(1) The outermost thin, elastic cell membrane or plasmalemma becomes attached to the substratum.

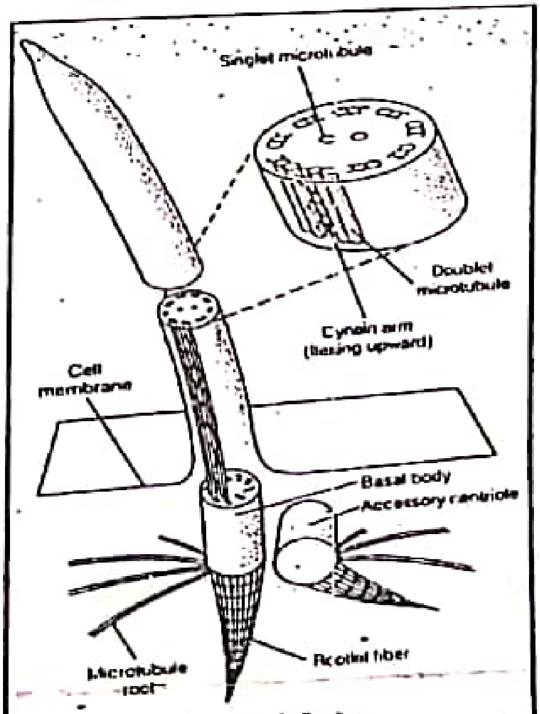
(2) There is a local partial liquefaction of the plasmagel at the anterior end. This causes the central plasmasol, under tension, to flow forward and force the plasmagel against this weakened area to produce a bulge or pseudopodium. As plasmasol enters the newly formed pseudopodium, it rapidly changes into plasmagel around the periphery (gelation), thus forming a gelatinized tube within which the plasmagel continues to flow forward.

(3) Posteriorly, inner surface of contractile plasmagel undergoes solation, so that a constant flow of plasmasol is maintained from behind forward in the direction of movement.

(4) The outer tube of elastic plasmagel contracts and moves from in front backwards, while the main bulk of body travels forward. The plasmagel thus exerts a squeezing motion from the sides and rear of amoeba, forcing the plasmasol to flow forward. At the tip of pseudopodium the endoplasm is changed to ectoplasm.

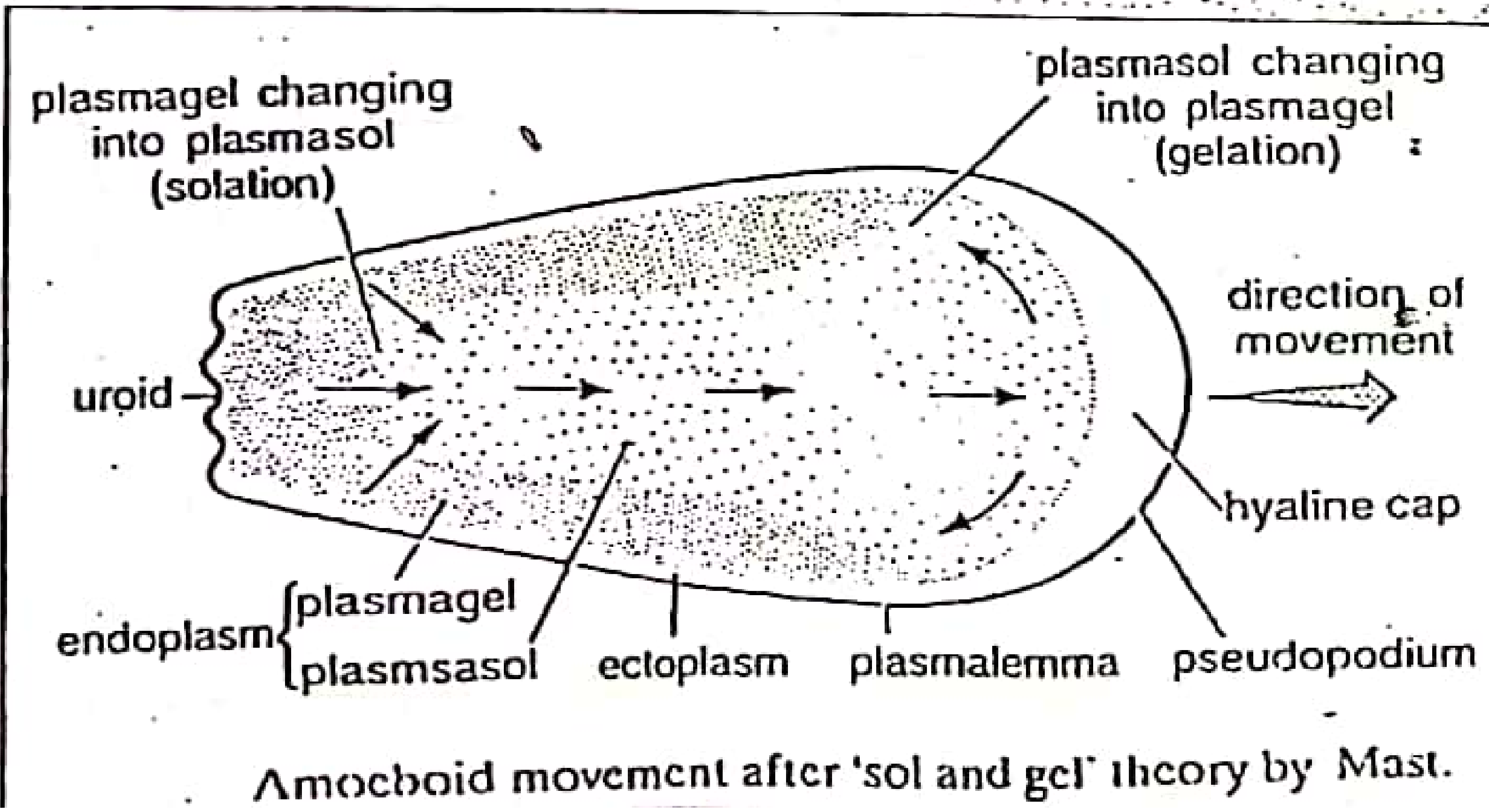
Flagella

Structure of flagella- Flagella are thread like projections on the cell surface of flagellate protozoa like *Euglena, Trypanosoma*, etc. A typical flagellum consists of an elongated, stiff axial filament, the axoneme, enclosed by an outer sheath. The axoneme consists of nine outer double microtubules that encircle two central single microtubules, forming the typical 9 x 2 + 2 pattern seen in cross-sections. Each of the peripheral pairs bears a double row of short

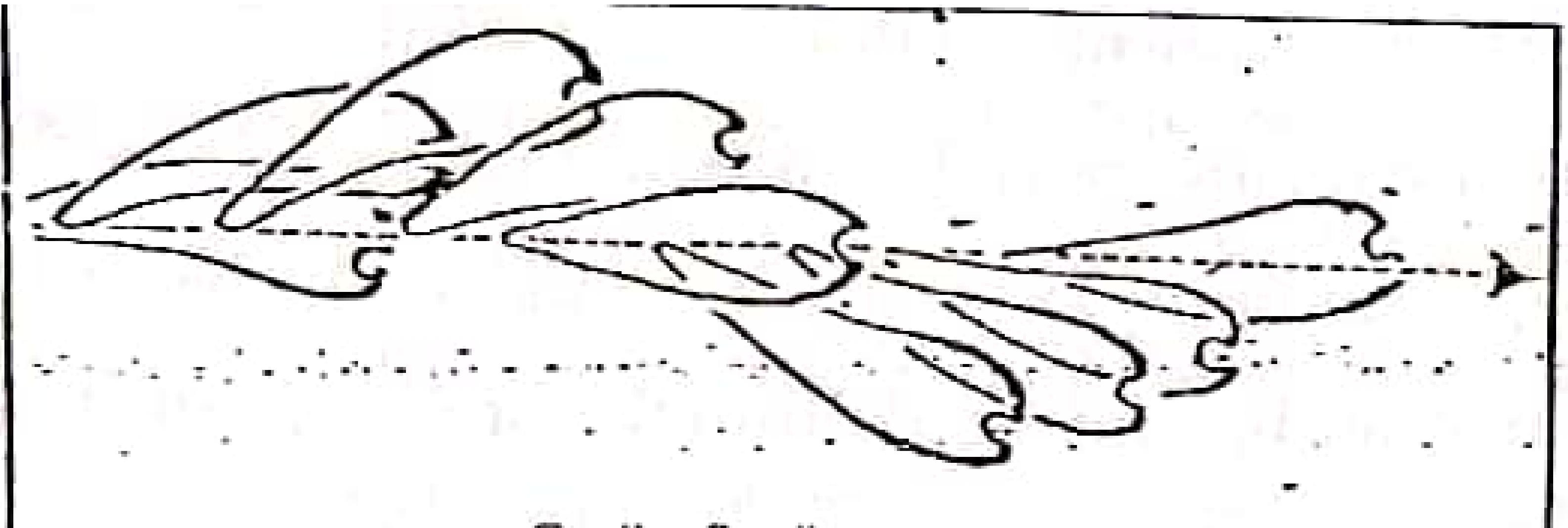


Ultrastructure of a flagellum

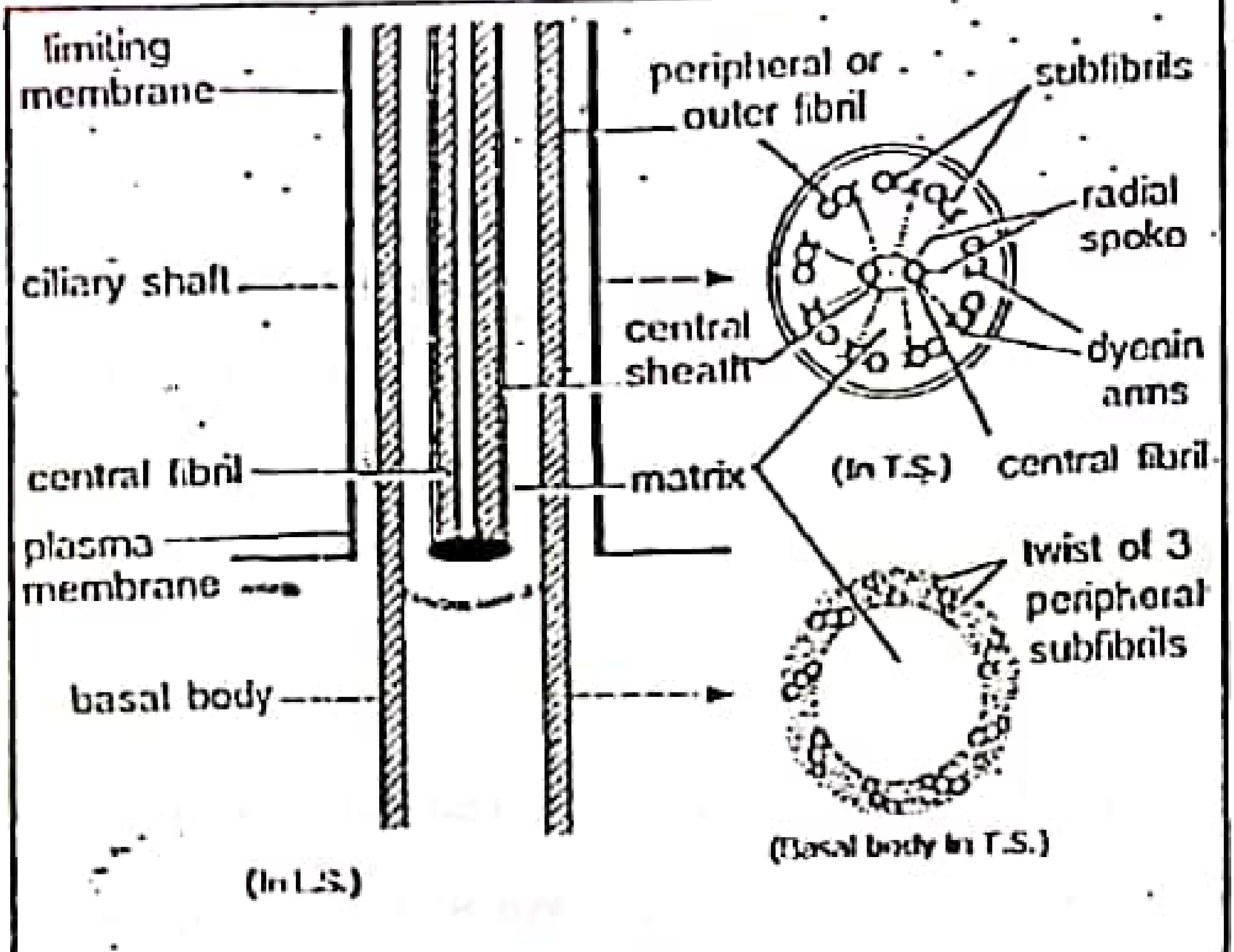
explanation for amoeboid locomotion. According to the ... f viscosity theory, cytoplasm of amoeba is differentiated in... toplasm and a granular inner endoplasm. The latter ... shed into an outer stiffer and jelly-like region, the plasmag... id region, the plasmasol. Amoeboid movement involves four ... rs simultaneously –



Amoeboid movement after 'sol and gel' theory by Mast.



Gyrating flagellar movement



UltraStructure of a cilium

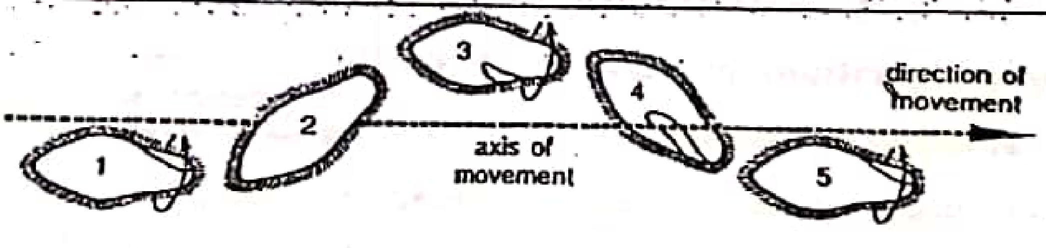
ent- Mechanism of ciliary movement in ciliates
that cilia are moved in a coordinating system. T
ripheral fibres located within them. The basal b
another by contractile bundles of fibres called k
t five cilia form one contractile unit called kin
inetics produce a metachronal wave of moveme
to the animal. The energy needed for fibrill
. Cilia also need liquid medium for their mover
e seen in ciliates-

contractile and can, on ... alter its orientation. When basal bodies are distributed to daughter cells during mitosis, they typically arrange themselves at each pole of the mitotic spindle and are then designated as centrioles.

