Lecture No. B1MICP1U5.2

General Account and Economic Importance of Protozoa (Amoeba , Paramecium , Euglena , Plasmodium)

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1. AMOEBA

Systematic Position

Phylum: Protozoa
Class: Rhizopodea
Order: Amoebida
Genus: Amoeba
Species: *proteus*

HABITAT-

Amoeba proteus is a unicellular organism widely distributed in ponds, lakes, freshwater pools and slow streams. Normally it is found creeping, feeding upon algae, bacteria etc. Amoeba proteus lives on the bottom of fresh water ponds, streams and ditches, gliding on the algae-covered mud or crawling on the surface of green submerged plants.

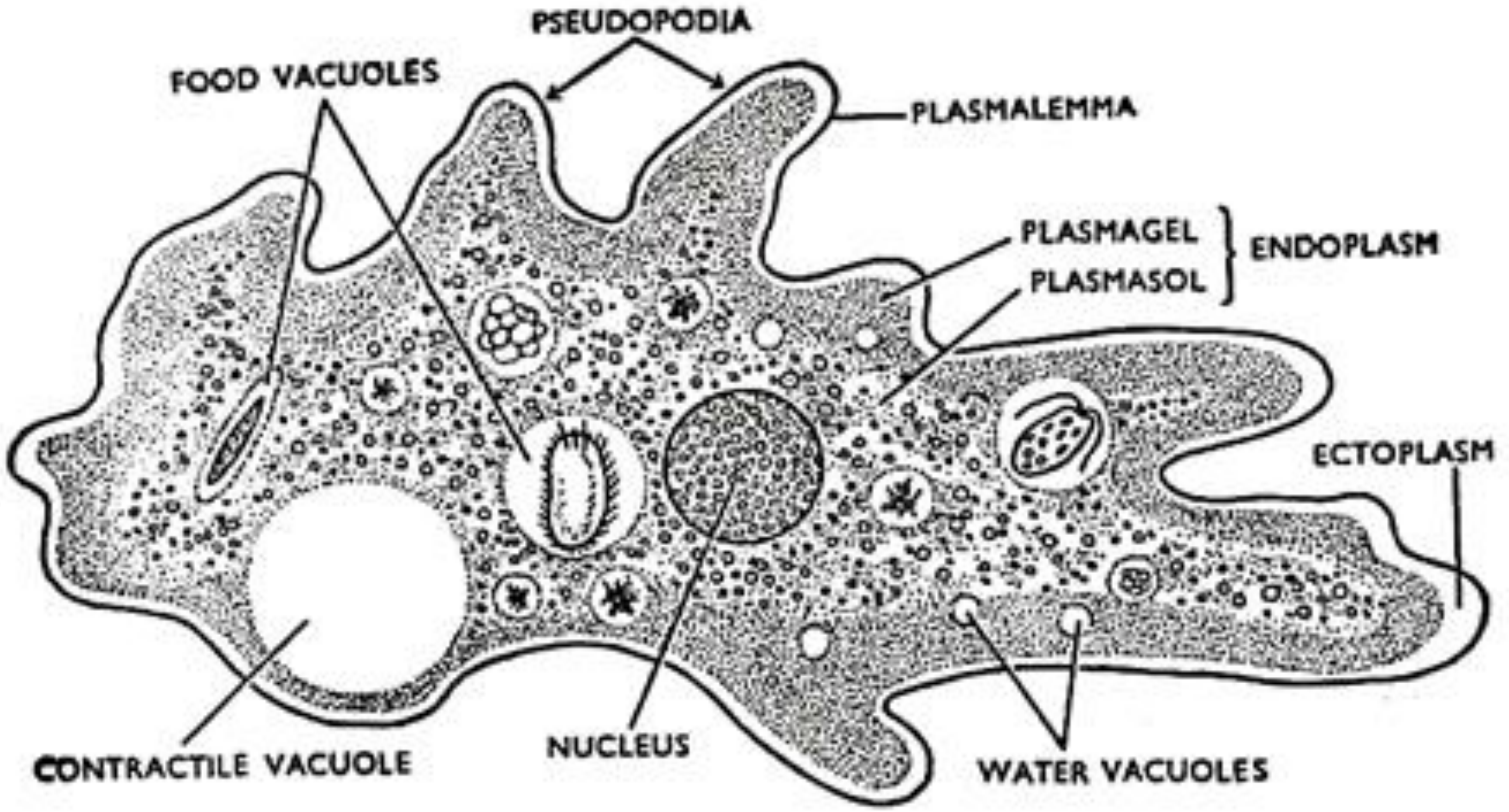


Fig. 46. *Amoeba proteus*.

Structure of Amoeba

It appears as irregular, jelly-like tiny mass of hyaline protoplasm. Amoeba has no fixed shape and the outline of body continues changing due to formation of small finger like outgrowths called pseudopodia. Pseudopodia are temporary finger like projections with blunt rounded tips which are constantly being given out or withdrawn by the body. Amoeba exhibits movement by the pseudopodia. It also helps in food capture.

Amoeba has 3 main parts: Plasma lemma or plasma membrane, Cytoplasm and nucleus.
Plasma lemma is a very thin, delicate and elastic cell membrane. It is composed of a double layer of lipid and protein molecules. This membrane is selectively permeable and regulates exchange of water, oxygen and carbon dioxide between the animal and the surrounding medium. From the outer surface, small ridge like projections arise which helps in fixing the organism to the substratum.

The cytoplasm is differentiated into Ectoplasm and endoplasm. The ectoplasm forms the outer and relatively firm layer lying just beneath the plasma lemma. It is a thin, clear (non-granular) and hyaline layer It is thickened into a hyaline cap at the advancing end at the tips of pseudopodia.

