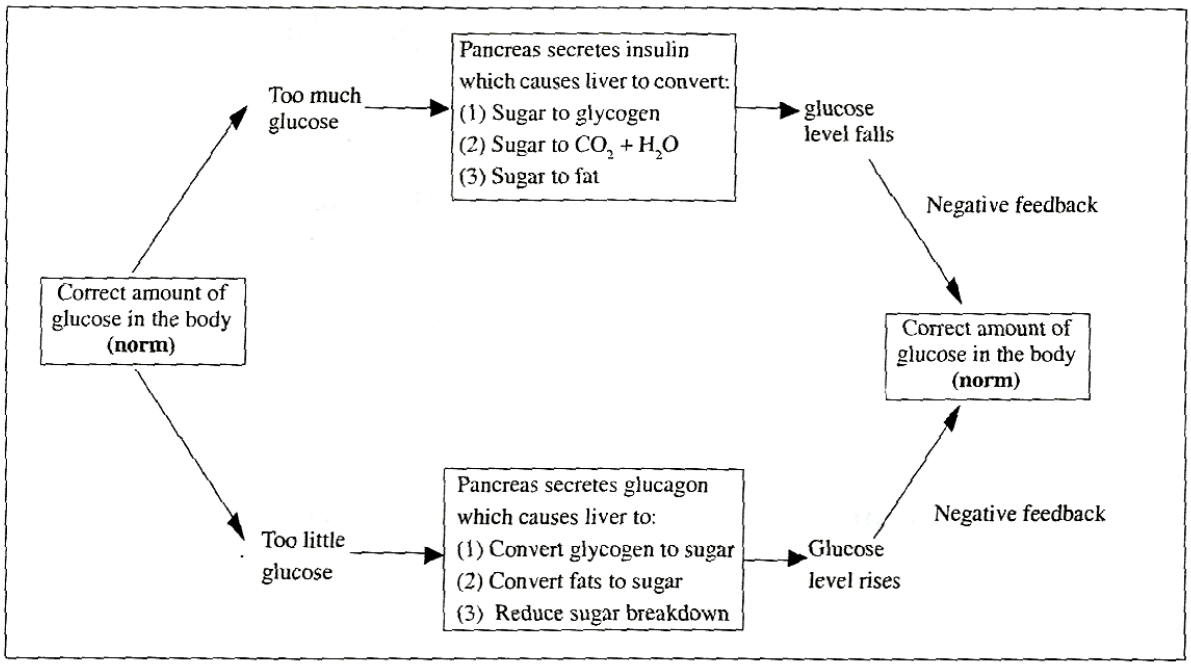


Fig. 5.9: Homeostatic scheme showing the regulation of blood sugar level by hormones

A summary of the mechanisms involved in regulation of blood glucose by insulin is given in the figure 5.9.

Another hormone that has homeostatic effect on glucose is adrenaline produced by adrenal glands. When in high concentration it causes increased hydrolysis of glycogen and this results in increase in blood sugar. This hormone is released during emergencies to increase available glucose for respiration and release of energy for the emergencies.

Diabetes Mellitus (Sugar Disease)

It is due to a deficiency in insulin secretion from the pancreas. The malfunctioning of the pancreas not to release or release inadequate insulin could be hereditary or caused by a disease. This leads to very high levels of sugar in the blood that cannot be utilised by cells hence it is eliminated by kidney. Excretion of glucose is accompanied by frequent passing of urine, loss of water, feeling of thirst and therefore large intake of water.

Diabetes mellitus is characterised by the following:

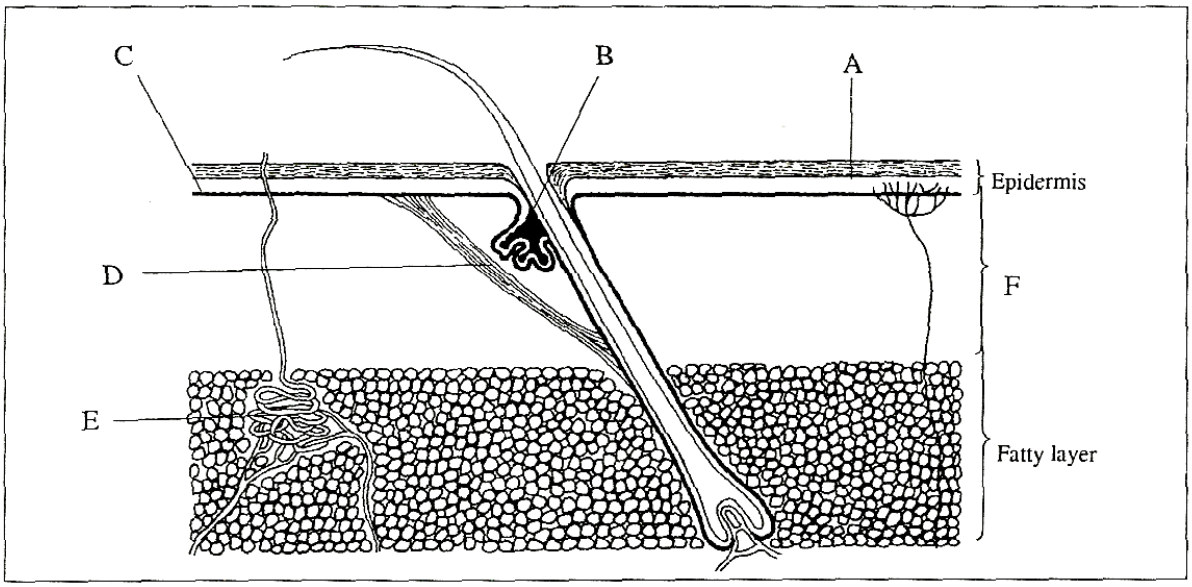
(a) Passing large amounts of urine.
(b) Excessive excretion of glucose in urine.
(c) Loss of body weight due to breakdown of proteins and fats.
(d) Chronic starvation.
(e) Feeling of thirst.