Flagellar movement- It is characteristic of Mastigophora which bears one or more flagella. The mechanism producing flagellar beat is not exactly known. It is believed that some or all of the axonemal fibres are involved. According to the latest *sliding tubule theory* of flagellar movement, adjacent doublets slide past each other, causing the entire flagellum to bend. Cross-bridges are formed and energy utilized for the process is supplied by ATP. The flagella need liquid medium for movement or locomotion. There are three types of flagellar movements:

(1) *Ciliary beats*- During the effective stroke, the cilium is outstretched stiffly and moves in an oar-like fashion, perpendicular to the cell surface. In the recovery stroke, the cilium flexes and snakes forward parallel to the cell surface. As the organism moves through the medium, the ciliary beat is coordinated over the surface of the cell. The cilia in any cross row are all in the same stage of the beat cycle, while those in front are in an earlier stage and those behind are in a later stage. This phase shift is seen as waves, called metachronal waves that pass over the surface of the cell like wind passes in waves over a wheat field.

(2) *Swimming*- Large ciliates are the swiftest swimmers. During the mode of swimming, the animal does not follow a straight tract but rotates spirally like a rifle bullet along a left- handed helix. The reason for this is two-fold. Firstly, the body cilia do not beat directly backwards but somewhat obliquely towards right, so that the animal rotates over to the left on its long axis. Secondly, the cilia of oral groove strike obliquely and more vigorously so as to turn the anterior end continually away from the oral side and move in circles. The combined effect causes the movement of animal along a fairly straight path, rotating about its axis in an anticlockwise direction.



Anticlockwise spiral path followed by a swimming *Paramecium*.

Pellicular Contractile Structures

In many protozoa are found contractile structures in pellicle or ectoplasm called myonemes. These are present in the form of ridges and grooves (e.g. *Euglena*), contractile myofibrils (large ciliates) or microtubules (e.g. *trypanosoma*). Such

Reproduction in Protozoa ✓

Reproduction occurs in all protozoans, in some at frequent interval with only a short period of growth whereas in others, at comparatively longer intervals with expanded period of growth which may last from days to week. Reproduction in protozoa is either asexual or sexual.

Asexual Reproduction

In this type, division of parent body occurs to produce one or more young individuals. It always involves a single parent and neither meiosis nor fertilization occurs. Nearly all protozoans reproduce by this method. It takes place by following methods:

1. Binary Fission
2. Plasmotomy
3. Budding
4. Multiple Fission
5. Plasmogamy
6. Regeneration

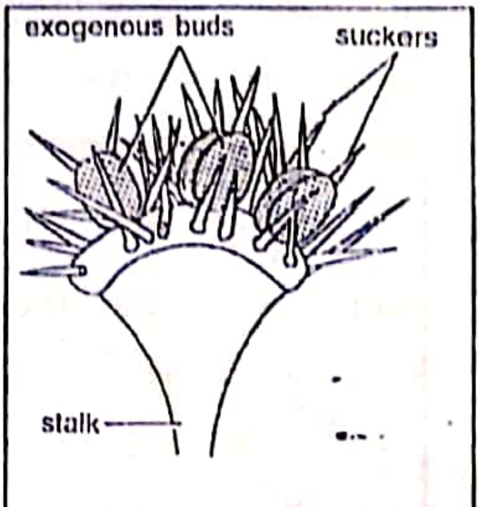
Sexual Reproduction

In this type, meiotic nuclear division is followed by the union of gametes. The gametes may arise from different parents (amphimixis) or may come from same parent (automixis). It helps in the replacement of old nucleus by genetic recombination for restoration of vigor. It is of the following types:

1. Syngamy
2. Conjugation
3. Parthenogenesis

Budding: Budding is the formation of one or more small individuals by separating from the parent body. Each bud receives a part of the parent nucleus and later on turns into an adult. The bud is smaller than the parent. When a parent body produces only one bud it is monotonic (e.g. *Vorticella*), while in multiple budding several buds are formed simultaneously (e.g. *Ephelota*).

Multiple fission: During multiple fissions, nuclear division is not immediately followed by the division of the cytoplasm. At first, nucleus divides by a series of divisions either by repeated binary fission (e.g. *Plasmodium*) or by simultaneous multiple fission (e.g. *Aggregata*). The body thus becomes multinucleate. It is quite a common phenomenon seen in Foraminifera, Radiolaria, Sporozoa and certain Mastigophora. The process receives different names according to the particular period in life cycle it occurs-



Multiple budding in *Ephelota*

Schizogony

- Occurs in the life cycle of *Plasmodium*.
- The resulting individuals are called merozoites.

Sporogony

- Seen in *Plasmodium*.
- Takes place after sexual reproduction and the products are termed sporozoites.

Plasmogamy: In certain Rhizopoda and Mycetozoa two or more individuals may fuse to form a plasmodium in which the nuclei remain distinct and they separate again unchanged afterwards. The process, which is thus non-sexual and not syngamy is called plasmogamy.

Regeneration: It has been observed that nucleated pieces of sufficient size may reform proportional missing parts and may assume normal shape. In ciliates like *Stentor* and *Euplotes* a piece of macronucleus is necessary for regeneration. Parasitic protozoa usually have slight regeneration capacity.

Sexual Reproduction

This type of reproduction is widespread, but not universal in protozoans. Many protozoans undergo sexual activities at irregular intervals but in many cases the life cycle cannot be completed without syngamy and gametogenesis.

Syngamy: This is the complete fusion of two sex cells or gametes, resulting in the formation of zygote. The fusion nucleus of zygote is called Synkaryon. Depending upon the degree of differentiation displayed by the fusing gametes, Syngamy is of following types.

- **Hologamy-** Two ordinary mature protozoan individuals themselves behave as gametes and fuse together to form zygote. E.g. Sarcodina and Mastigophora (e.g. *Copromonas*).
- **Isogamy-** Two fusing gametes are similar in size and shape. E.g. *Monocystis* and *Chlamydomonas*
- **Anisogamy-** Two fusing gametes are unequal in shape and size. Small or motile gametes are male or microgametes and large non-motile ones are the female or macrogametes. E.g. *Plasmodium* and *Volvox*.
- **Autogamy-** Fusion of gametes derived from the same parent cell. E.g. *Actinophrys* and *Actinosphaerium*.

Conjugation (amphimixis): It is the temporary union of two protozoan

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11. Four daughter nuclei (in each exconjugant) enlarge to become macronuclei and other 4 become micronuclei. Three micronuclei disintegrate and disappear.

12. Remaining one micronucleus of exconjugant divides with binary fission.

13. Each exconjugant produces 2 daughter paramecia, each containing 2 macronuclei and 1 micronucleus.

14. Further division of each daughter paramecium forms 2 individuals, each containing one macronucleus and one micronucleus. Thus, each conjugant produces four daughter individuals at the end of conjugation.

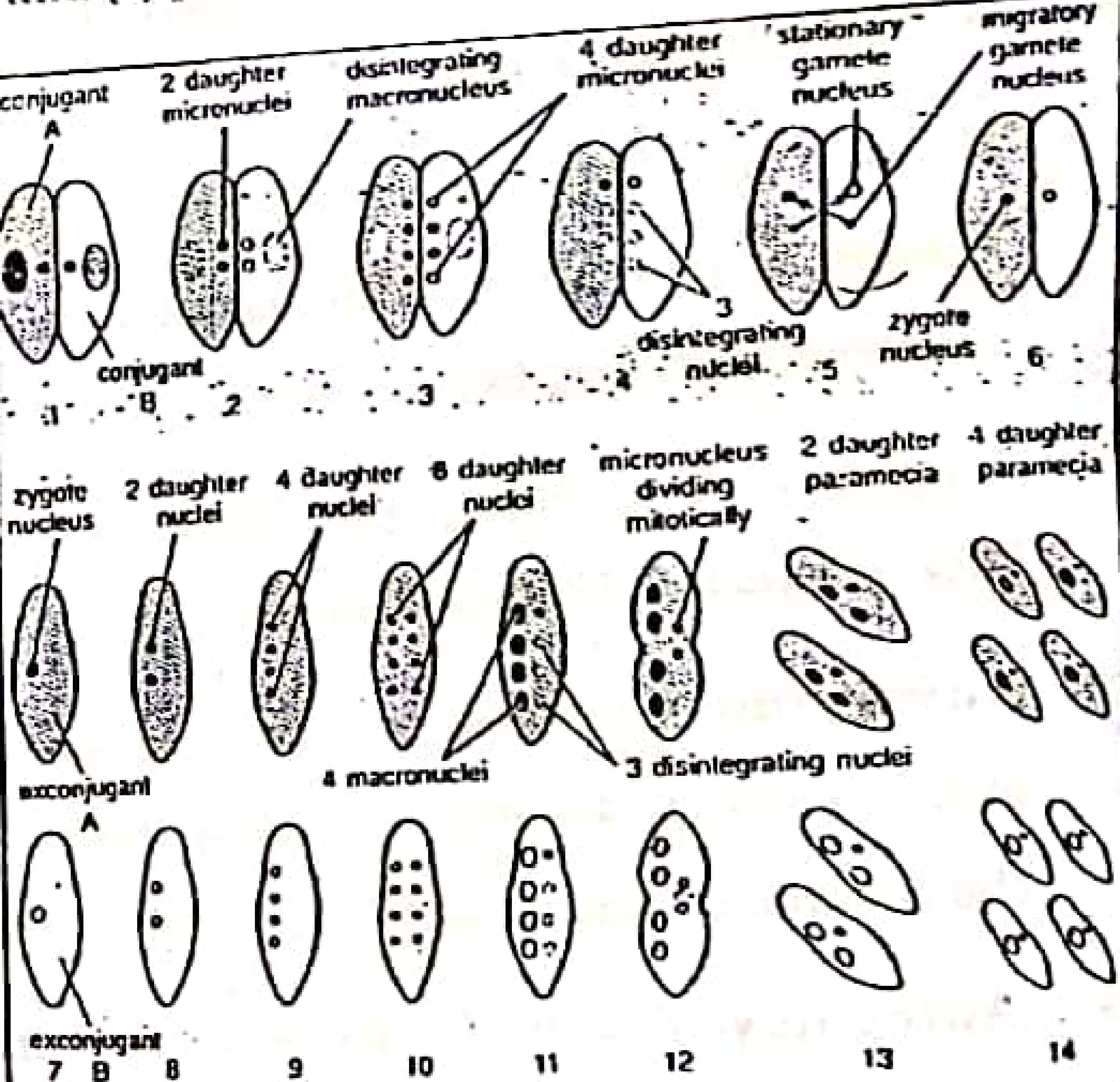
Parthenogenesis: In *Actinophrys* the gametes which fail to cross-fertilize develop parthenogenetically. It also occurs in *Chlamydomonas* and others when syngamy has been missed. Individuals of *Polytoma*, which are potential gametes can grow and divide parthenogenetically.

Encystment:

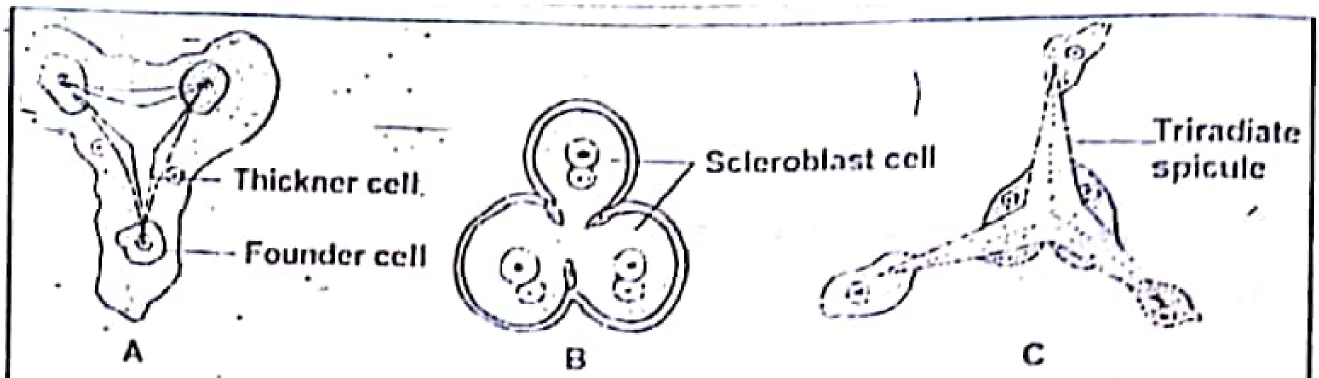
Encystment is characteristic of the life cycle of many protozoa, including the majority of freshwater species. In forming a cyst, the protozoan secretes a thickened envelop about it and becomes inactive. Depending on the species, the protective cyst is resistant to desiccation or low temperatures and encystment enables the cell to pass through unfavorable environmental conditions. However, the more complex life cycles are often characterized by encysted zygotes or by formation of special reproductive cysts in which fission, gametogenesis, or other reproductive processes take place. Protozoa may be dispersed over long distances in either the active or encysted stages. Water currents, wind, and mud and debris on the bodies of waterbirds and other animals are common means of dispersal.

Evolution of Sex in Protozoa

Asexual reproduction is generally quick, has less energy demands and is a simple process and hence the early protozoan adopted this method as the and (b) passive stationary gametic nuclei.



Paramecium. Stages in conjugation. (See text for details)



Formation of tri-radiate spicule. (A) Scleroblast cell, (B) Cells dividing (C) Triaxon spicule

Tetraxon spicules are formed when an additional scleroblast cell is added along with three scleroblasts.

Spongin

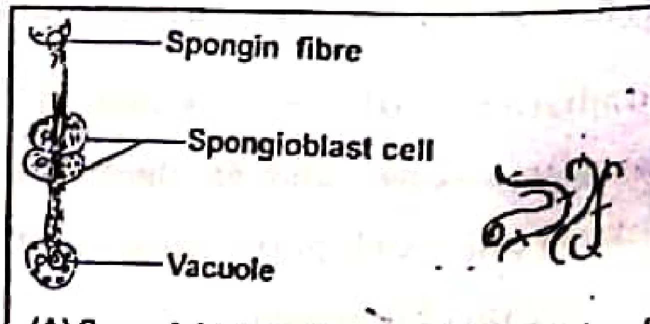
It is an organic horny, elastic substance consisting of scleroprotein containing sulphur and is chemically similar to collagen. Spongin is insoluble, chemically inert and is not acted upon by the digestive enzymes. Spongin contains a large amount of iodine, reaching 8 to 14 percent in certain tropical species of the *Spongiidae* and *Aplysinidae*.

Development of Spongin

Spongin fibres are made up of five threads having a granular axial core or medulla surrounded by spongin which is secreted by spongioblast cells present in the mesenchyme. The spongioblast cells get arranged in rows, develop a vacuole within which spongin material is collected. Later on, spongin secreted by each spongioblast cells fuses with the neighboring cells to form long fibres.