The ectoplasm has a number of conspicuous longitudinal ridges. Due to the presence of longitudinal ridges in the ectoplasm, it is considered as a supporting layer. The endoplasm forms the main body mass completely surrounded by the ectoplasm. It is granular heterogeneous fluid. The endoplasm is made up of an outer, relatively stiff plasmagel and a more fluid inner plasmasol.

Nucleus:
In Amoeba proteus, there is a single conspicuous nucleus. The nucleus appears as a biconcave disc in young specimens but it is often folded and convoluted in older specimens. The nucleus has a firm nuclear membrane and contains a clear achromatic substance with minute chromatin granules or chromidia distributed uniformly near the surface. The nucleoplasm is small in quantity. Such a nucleus is called **massive or granular nucleus**.

Contractile vacuole:
The outer part of the endoplasm near the posterior end contains a clear, rounded and pulsating vacuole filled with a watery fluid. This vacuole, called the contractile vacuole, is enclosed by a unit membrane.

Food vacuoles:
Numerous food vacuoles are scattered in the endoplasm. These are non- contractile and of different size. Each food vacuole contains a morsel of food under digestion. The food vacuoles are carried about by the movements of the endoplasm. Digestion of food takes place inside the food vacuole.

Reproduction in amoeba is a periodic process taking place at intervals. Reproduction in amoeba chiefly occurs by asexual method, i.e., by **binary fission**, **multiple fission** and **sporulation.**

(i) Binary fission:

It is the most common mode of reproduction. In this process, the whole body divides into two daughter amoebae by mitosis. The division involves nuclear division (karyokinesis) followed by division of cytoplasm (cytokinesis) .This takes place during favourable conditions.