Control

Administration of regular injection of the insulin hormone to patients will decrease the blood glucose level and reduce the symptoms associated with the disease. People suffering from diabetes should avoid food rich in sugars and excessive intake of alcohol.

Revision Questions

1. Figure 4.11 represents a transverse section through the human skin.



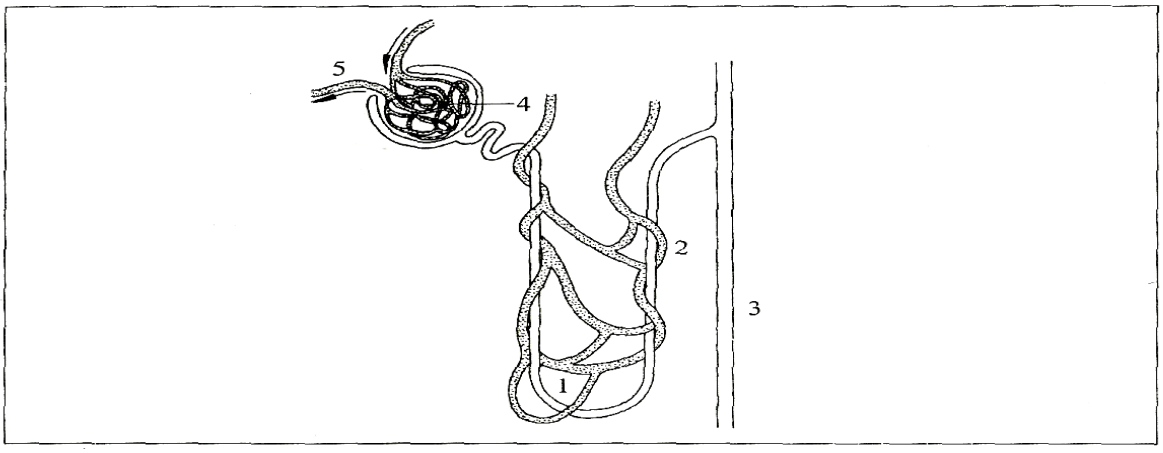
(a) Name the structures labelled A to F.

(b) (i) Explain how the hair in human beings helps in keeping the body warm.

(ii) Explain other methods by which the skin helps to keep the body warm.

2. Figure 4.12 illustrates a mammalian nephron. Use it to answer the questions that follow:

a. Explain what happens to the concentration of sodium ions between 1 and 2.
b. What would happen to the functioning of portion 3 in the absence of anti-diuretic hormone (ADH).
c. What would happen at point 4 if there was partial constriction at point 5?
d. Suggest adaptive structural differences between nephrons of a desert animal for example, kangaroo rat, and those of a fresh water fish, for example tilapia.



3. (a) State two advantages which a constant temperature gives mammals and birds over other animals.

(b) How does body size affect heat loss in an animal?

(c) How does sweating increase heat loss in mammal?

4. (a) What is homeostasis?
   (b) Explain the homeostatic role of kidney in mammals.
5. Explain how animals regulate their body temperature and relate this to their body size.
6. The internal environment of an organism requires to be kept constant for the survival of the organism. Discuss,
7. Explain the cause of diabetes mellitus. How can it be controlled?
8. Explain the role of the following in homeostasis:
   (a) Skin.
   (b) Liver.
   (c) Hypothalamus.
9. What is the difference between homoitherms and ectotherms (poikilotherms)?
10. (a) Name the conditions under which urine production is increased in mammals.
    (b) What is meant by diuresis?
    (c) What is diabetes insipidus?
    (d) Describe how the kidney functions as an osmoregulatory organ.
11. Name two common diseases that affect the liver and the kidney.
    For each of the diseases given above, describe the mode of infection and control measures.
12. (a) Name any four organic waste products in animals
    (b) Describe the mechanisms of excretion?