Canal system in Porifera

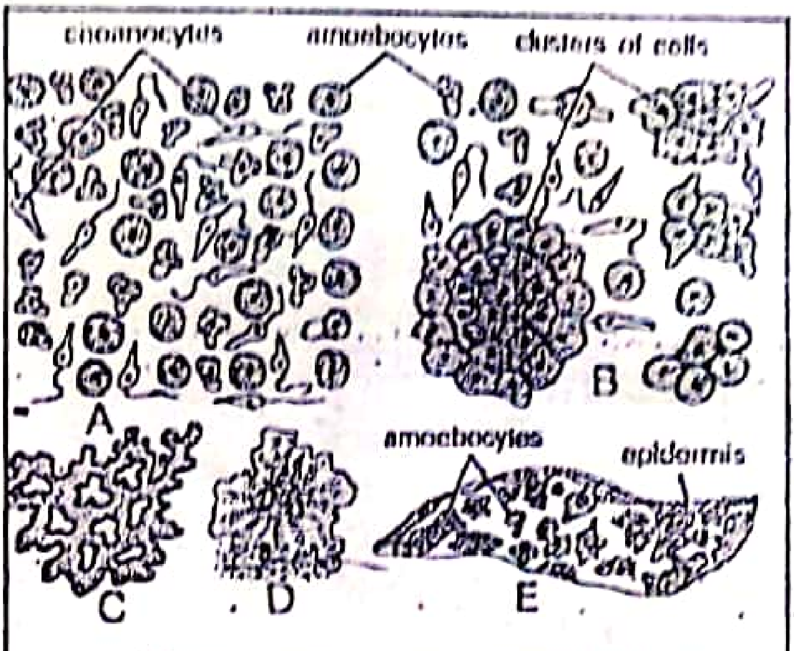
A distinguishing feature of all sponges is the perforation of body surface by numerous apertures for the entry and exit of water current. Inside body, the water current flows through a certain system of spaces collectively forming the canal



(A) Spongioblast cells assemble to form spongin fibre (B) Formation of spongin fibres

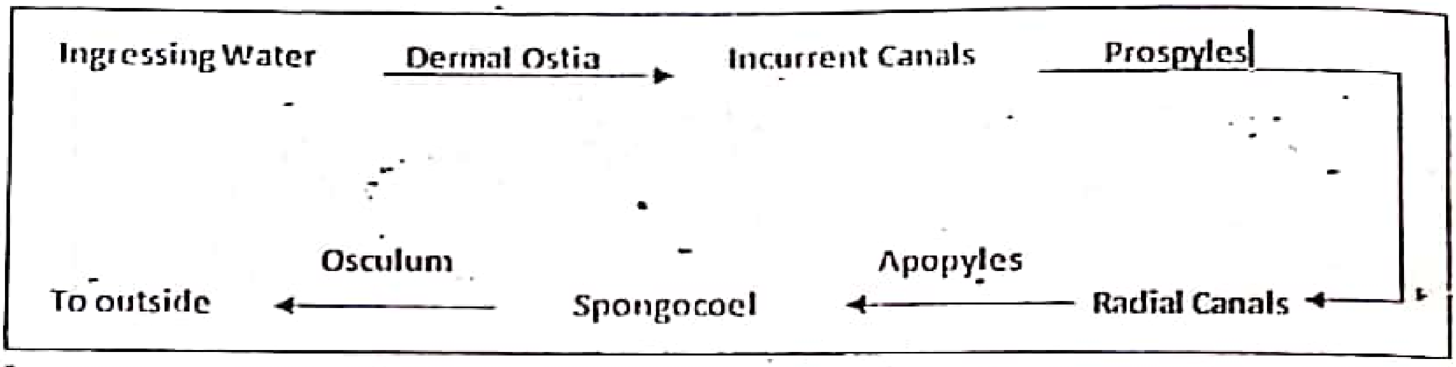
Ingressing Water —(Dermal Ostia)→ Subdermal space → Incurrent Canal —(Prospyles)→ Flagellated chamber —(Apopyle)→ Excurrent canals → Spongocoel —(Osculum)→ To outside

Significance of Canal System



Wilson's experiment on regeneration in sponges. A – Cells of *Microciona* separated by squeezing living sponge through bolting cloth. B – Cells aggregating into small masses. C – A reticulate reunion mass. D – Later stage forming a young sponge or spongelet. E – Section through a stage like D.

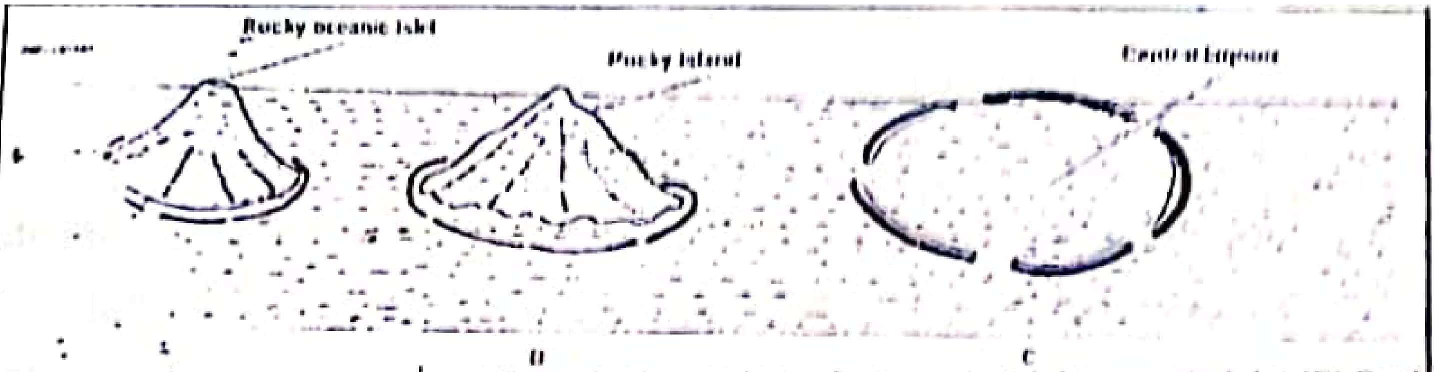
The flagella of choanocytes beat to produce water current which enters the sponogocoel through ostia. It carries food particles and oxygen and sweeps away the metabolic wastes through osculum. It therefore subserves the function of ingestion, respiration, and excretion. In simple type of canal system, there is lesser number of cells but as the canal system becomes complex, the number of flagellated cells increases and the force to draw water current is also increased. The syconoid canal system is therefore more efficient than the asconoid type and the leuconoid type still more efficient. The increase in total area of the choanocyte surface increases the efficiency of canal system.



In more complex sycon type, as illustrated by *Grantia*, the incurrent canals are irregular, branching and anastomosing, forming large sub-dermal spaces. The incurrent canals traverse along irregular course through the cortex before reaching the outer ends of the radial canals.

Leucon Type:

In this case, the radial canals of syconoid stage get divided into small rounded or oval flagellated chambers by further folding. This is characteristic of leuconoid sponges, such as *Spongilla*. Incurrent canals open into flagellated chambers through prosopyles. Flagellated chambers, in their turn, communicate with excurrent canals through apopyles. Excurrent canals are developed as a result of shrinkage and division of spongocoel which has disappeared. Thus excurrent canals communicate with the outside through an osculum. Course taken by water current is as follows:



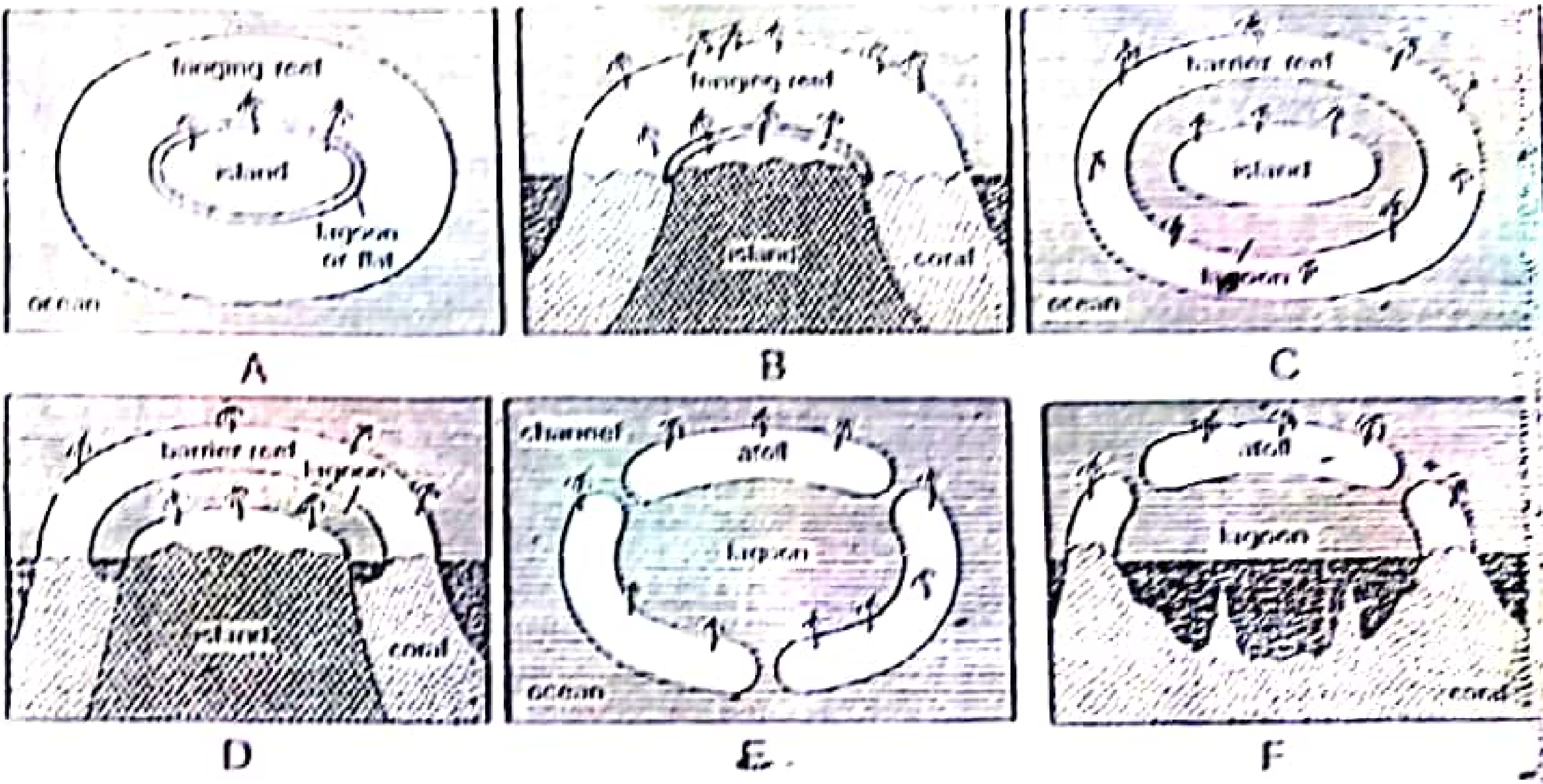
Formation of coral reef (A) Fringing reef growing round a rocky oceanic islet (B) Reef enlarges as land sinks or sea level rises (C) subsidence of land resulting in the formation of an atoll showing central lagoon

Rate of Growth of Corals

Most reefs grew at the rate of 10-200 mm each year. Most of the existing ree could have been formed within a period of 15,000 to 30,000 years.

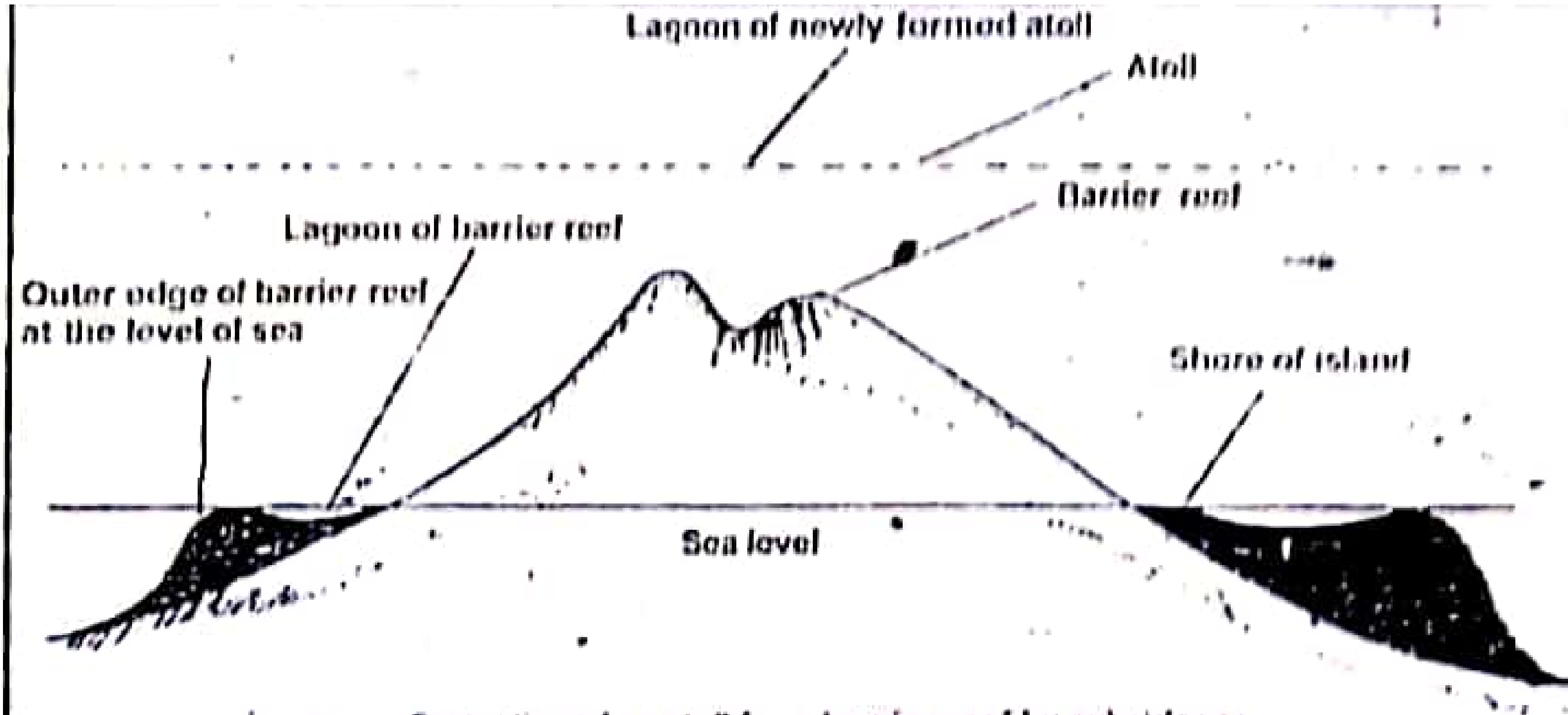
Economic importance of coral reefs.