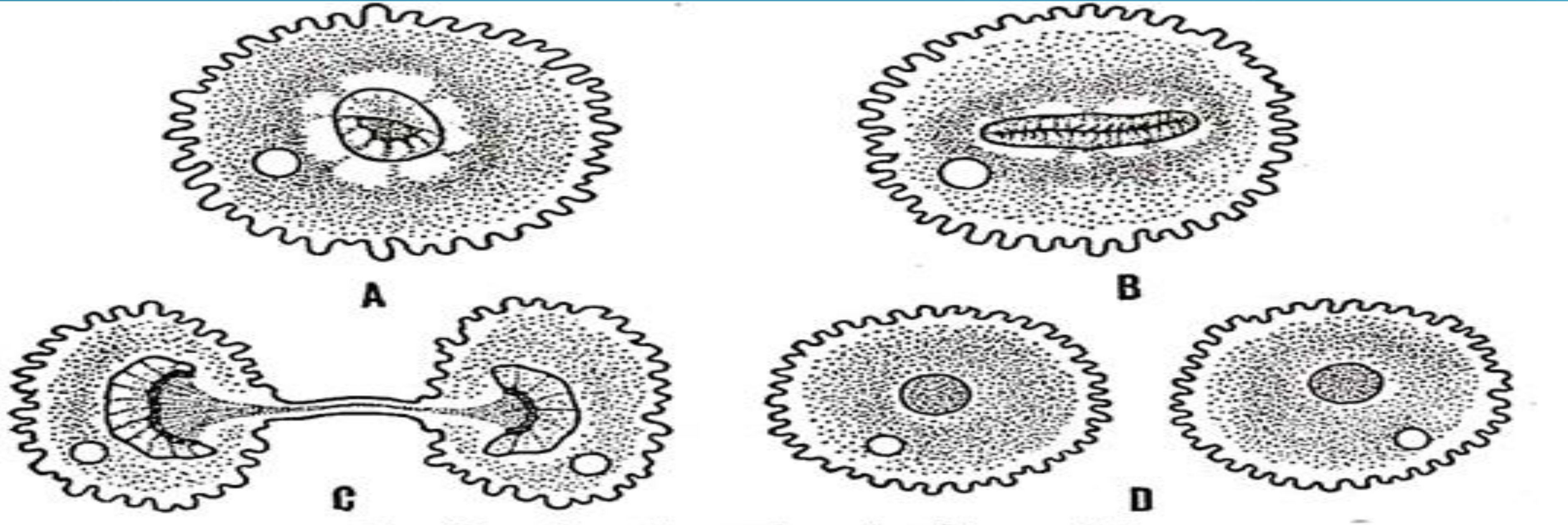


Fig. 48. Amoeba undergoing binary fission.

Sporulation:

Under un-favourable conditions amoeba reproduces by formation of spores internally. It starts with the breakdown of nuclear membrane and release of chromatin blocks into the cytoplasm. Each chromatin blocks acquires a nuclear membrane and becomes a small daughter nuclei. The newly formed nuclei get surrounded by cytoplasm to form amoebulae.

About 200 such spores are formed inside a single parent amoeba. Finally the body of parent amoeba disintegrates to release the spores. The spore remain inactive for some time and on getting favourable conditions each spore forms a young amoeba.