Corals of the remote geological past formed coral reef structures that becan highly favourable sites for the accumulation of petroleum deposits. Thus co reefs are of much importance to oil industry. Large quantities of corals a shipped every year for the curio trade. The coral reefs serve as habitats for ma plants and animals like sponges, molluscs, echinoderms, fishes etc. Some co reefs are used as habitations by man as well. Some corals are highly prized



Coral reefs. A – Fringing reef. B – Fringing reef in section. C – Barrier reef. D – Barrier reef in section. E – Atoll. F – Atoll in section

(2) Barrier Reef: Barrier reefs are like fringing reefs but they are located so distance away from the shore. The stretch of water, separating the barrier r from land, may be half a mile to 10 miles or more in width. It is called a lago It is 10 to 50 fathoms deep and suitable for navigation. Most notable exampl barrier reef is the Great Barrier Reef along the North-eastern coast of Austra It is about 2000 Km long and up to 150 km from the shore.



Formation of an atoll from barrier reef by subsidence

...ation of coral reefs

...ving important theories have been put forward to explain the formn... reefs:

Darwin's Subsidence Theory: According to this theory, all know...

When hydrocalus has reached full development, it produces special club-shaped ~~bodies called~~ blastostyles or blastozooids or gonozooids. The perisarc covering blastostyle, forms a loose, transparent, vase-like capsule, the gonotheca. The blastostyle, by lateral asexual budding, produces sexual individuals called medusae or gonophores. Fully formed medusae detach from blastostyle through an aperture, the gonopore. Gonotheca, together with blastostyle and medusae is referred to as gonangium.

Hydroid *Obelia* colony with medusae becomes trimorphic containing hydranths, blastostyles and medusae.

Histology of colony:

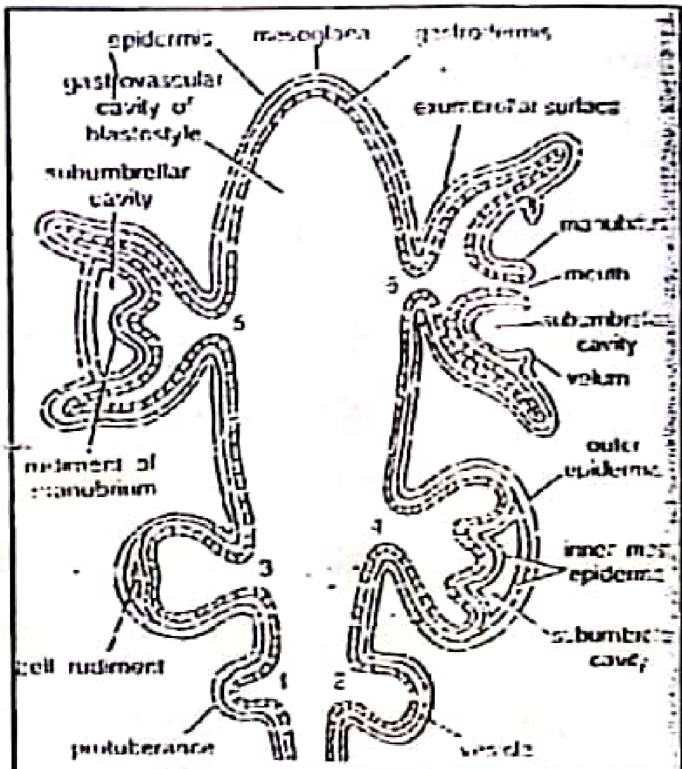
The body wall of colony is composed of two layers of cells, outer epidermis and inner gastrodermis. Between them, is a thin delicate, transparent, non-cellular gelatinous layer called mesogloea or supporting lamella. Epidermis contains stinging cells or nematocysts which are especially abundant on tentacles forming annular batteries. A nerve-net, composed of large and branched nerve cells, is present on each side of the mesogloea. Gastrodermis chiefly consists of large columnar nutritive-muscle cells and narrower gland cells that help in digestion.

Physiology of colony:

1. Locomotion- Hydroid *Obelia* colony, being sessile, does not exhibit bodily movements. However, annular constrictions of perisarc permit slight swaying movements under the influence of water currents.
2. Nutrition- Polyps or Hydranths are the gastrozooids and are mostly carnivorous that prey upon small crustaceans, nematodes and other worms. Their tentacles capture the prey and convey it to mouth. Digestive juices, secreted by gland-cells bring about partial extracellular digestion. Gastrodermal cells engulf small pieces of partly digested food and digest them intracellularly. Digested food diffuses into the cells of entire colony. Undigested food is egested through mouth as there is no anus.

3. Respiration and Excretion- There are no special organs of respiration and excretion. Oxygen from surrounding water diffuses directly into cells and CO_2 and nitrogenous excretory products diffuse out.

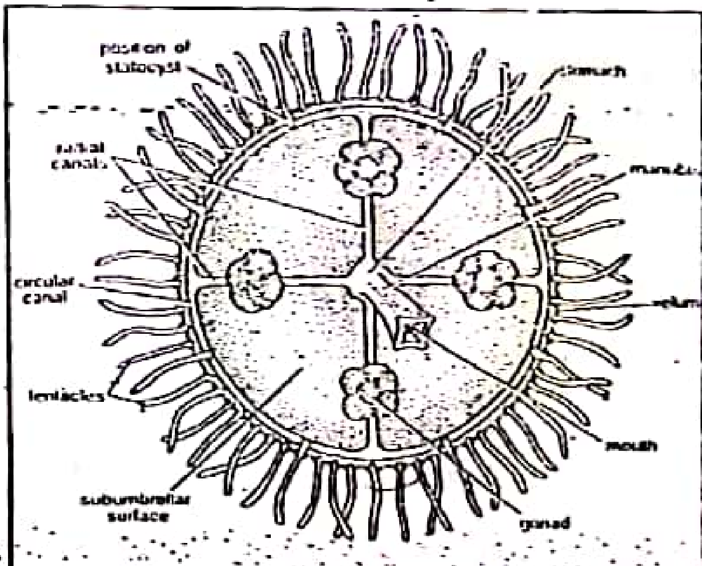
4. Asexual Reproduction- *Obelia* colony propagates by the asexual method of budding. Hydrorhizae sprout new vertical stems or hydrocauli that increase the number of individuals by budding. Blastostyles are specialized reproductive-zooids forming medusae by budding.



Obelia Blastostyle in V.S. showing various stages (1 to 6) of development of a medusa

Medusa

Medusae are modified zooids meant for sexual reproduction. They arise from blastostyles by a process of asexual budding.



Obelia A medusa in oral view

Development of medusa

In spring and summer, a large number of medusa buds and in various stages of development can be seen on a blastostyle. Medusa-formation begins as a small outpushing or hollow protuberance on the wall of blastostyle (1). It soon enlarges into a vesicle (2). Apical epidermis of vesicle now splits into two layers. Inner layer again splits and acquires a small cavity called bell-rudiment (3) that subsequently enlarges to become sub-umbrellar cavity (4). During further development, a narrow circular shelf, called velum projects inwards from the margin of umbrella, Velum is permanent and conspicuous in most hydroid in the regulation of blood sugar.

6. Absorption of water, salts, vitamins, and end products of food digestion.

7. Maintenance of water balance of the body through the phenomenon of thirst.

Digestive Enzymes

Digestive enzymes play an important role in digestion as they regulate (mediate) the chemical reactions in the breakdown of food. Most digestive enzymes are *Hydrolases* and produce their catalytic action by the process of *Hydrolysis* (Fig. 14.1), in which a molecule of water is chemically added

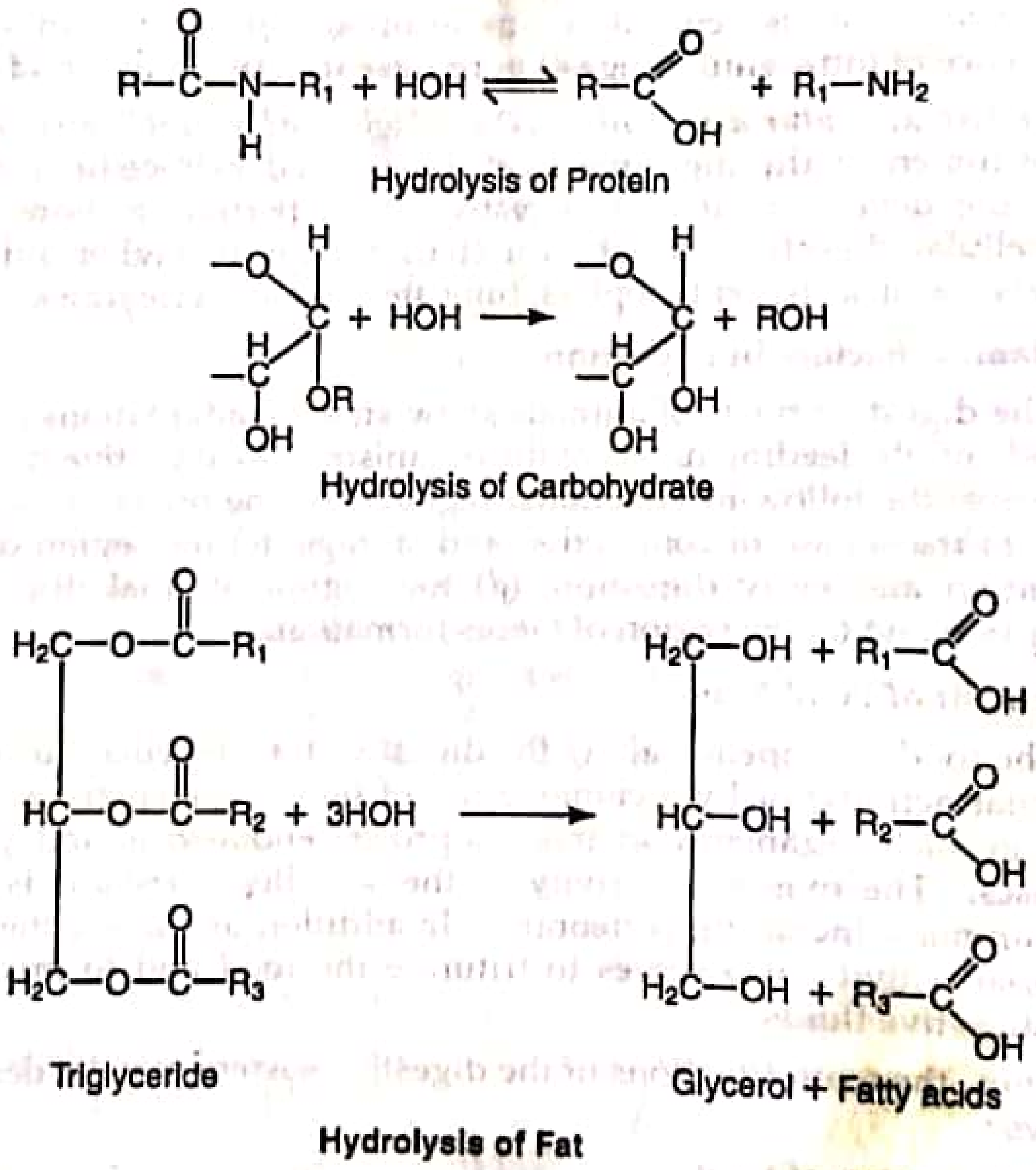


Fig. 14.1. Hydrolysis of protein, carbohydrate and fat by the addition of the elements of water. The R represents a complex carbon skeleton.

14

PHYSIOLOGY OF DIGESTION

Digestion can be defined as a *process that involves chemical breakdown of complex food materials into simpler molecules which can be readily usd by the animal through absorption and assimilation.*

Kinds of Digestion

(1) ***Intracellular digestion*** : When digestion takes place inside the cells and is carried out in food vacuoles within the organism itself, then it is called intracellular digestion. This mode of digestion is a characteristic of lower animals like protozoans and sponges. However, it is also employed by some more complex animals like coelenterates wherein the digestion is partially extracellular but largely intracellular. Many platyhelminths and *Limulus* are also considered as examples of animals in which the occurrence of intracellular digestion represents a primitive condition.

(2) ***Extracellular digestion*** : When digestion is practically completed in the lumen of the digestive tract, it is called extracellular digestion. Thus, the development of a digestive tract, permits a more complete extracellular digestion, which is a characteristic of higher animals like crustaceans, insects

When polysaccharides are hydrolyzed, they break up into many simple sugars. For example, the hydrolysis of *starch* yields several molecules of *dextrin*, which is then hydrolyzed into the disaccharide maltose, and this into the monosaccharide glucose.

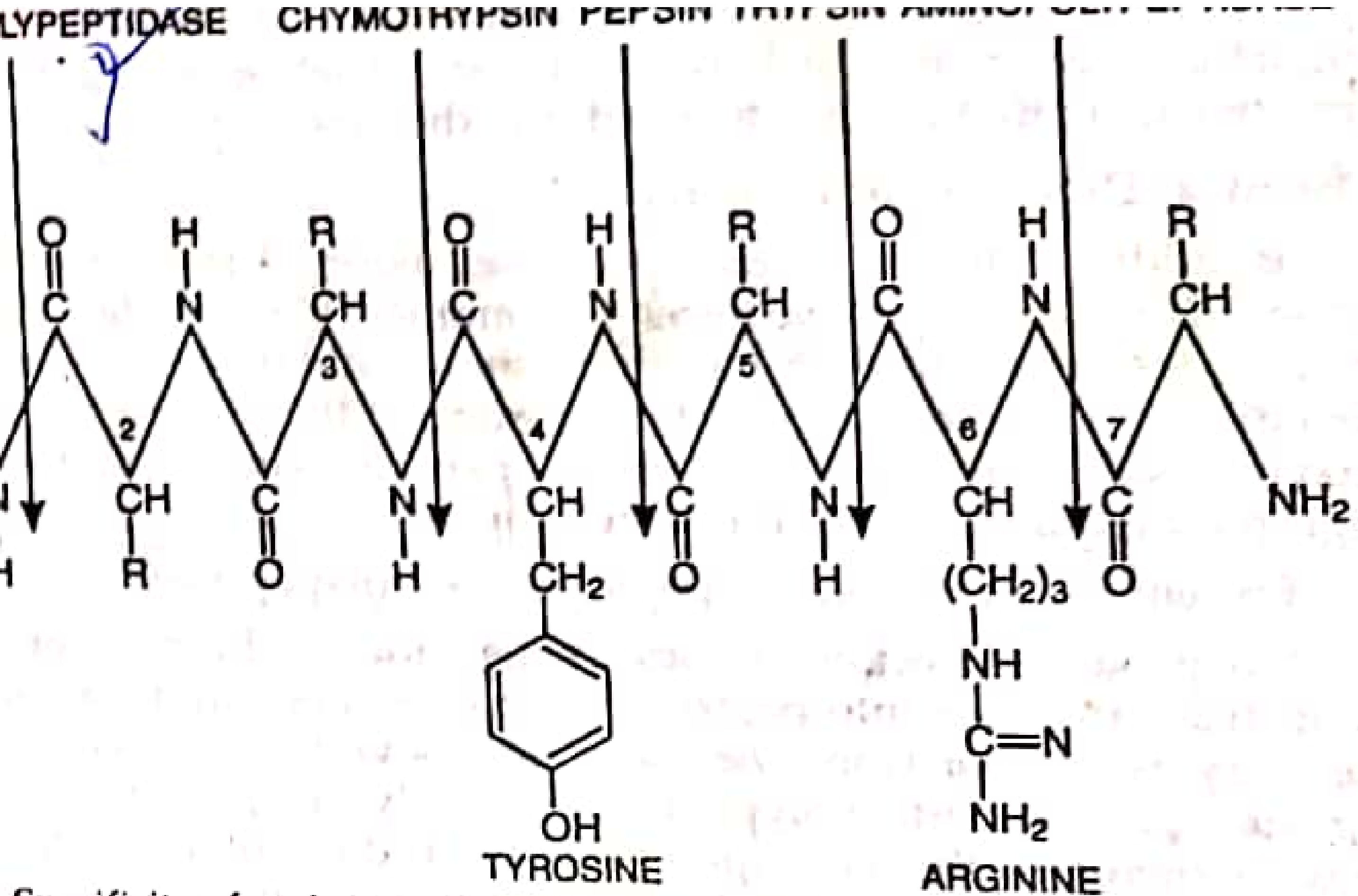
The chemical digestion or hydrolysis of carbohydrates occurs in the presence of different enzymes known as *glycosidases*. Two enzymes, ptyalin and maltase are present in the saliva. *Ptyalin* or salivary amylase hydrolyzes starch to dextrin and maltose, and then *maltase* converts maltose to glucose. Enzymes secreted by the small intestine continue the process : *maltase* hydrolyzes maltose to glucose, *invertase* (sucrase) acts upon sucrose and hydrolyzes it to glucose and fructose, and *lactase* hydrolyzes lactose (milk sugar) to glucose and galactose. Glucose, fructose, and galactose are all simple sugars that can be absorbed into the blood.

Chemical Digestion of Proteins

In addition to the dietary proteins, about 10 to 30 g of protein are present in various digestive juices and another 10 g of protein are contained in cells desquamated each day from the intestinal lining. This protein is also digested and absorbed. The digestion of the protein by a proteolytic enzyme occurs by the hydrolysis of peptide bonds and the protein is digested according to the following sequence :

Protein → proteoses → peptones → polypeptides → amino acids

No protein digestion occurs in the mouth. In the stomach *pepsin* hydrolyzes proteins into proteoses and peptones. In the small intestine the enzyme *trypsin* from the pancreas converts proteins and partially digested proteins into polypeptides. Finally, in the small intestine the enzyme *erepsin* further acts upon the split products of the gastric digestion of proteins to form ami[illegible]



Specificity of various proteolylic enzymes. The numbers 1 to 7 refer to
acid residues only two of which, tyrosine and arginine are labelled below

The normal rate of respiration in the adult is 14 breaths/minute, but in children it may be up to 30/minute. In exercise it is further increased. Each inspiration admits about 350 ml of new air to mix with the 2500 ml of old air present in the lungs. The quantity of new air that enters the lungs per minute is known as the *minute volume,* which in the average adult is about 4900 ml (350 × 14).

Physiology of Respiration

It may be discussed under the following heads : (*a*) Gaseous exchange in the lungs ; (*b*) Transport of gases by the blood ; and (*c*) Cellular (internal) respiration and oxidation.

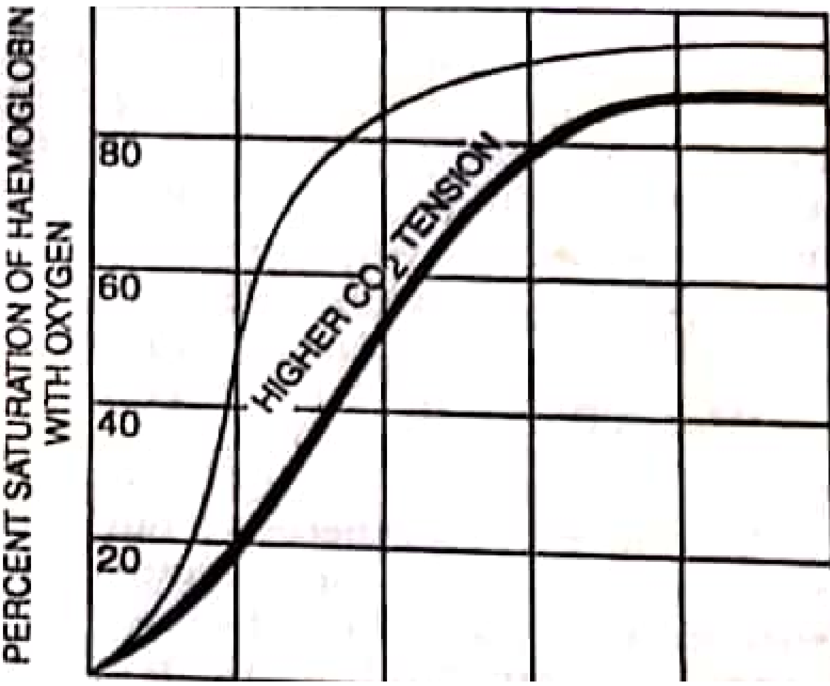
Gaseous Exchange in the Lungs (external respiration)

The respiratory membrane through which gaseous exchange takes place, consists of the thin lining of the alveoli, the endothelium of the capillaries, and the delicate interstitial connective tissue layer. The uptake of oxygen and the release of carbon dioxide by the blood of the alveolar capillaries can be explained by *diffusion, i.e.,* the gases pass from the regions of high pressure to those of low pressure. The pressure of the gas refers to the *partial pressure* that the gas exerts in a mixture of gases. If the atmospheric pressure at the sea level is 760 mm of mercury, the partial pressure of oxygen will be 21% (percentage of O_2 in air) of 760 mm or 159 mm. The partial pressure of O_2 (Po_2) in the alveolar air is about 100 mm of mercury (Since O_2 constitutes only 13% of alveolar air) compared with that of 159 mm of mercury for the O_2 in the atmosphere. The partial pressure of O_2 in the blood of the alveolar capillaries is considerably lower, being only about 40 mm. Accordingly, the oxygen diffuses from the alveolar air into the blood. By the time the blood leaves the capillaries, its O_2 pressure has been raised to about 100 mm of Hg, the same as alveolar O_2.

In a similar manner, the CO_2 in the blood of the lung capillaries has a higher concentration (46 mm) than it has in the lung alveoli (40 mm). This accounts for the diffusion of CO_2 out of the blood into the alveoli. By the time the blood leaves the lungs, its CO_2 pressure has been lowered to approximately 40 mm. Thus, in the diffusion of both these gases there … that determines the direction of their flow.

molecule possesses 4 atoms of iron, it can transport 4 molecules of oxygen.

Under the normal conditions the arterial blood which has been exposed to the alveoli of the lungs is not quite completely oxygenated. With an O_2 tension of 100 mm of Hg, it is usually 98% saturated and therefore, contains 19.6 ml of O_2 (combined to haemoglobin) per 100 ml of blood. In addition to this there is about 0.2 to 0.3 ml of O_2 which is dissolved in the



net result of these two events is to maintain the pH essentially unchanged, ınd K^+ ions within the red blood cell, previously neutralized by HbO_2, ıre now neutralized by the newly formed bicarbonate (HCO_3^-) ions. Consequently, the major portion of the CO_2 that diffused into the red ılood cell from the tissues leaves the capillary in venous blood as red cell HCO_3^-. This set of transformations is termed the *isohydric shift*.

Iamburgers Phenomenon or Chloride Shift

As shown above the dissociation of H_2CO_3 increases the number of icarbonate ions in the red blood cells, and therefore the ions tend to iffuse away into the plasma. For each bicarbonate ion that comes out om the red cells, one negatively charged chloride ion present in the lasma moves into the red cells in order to maintain acid-base equilibrium or the blood and the electrical neutrality of the red blood corpuscles. hus, *chloride shift involves the passage of chloride ions from the plasma into ie red blood corpuscles to balance the bicarbonate ions that have passed from the d blood corpuscles into the plasma* (Fig. 15.5). The carbon dioxide capacity f the red blood corpuscles is further increased by the chloride shift, ecause the removal of bicarbonates, in this way, enhances their formation om the carbonic acid.

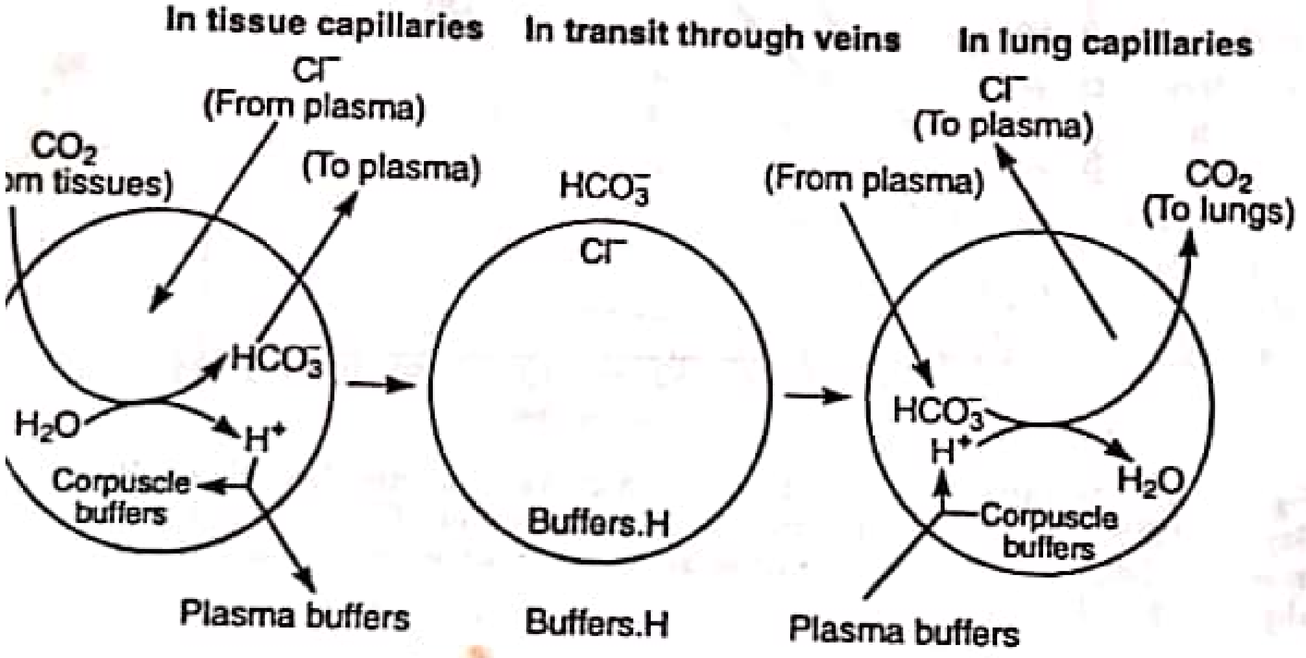


Fig. 15.5. The Chloride shift.

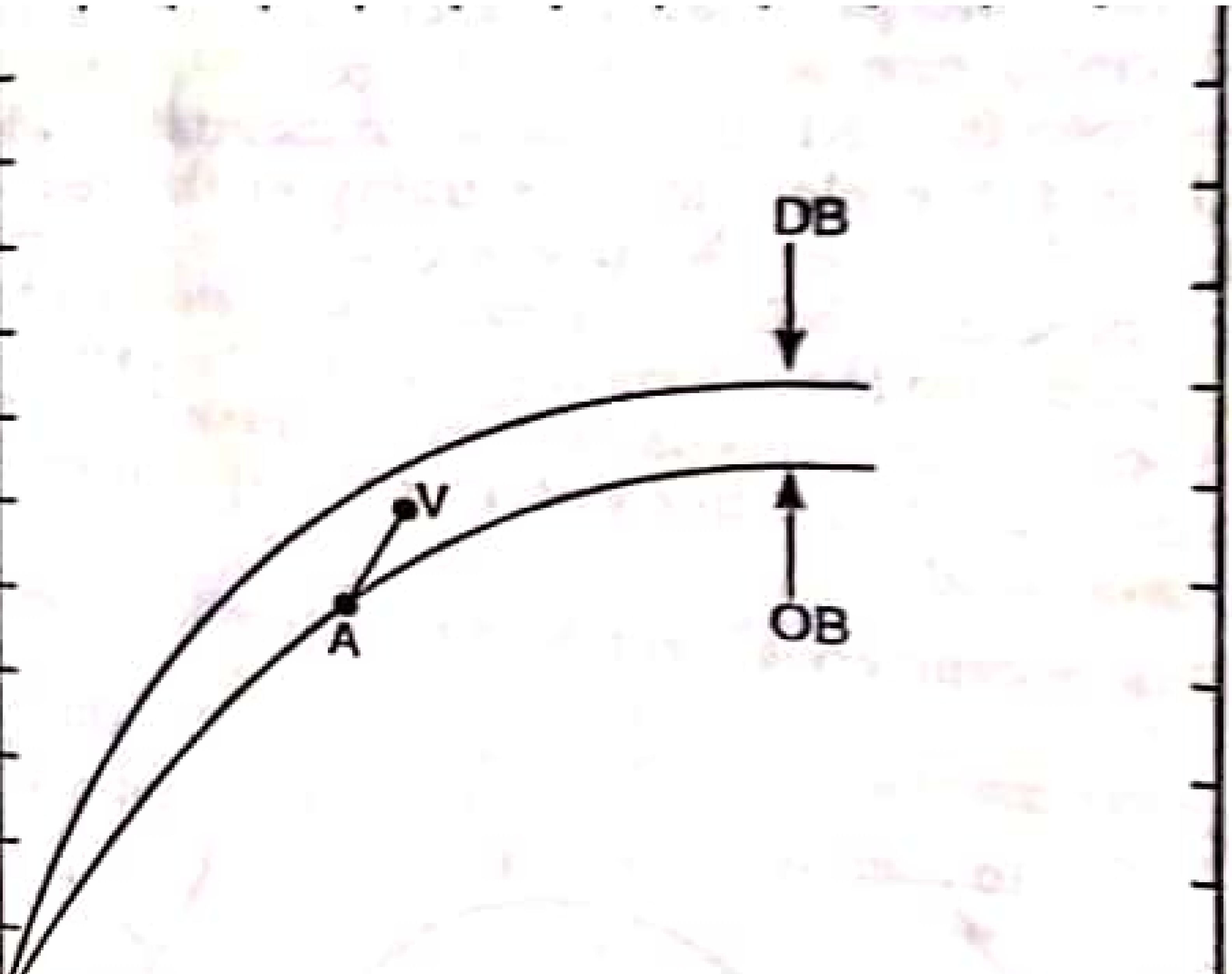
In the red blood corpuscles most of the buffering is provided by the emoglobin (Hb) itself. The latter is a negatively charged blood protein l combines with positively charged hydrogen ions (formed in the isation of (H_2CO_3), forming the haemoglobinic acid. This reaction is wn as follows :

$$BHb + H^+ \rightleftharpoons \underset{\text{(haemoglobinic acid)}}{HHb} + B^+$$