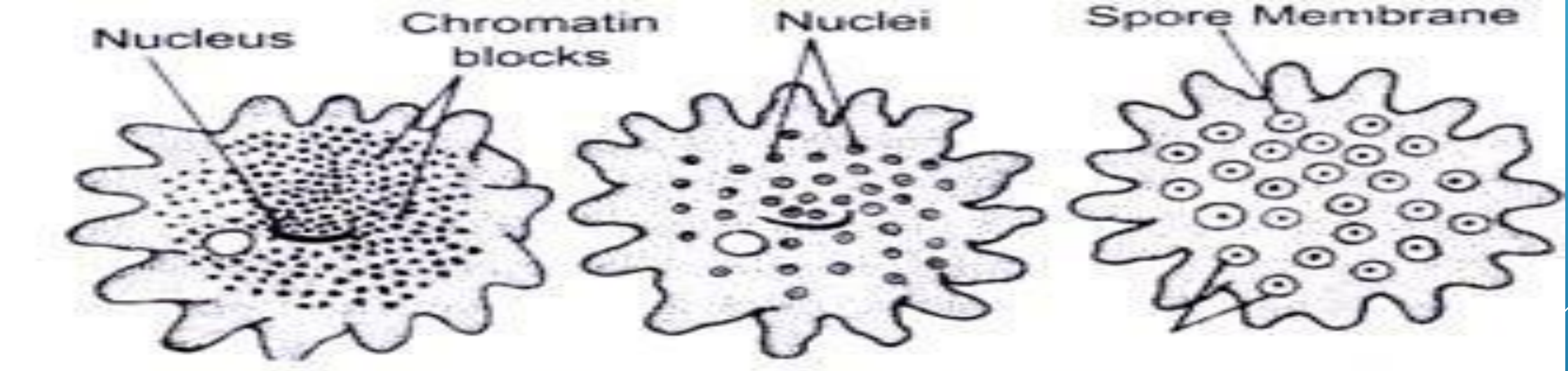


Fig. 9.9 Sporulation in Amoeba

iii) Multiple fission:

In un-favourable conditions, amoeba divides by multiple fission. It withdraws its pseudopodia, becomes spherical and secretes three layered cyst around itself. Its nucleus undergoes repeated mitosis division forming 500- 600 daughter nuclei. Each daughter nucei gets surrounded by mass of cytoplasm and divides into minute amoebulae. On getting favourable conditions the cyst ruptures to release the amoebulae which soon grows into adult amoeba