The resulting cation (B^+) from haemoglobin is balanced by the Cl^-.

eration of CO_2 in the Lungs

The CO_2 is carried by the blood-stream to the lungs in the form of



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tension of CO_2 in the lung capillaries (than the tension of CO_2 in the lung alveoli), CO_2 is given off from the blood and the reactions taking place are as follows :

(i) $H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} H_2O + CO_2$

(ii) $NaHCO_3 \xrightarrow{\text{acidity of oxyhaemoglobin}} Na^+ + HCO_3^-$

or $2NaHCO_3 \xrightarrow{\text{acidity of oxyhaemoglobin}} Na_2CO_3 + H_2O + CO_2$

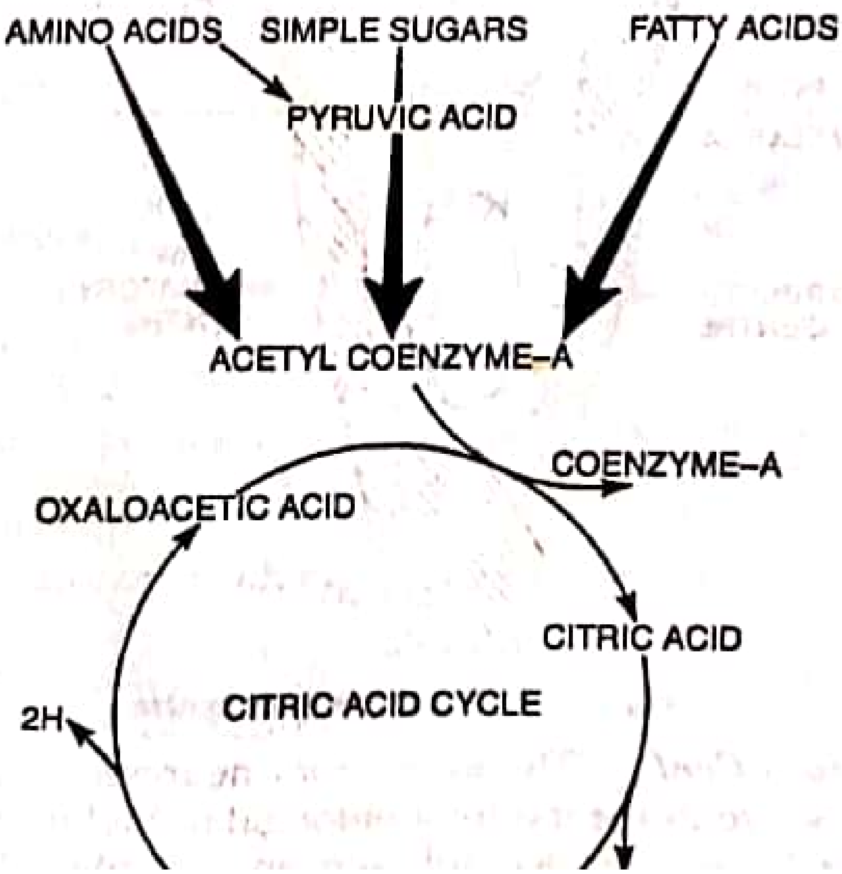
(iii) $HbNHCOOH \xrightarrow{\text{increasing oxyhaemoglobin}} HbNH_2 + CO_2$

The reciprocal effect of oxygenation on acid strength of the haemoglobin, the so-called *Haldane effect*, accounts for the CO_2 exchange. In the lungs chloride ions move out of the red blood corpuscles and bicarbonate ions move back in. The enzyme carbonic anhydrase then promotes the rapid reformation of free CO_2, and this gas diffuses from the blood into the lung alveoli (Fig. 15.5).

(c) Cellular (internal) Respiration and Oxidation

The ultimate aim of all the respiratory activities is the cellular oxidation *i.e.*, the aerobic breakdown of the digested food materials and the release of energy thereby. The breakdown of carbohydrate may be represented by the following overall equation :

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy (686 Kcal/mole)}$$



(iii) Transport of CO_2 as bicarbonates : The rest , or about 85% of the total CO_2 is carried in the form of bicarbonates in both the plasma and red blood cells. As CO_2 enters the blood cells from the tissues, it combines with water to form carbonic acid (H_2CO_3), which dissociates to hydrogen ions (H^+) and bicarbonate ions (HCO_3^-). The latter diffuse into the plasma and with sodium or potassium ions in the plasma, form sodium or potassium bicarbonate.

$$Na^+ + HCO_3^- \longrightarrow NaHCO_3 \quad \text{(sodium bicarbonate)}$$
$$K^+ + HCO_3^- \longrightarrow KHCO_3 \quad \text{(potassium bicarbonate)}$$

It means at normal pH of mammalian blood, most of the total carbon dioxide will be present in the form of bicarbonate ion. According to Henderson-Hasselbalch equation, at pH 7.4 the ratio of carbonic acid to bicarbonate ion is 1 : 20 *i.e.*, for each one part of carbon dioxide present as acid, twenty times as much carbon dioxide is present as bicarbonate ion. The hydrogen ion formed as a result of the ionic dissociation of the carbonic acid is buffered by the various buffering substances in the blood, and the effect of carbon dioxide on the pH of the blood is therefore only moderate.

Thus, CO_2 relies on the blood salts for most of its transportation. The red blood cells contain an enzyme, *carbonic anhydrase*, which increases the speed of reaction between CO_2 and H_2O, resulting in the formation of H_2CO_3 which is rapidly converted to bicarbonates as indicated above. Thus, the enzyme is responsible in large part for the fact that most of the CO_2 in the blood is ultimately converted to the form of bicarbonate ions. But like all other enzymes, carbonic anhydrase also catalyzes the reversible reaction, that is the splitting of carbonic acid to water and carbon dioxide.

$$CO_2 + H_2O \underset{\text{(in lung capillaries)}}{\overset{\text{(in tissue capillaries)}}{\underset{\textit{carbonic anhydrase}}{\rightleftarrows}}} H_2CO_3$$

Thus, the enzyme also accounts for the rapid release of CO_2 from the blood during its passage through the lungs. Thus despite the low concentration gradient (tissue P_{CO_2} is 45 mm Hg, that of arteriolar capillaries is 40 mm Hg) carbon dioxide diffuses rapidly from the tissues into the blood. This is a good example of facilitated diffusion.

Carbon dioxide Dissociation Curve

By plotting on the ordinate the total amount of CO_2 in the blood and on the abscissa the various CO_2 partial pressures, a CO_2 dissociation curve may be constructed (Fig. 15.4). However, the curves for oxygenated and deoxygenated blood differ somewhat. This is because oxyhaemoglobin is slightly more acidic than haemoglobin. Hence, oxygenated blood will bind slightly less CO_2. This phenomenon is closely related to the *Bohr effect* which shows the other side of the coin, *i.e.*, an increase in the CO_2 shifts the oxygen dissociation curve to the right giving more oxygen from the blood to the tissues. When CO_2 is added to the blood, it pushes the containing less haemoglobin (as in anemia) carries less O_2 to the cells and tissues.

(v) Effect of pH : The acidity of the blood (pH) also affects the degree of haemoglobin saturation with oxygen. An increase in the metabolic rate in the tissues increases the CO_2 and acid metabolites. The O_2 partial pressure is thus lowered, thereby more O_2 is liberated and made available to the tissues.

(vi) Effect of 2, 3- diphosphoglycerate (DPG) : A major fraction of the phosphate in erythrocytes is present as DPG which plays an important role in the release of oxygen to the tissues. An increase in DPG concentration is associated with decreased oxygen levels such as are found in anaemia or cardiac inefficiency. DPG reacts with haemoglobin to reduce the affinity of haemoglobin for oxygen and so makes more oxygen available to the anoxic tissues. In some genetic abnormalities, DPG is reduced and the red blood cells have a short survival time.

$$HbO_2 + DPG \rightleftharpoons Hb.DPG + O_2$$

(b) Transport of Carbon dioxide

Carbon dioxide is evolved in the body as a result of haemoglobin is present as oxyhaemoglobin. As the O_2 pressure decreases further, more O_2 is given off, and all is given up when the O_2 pressure reaches zero. Thus, the degree of haemoglobin saturation is lowered with the fall in the partial pressure of O_2. In the passage of blood through the tissues where the O_2 tension is low, rapid dissociation of oxyhaemoglobin occurs, yielding a comparatively large quantity of O_2 to the surrounding tissues and cells where it is most needed.

Lungs (Po_2 = 100 mm Hg)

$$Hb + O_2 \longrightarrow HbO_2 \text{ (oxyhaemoglobin)}$$

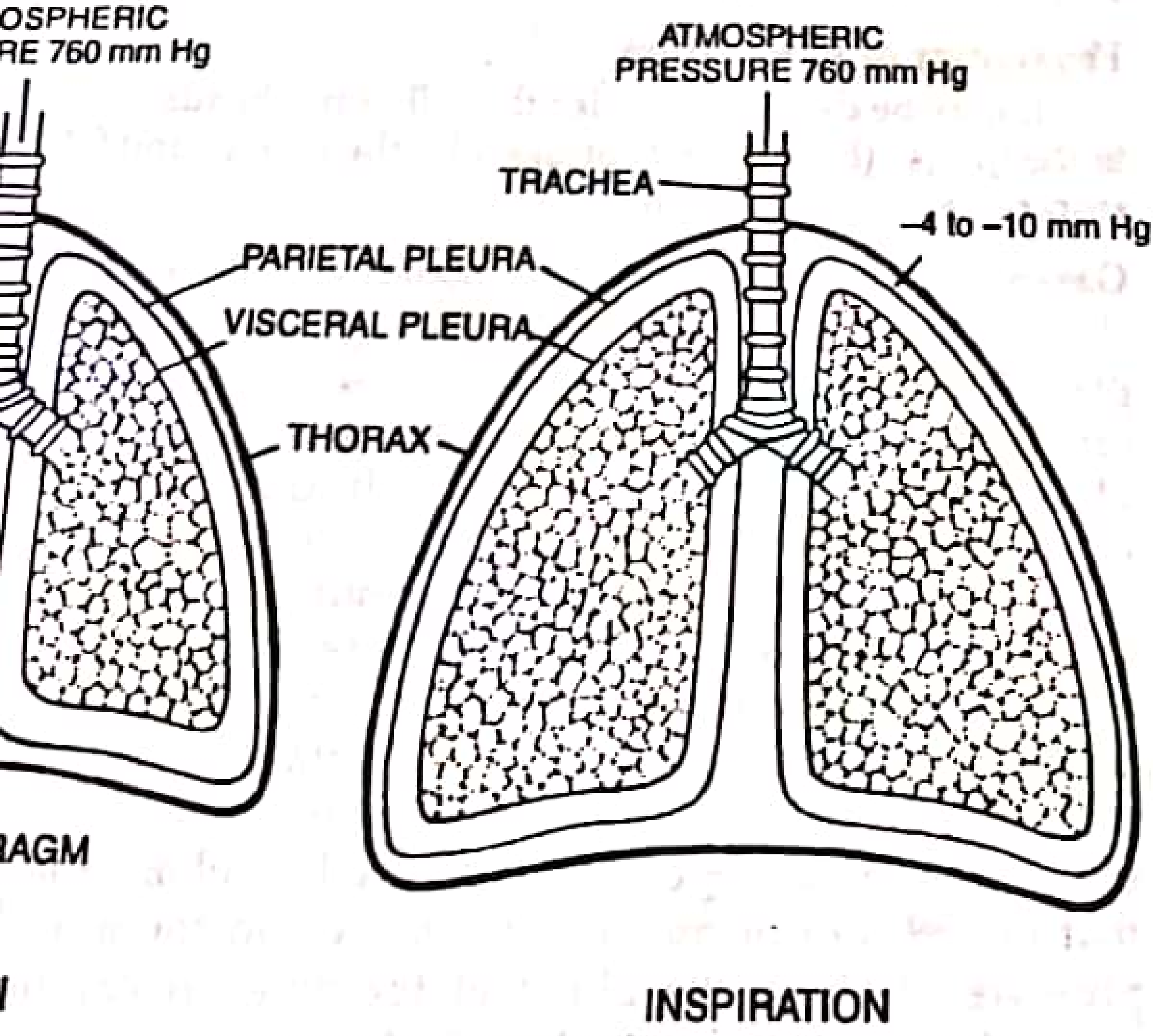
tissues (Po_2 = 30 to 40 mm Hg)

$$HbO_2 \longrightarrow Hb + O_2$$

During exercise, there is a fall in tissue Po_2, an increase in Pco_2, and an increase in pH, local temperature and 2, 3-diphosphoglycerate concentration. All these factors promote the release of oxygen from oxyhaemoglobin (shifting the oxygen-haemoglobin dissociation curve to the right) and thus increasing the efficiency of oxygen delivery to the active tissues.

Factors Affecting the Oxygen-Haemoglobin Dissociation Curve

(i) ***Effect of partial pressure of O_2*** : The degree of saturation of haemoglobin completely depends on the partial pressure of O_2. An examination of the curve tells us that haemoglobin is almost completely ... O_2 tension of 100 mm Hg, which is the same as that in ... partial pressure of O_2 beyond 100 ... haemoglobin scent of the diaphragm, decreases intrathoracic pressure from n Hg, and air pushes into the lungs. Thus, in inspiration the tending passively in response to the various mechanisms that increase in thoracic volume. In expiration, the size of the reased , the intrathoracic pressure is raised to –2 mm Hg, and ut of the lungs (Fig. 15.2).



nges in intrapleural pressure responsible for inspiration and expiration.

that the diaphragm is the main muscle of inspiration pharynx, epiglottis, glottis, larynx or voice box, trachea or windpipe and two bronchi (Fig. 15.1). Within the lungs each bronchus divides and subdivides into smaller tubes (bronchioles) which lead to the *air sacs* and alveoli.