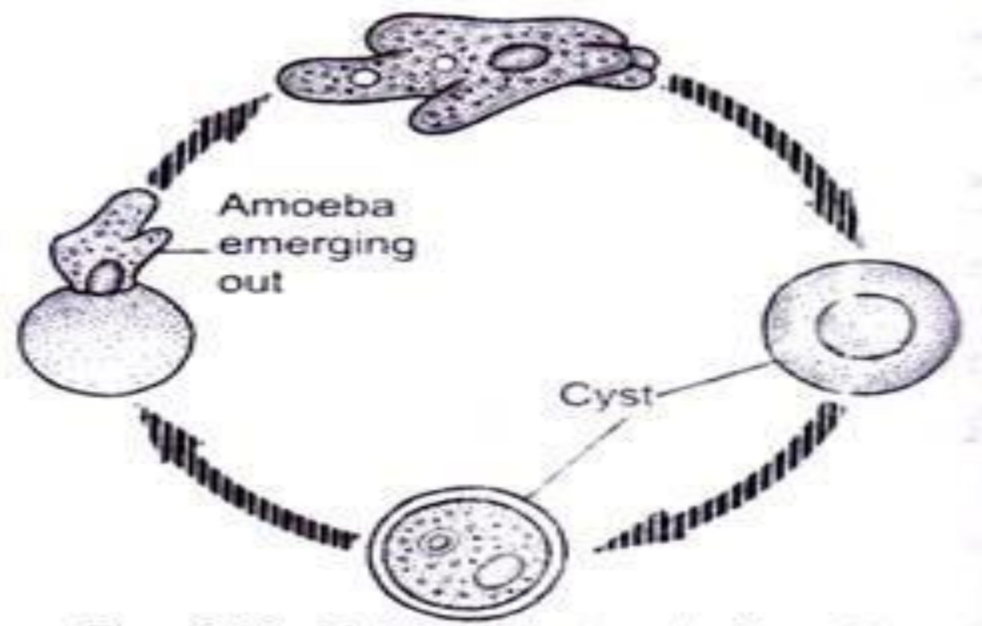


Fig. 9.10. Multiple Fission in Amoeba

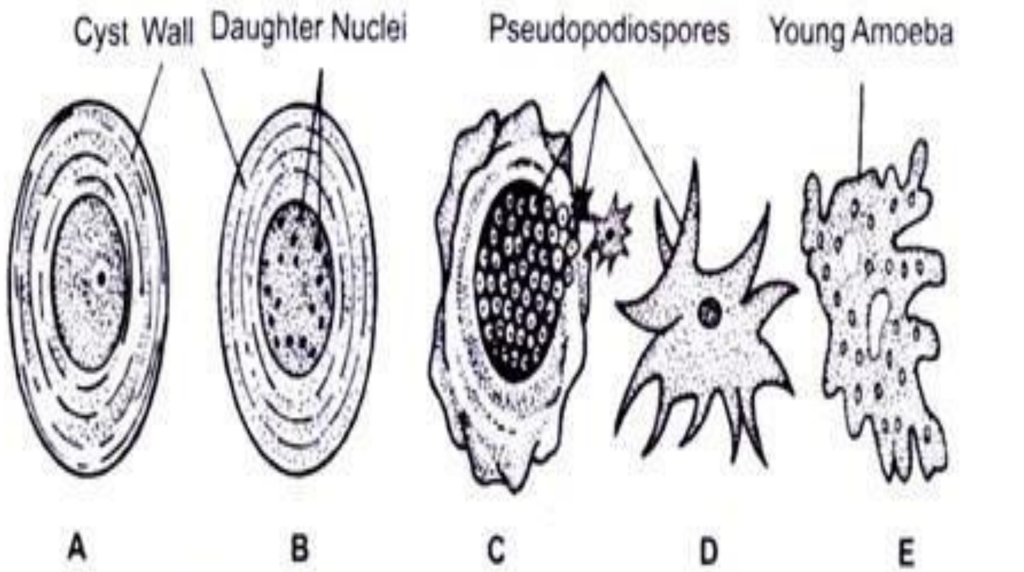


Fig. 9.11. Stages of multiple fission in Amoeba.

Regeneration:
Amoeba has tremendous power of regeneration. If it is cut into small pieces, each piece regenerates into a new amoeba, however, a piece without nuclear fragment does not regenerate

Nutrition

The food of Amoeba consists of small algae and other actively moving protozoa
Its dishes include Desmids, Oscillatoria, Paramoecium, Colpidium, and a small flagellate called Chilomonas. Food may be ingested anywhere on the surface of the body but it is usually taken in at the anterior end. . The Amoeba sends out pseudopodia which engulf the prey by forming a food-cup. the food is completely surrounded on all sides along with a drop of water. The result is a food vacuole whose walls are formed by the plasma- membrane and which contains the food suspended in water . The food vacuole serves as a temporary stomach secreting digestive juice. The digestive juice contains free hydrochloric acid and appropriate enzymesThe food vacuole gradually decreases in size with the progress of digestion, and at the end only indigestible residue is left behind. This is now egested out of the body.