The human lungs are made up of some 7.5×10^8 alveoli, the total surface of which is about 100 square metres, or about fifty times that of the skin surface. Thus, each lung consists of its bronchial tree with its many air sacs and alveoli units together with other associated structures such as the blood vessels, nerves and pleura. All are supported and attached to one another by the connective tissue. Externally they are covered by the *visceral pleura* (a thin layer of smooth epithelium) which is also surrounded by another similar layer, the *parietal pleura* forming the inner lining of the wall of the chest. A small amount of pleural fluid for lubrication is found in the *pleural cavity*. The normal pressure of the fluid in the intrapleural space is –10 to –15 mm Hg. This unusually negative pressure in the intrathoracic space is caused by the continuous reabsorption of fluid into the pleural capillaries by a special lymph-pump system. The *diaphragm*, a dome-shaped partition forms the floor of the chest cavity and separates it from the abdomen.

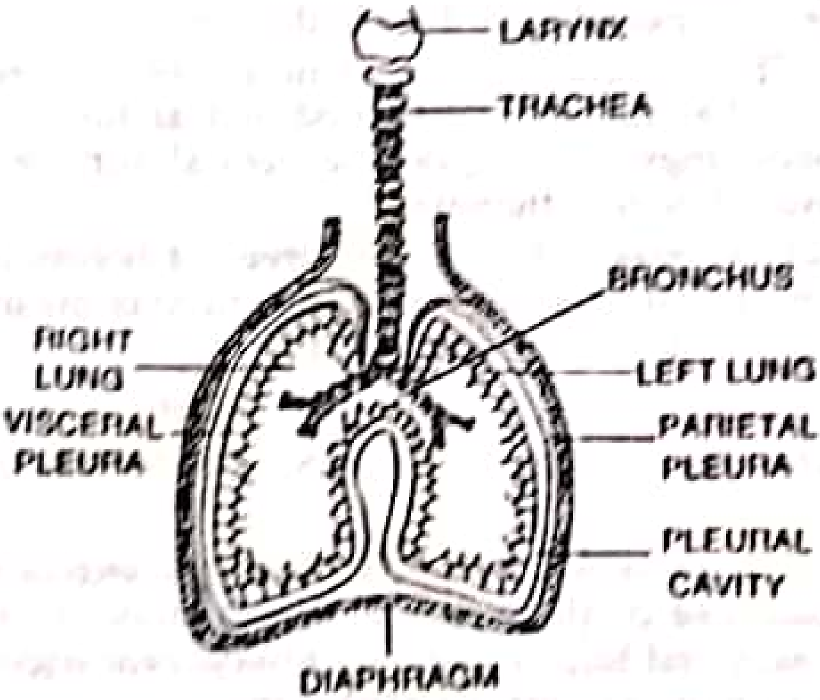


Fig. 15.1. Lungs and diaphragm in man.

Mechanism of Breathing

Breathing is a mechanical process and is completed in two phases, inspiration and expiration. In *inspiration*, the ribs are elevated and the diaphragm contracted and flattened, the chest cavity is enlarged. This and *Schepartz*, 1967). Similarly, expopeptidases are also specific in their action. *Aminopolypeptidases* attack a polypeptide on the end where a free amino group exists. *Carboxypolypeptidases* attack a polypeptide on the end where a free carboxyl group is present. The result of each reaction is the production of a free amino acid and a polypeptide molecule with reduced molecular weight. Many *dipeptidases* probably exist, each one specific to a particular dipeptide (*Smith*, 1960).

Chemical Digestion of Fats

Enzymatic hydrolysis of fat converts it into 2 kinds of smaller molecules: glycerol and fatty acids. For example, the fat known as *stearin* hydrolyzes as follows :

$$\underset{\text{stearin}}{C_3H_5O_3\,(C_{17}H_{35}CO)_3} + \underset{\text{water}}{3H_2O} \xrightarrow{\textit{lipase}} \underset{\text{1 glycerol}}{C_3H_5(OH)_3} + \underset{\text{3 stearic acid}}{3HC_{18}H_{35}O_2}$$

The digestion of fat starts in the stomach, no digestion of fat occurring in the mouth. The *lipase* of the gastric juice acts on emulsified fats such as cream. Most fat is digested in the small intestine. In the duodenum the bolus of food encounters the bile and the pancreatic juice. The presence of lipid in the small intestine stimulates the release of the gastrointestinal tentacles arise from the circumference of umbrella (5 and 6). Finally the stalk connecting the medusa bud with blastostyle breaks. The young medusa is free and it escapes through gonopore of gonangium.

Morphology of medusa:

1. Shape and Size- A fully grown *Obelia* medusa is like a radially symmetrical tiny umbrella, measuring 1 or 2 mm in diameter. Outer convex surface of the umbrella is known as ex-umbrella, while inner concave surface as sub-umbrella. Subumbrellar surface shows four radial canals and a circular canal. A mature medusa bears four gonads, one in the middle of each radial canal.

2. Manubrium- From the centre of concave sub-umbrellar surface hangs down a short, hallow, handle-shaped process, the manubrium, bearing at its free distal end a four-sided mouth surrounded by four oral lobes.

3. Velum- Circular edge of umbrella is produced inwards into a very narrow, rudimentary fold or shelf, called velum.

4. Tentacles- Rim or margin of umbrella also bears numerous short tentacles. Their bases are swollen to form tentacular bulbs that lodge sense organs called statocysts.

5. Gastro-vascular cavity- The rectangular mouth leads into a narrow passage running through the manubrium, called gullet. It is followed by a dilated gastro-vascular cavity or stomach lying at the base of manubrium and occupying the central part of umbrella.

6. Nervous System- On each side of mesogloea, nerve cells belonging to epidermis as well as gastrodermis, form nerve nets. Nerve cells are especially concentrated along the margin of bell forming two circular nerve rings, one just above and other just below the base of velum.

Histology of medusa

Basic histological structure of medusa closely resembles that of hydranth. All exposed parts i.e. exumbrellar and subumbrellar surfaces and manubrium, are

Family : Eucopidae

Genus : *Obelia*

Species : *geniculata*

Habits and Habitat

It is abundant in both Atlantic and Pacific coastal waters and occurs as asexu and sexual forms.

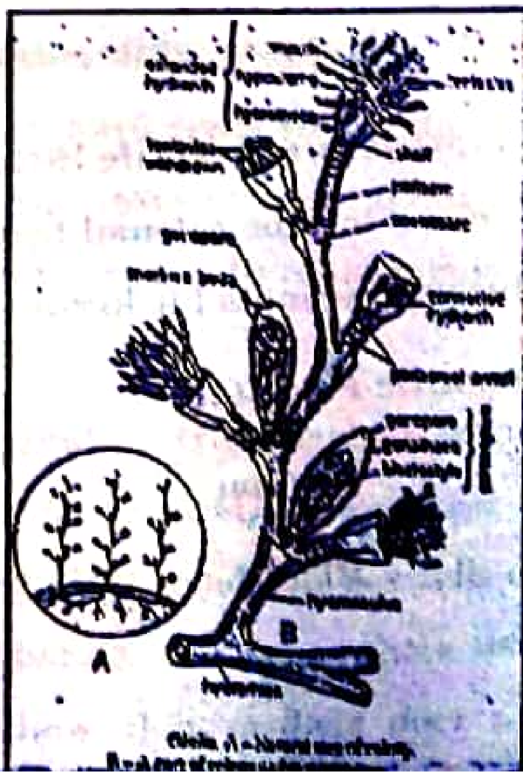
The asexual form is a prominent branched hydroid colony found attached rocks, stones, shells of animals, wooden piling , wharves, and fronds of lar seaweeds. It looks like a delicate, whitish, or light brown, almost fur-like growt

The sexual form is an inconspicuous bell or an umbrella-like face-swimmi stage, called medusa.

Hydroid Colony

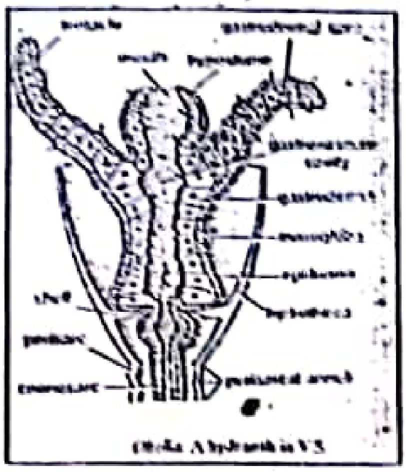
Morphology of colony:

1. **External features:** It consists of vertical branching stems, call hydrocaulus, raising 2 to 3 cm above a root-like stolon or hydrorhiza. Ea hydrocaulus branches in an alternate manner. Each ultimate bran terminates in a nutritive zooid, the polyp or hydranth. In the axils of older polyps are placed cylindrical reproductive zooids, the blastostyles or gonangia. Thus, *Obelia* colony is dimorphic, exhibiting two types of zooids. When blastostyles develop saucer-shaped bodies, called medusae, the colony becomes trimorphic.

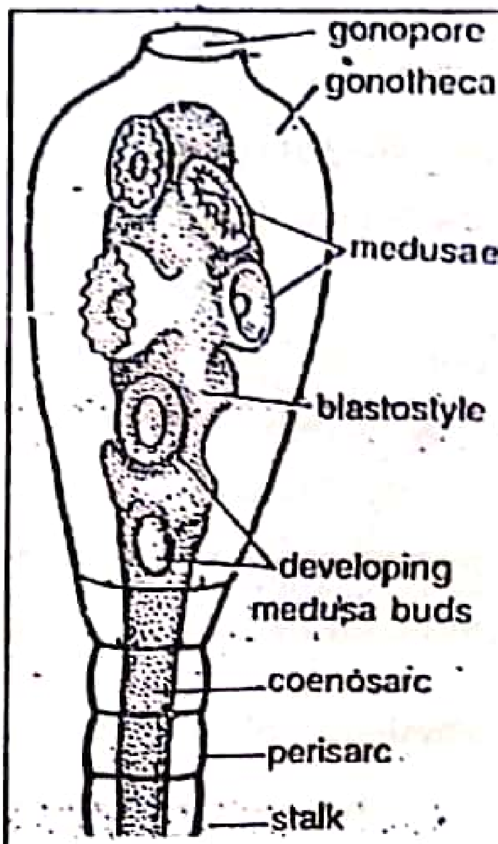


2. **Coenosarc:** Branches and zooids of colony consist of an inner, tubular and living portion, the coenosarc. It consists of a

coenosarcal or gastrovascular cavity. The cellular wall consists of two layers, an outer epidermis and an inner gasrodermis, with a gelatinous mesogloea in between.



3. Perisarc- Coenosarc is surrounded externally by a yellowish or brown, tough, transparent, and non-living chitinous layer, called perisarc. It protects the colony and serves as a supporting exoskeleton. At the base of each zooid, perisarc bears annular constrictions, called perisarcal annuli that permit limited swaying movements under the influence of water currents.



Obelia. A gonangium

4. Zooids- Hydroid colony of *Obelia* exhibits two types of zooids-

(a) Polyps or hydranths and

(b) Gonangia

(a) Polyp or Hydranth:

It is the nutritive zooid of the colony and is also called gastrozooid or trophozooid. It is yellowish in colour. Its narrow proximal end is continuous with coenosarc and distal end is produced into a conical elevation, the manubrium or hypostome. Hypostome bears a terminal aperture, the mouth and from the base of hypostome arises a circle of up to 30 filiform tentacles. Perisarc, surrounding the hydranth, dilates to form a loose, cup-like, transparent protective sheath, the hydrotheca. At the base, it is produced internally into a ring-like horizontal shelf on which rests the base of hydranth.

(b) Blastostyle or gonangium:

depolarizes cardiac muscles. Severe pain, illness and even death in human beings may occur due to the injury inflicted by siphonophores and scyphomedusae.

Thus, Nematocysts are extremely efficient weapons and are not only used for defense and for immobilizing and killing the prey but also play a very important role in locomotion.

Coral reefs and their formation

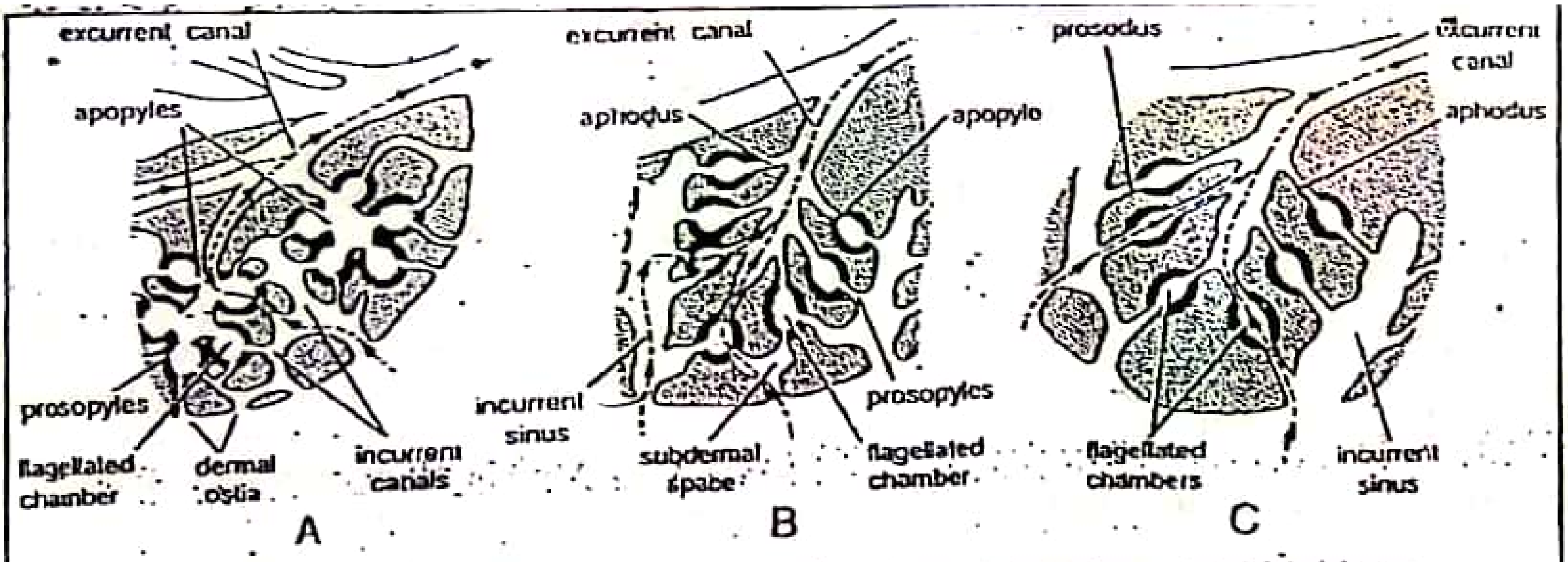
Corals

Coral animals or corals are marine, mostly colonial polyploid coelenterates, looking like miniature sea anemones and living in a skeleton of their own. Their calcareous or horny skeleton is also commonly known as coral. The coral colony grows continuously in size by budding of the polyp and often forms coral reefs and coral islands. According to Vaughan (1917), "A coral reef is a ridge or mound of lime stone, the upper surface of which is near the surface of the sea and it is formed of Calcium carbonate by the action of organisms, chiefly corals," The coral reefs are banks of coral rocks built upon the sea-bottom, about the shores of tropical islands. They are confined to zones extending about 28 degree on either side of the equator. They secrete calcareous skeleton, which along with the shells of molluscs, echinoderms, annelids, and foraminifera's get cemented together into a compact rock by encrusting organisms and by depositing lime in course of time assume huge size.