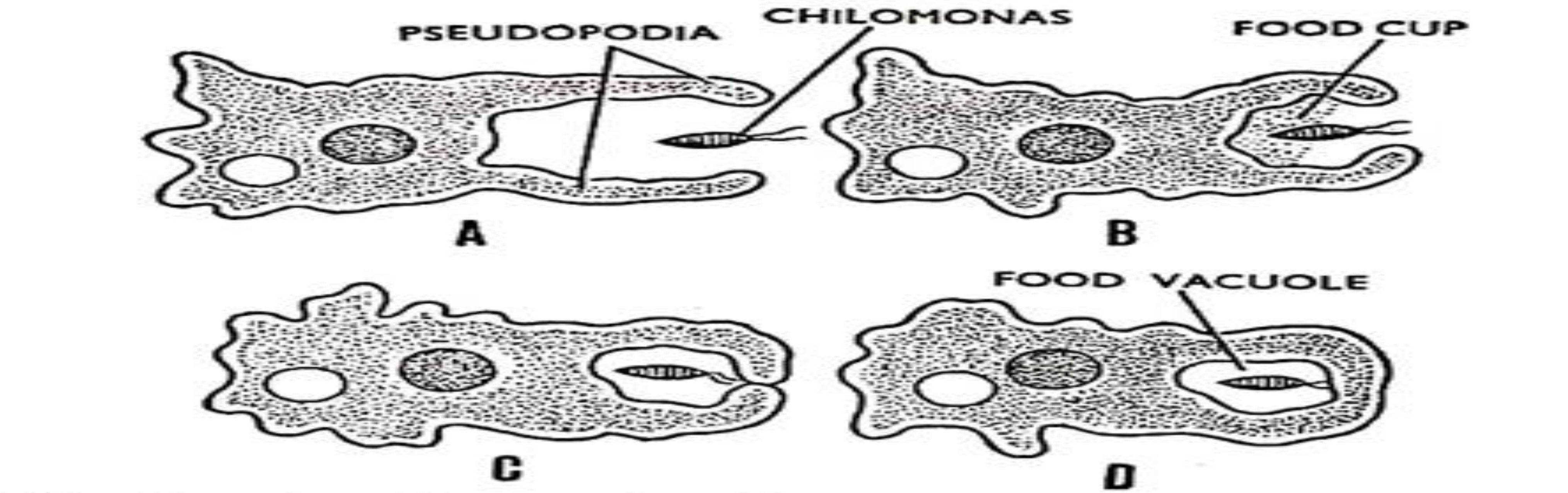


Fig. 47. Amoeba running after and engulfing a Chilomonas.

Excretion

The Amoeba forms nitrogenous waste products such as ammonia and urea, and other mineral substances in the course of its metabolism .Major part of the waste products are, however, eliminated through the permeable plasma lemma from the surface of the body.

Respiration

The Amoeba requires oxygen for the physiological burning of stored food, so that it may derive energy for its locomotion. The oxygen diffuses into the cytoplasm through the plasma lemma. The resulting CO_2 collects as bubbles in the contractile vacuole and is expelled from the body

2. Paramecium

Habitat

Paramecium caudatum (Gr., paramekes = oblong; L., caudata = tail) is commonly found in freshwater ponds, pools, ditches, streams, lakes, reservoirs and rivers. It is specially found in abundance in stagnant ponds rich in decaying matter, in organic infusions, and in the sewage water.