Kinds of coral reefs

The coral reefs are mainly of three types:

(1) Fringing Reef: Coral reefs lying close to the shores of some volcanic island or part of some continent are called fringing reefs. A fringing reef may extend out to a distance of a quarter mile from the shore with the most active zone of the coral growth facing the sea. This seaward zone is commonly called the edge or front. A shallow water channel, 50 to100 meters broad, lies between the reef-



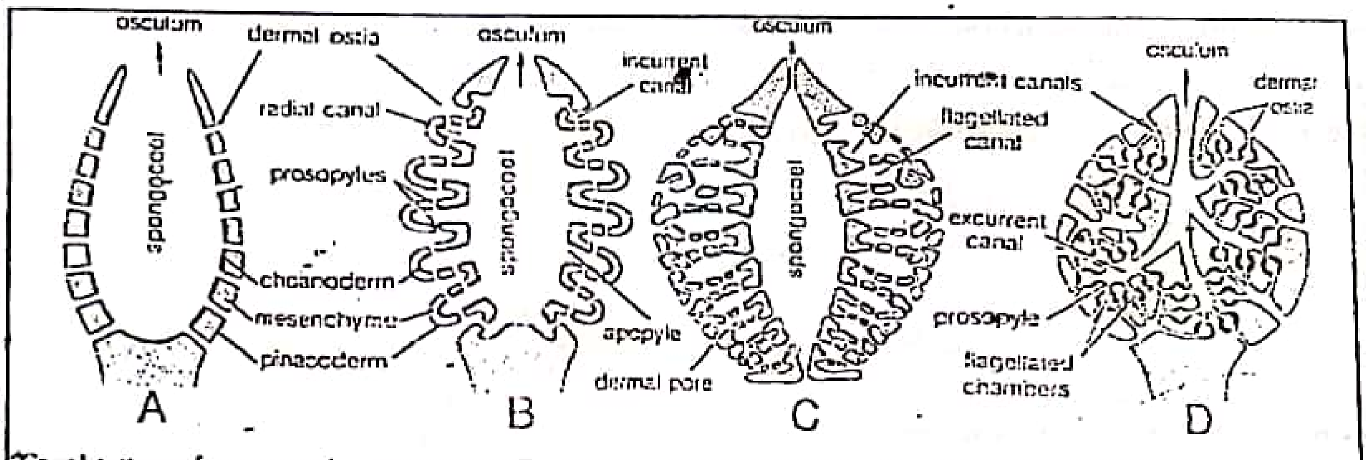
Grades in leucon type of canal system. A – Eurypylous. B – Aphodal type. C – Diplodal type.

1. Ascon type

2. Sycon type

3. Leucon type

4. Rhagon type



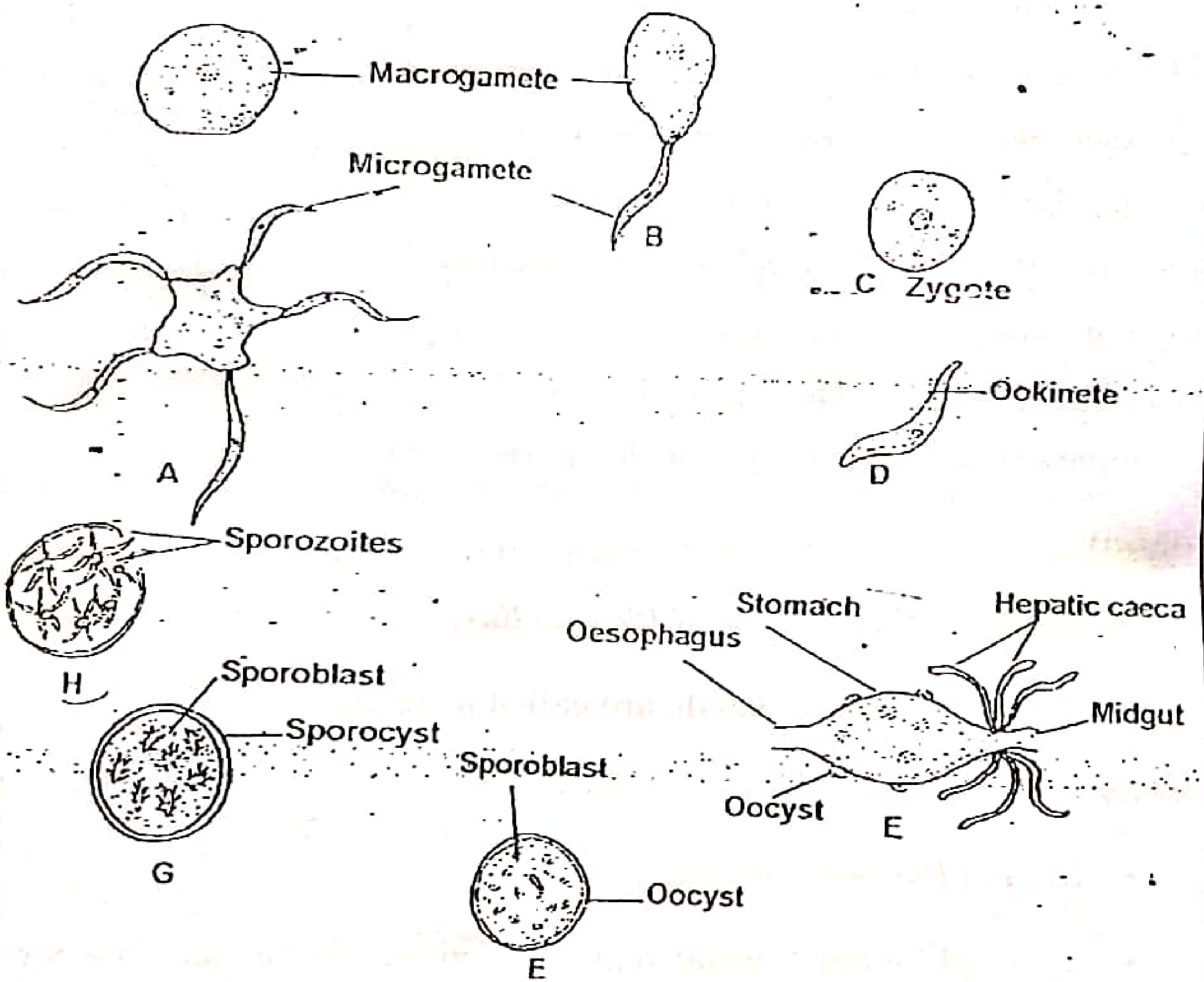
Canal system of sponges. A—Ascon type. B—Simple sycon type. C—Complex syconoid type with cortex, D—Leucon Type

Ascon type:

It is the simplest type of canal system and is found in *Leucosolenia*. The canals originate from certain pores or ostia, present on the surface of the body wall and lead directly into the spongocoel. Spongocoel is lined by flagellated choanocyte cells. Spongocoel opens to outside through a narrow circular opening, the osculum located at the distal free end. The course of water current is as under:-

Ingressing water —Through Ostia→ Spongocoel —Through Osculum→ To outside

This type of canal system is a more complex system of pores and canals and is characteristic of syconoid sponges, like *Scypha* and *Grantia*. It can be theoretically derived from the asconoid type by horizontal folding of its wall. Body wall of syconoid sponges includes two types of canals, incurrent and radial, paralleling and alternating with each other. Both types of canals end blindly in body wall but are interconnected by minute pores. Incurrent pores or



Sporogony in *Plasmodium*. (A) Macrogamete and microgamete (B) Fusion of gametes (C) Zygote (D) Ookinete (E) Stomach of female *Anopheles* showing oocyst (F) Development of sporoblast (G) Formation of sporozoites (H) Liberatian of sporozoites

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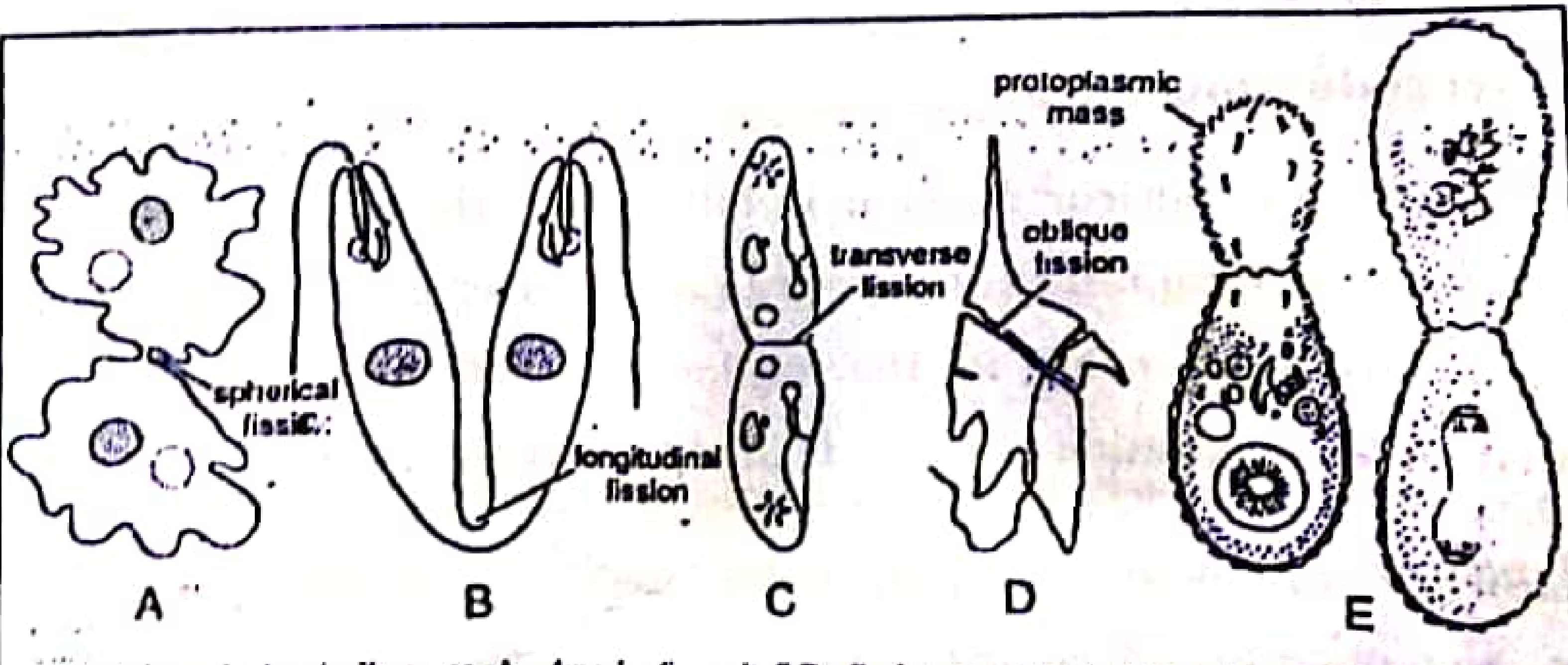
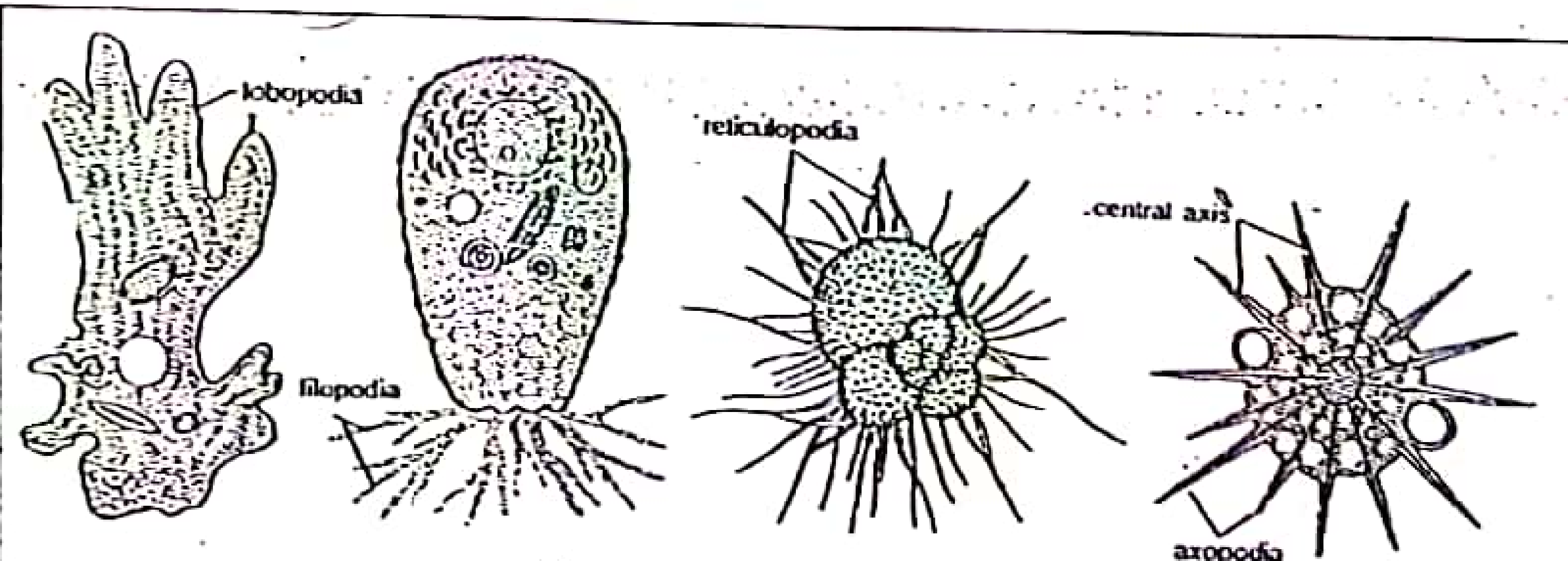
helled Sarcodina (e.g. *Euglypha, Arcella)* a mass of protoplasm extends ... opening of shell, which secretes a new shell. This double-shelled organ... divides into two.



Binary fission in Protozoa. A–*Amoeba* (irregular) B–*Euglena* (longitudinal). C–*Paramecium* (transverse) D–*Ceratium* (oblique). E–*Euglypha* (Two stages in fission).

eudopodia

ucture of Pseudopodia- Pseudopodia, also known as false feet, nporary structures formed by the streaming flow of cytoplasm. They are r types:



Types of Pseudopodia