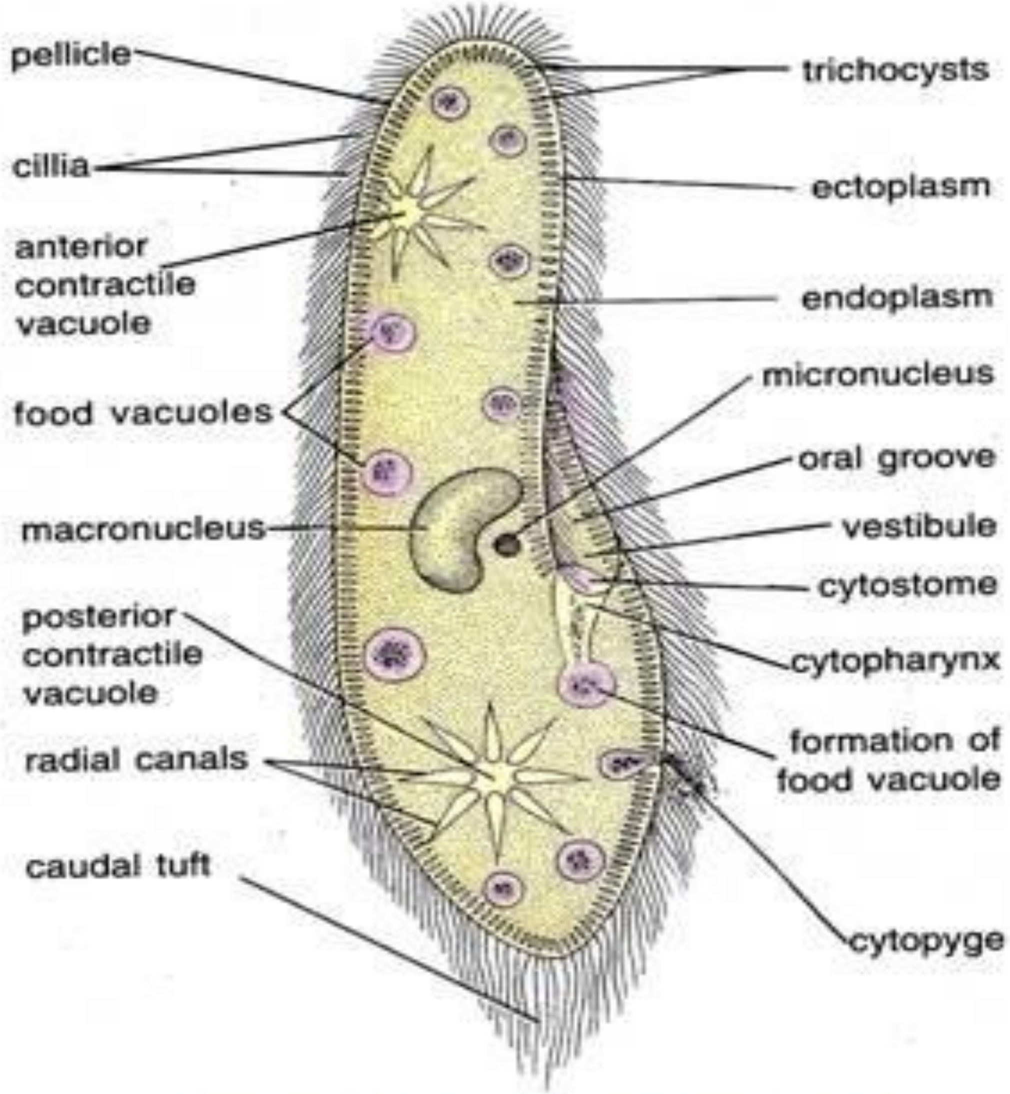


Fig. 20.1. *Paramecium caudatum.*

Paramoecium caudatum is a microscopic organism and visible to the naked eyes as a minute elongated body.

It appears light gray or white measuring commonly between 170 to 290 microns in length and may attain a length up to 300-350 microns. P. *caudatum* looks like the sole of a slipper or shoe, hence, the animal is commonly known as **slipper animalcule.**

The anterior part is slender with a blunt or rounded end, while the posterior end is pointed or cone-shaped. The widest part of the organism is just below the middle. The body of the animal is **asymmetrical** in form showing a well defined oral or ventral surface and an aboral or dorsal one.

pellicle The body is covered by a thin, double layered, elastic and firm pellicle made of gelatin The pellicle has double membrane, the outer membrane is continuous with the cilia and the inner membrane with the ectoplasm.
The anterior and posterior margins of hexagonal depressions bear the openings of trichocysts the hexagonal depressions correspond to regular series of cavities, the alveoli. All alveoli collectively form a continuous alveolar layer, which is delimited by an outer alveolar and inner alveolar membranes.

Cilia:

The entire body is covered with numerous, small, hair like projections called cilia. Cilia occur in longitudinal rows all over the body, this condition is known as holo-trichous in which the body cilia are equal.

Each cilium arises from a basal granule or kinetosome.

Oral Groove and Cytopyge:

On the ventrolateral side is a large oblique, shallow depression called oral groove or peristome which gives the animal an asymmetrical appearance. It runs obliquely backwards from one side (usually left to right but in some cases right to left) and ending a little behind the middle body. The oral groove leads into a short conical funnel-shaped depression called vestibule.

The vestibule leads directly into the fixed, oval-shaped opening called cytostome (mouth). Extending directly from the cytostome toward the centre of the body is the wide cytopharynx. The cytopharynx then turns sharply towards the posterior side to become the slender tapering oesophagus.

Thus, the oesophagus is roughly parallel to the body surface of Paramecium except at its posterior extremity.

The cytopyge (also termed cell anus or anal spot or cytoproct) lies on the ventral surface of the body almost vertically behind the cytostome or mouth. Undigested food particles are eliminated through the cytopyge.

Cytoplasm:
The cytoplasm is differentiated into a narrow, external or cortical zone called the ectoplasm and a larger, internal or medullary region called the endoplasm.
Ectoplasm:
The ectoplasm is a permanent part of the body, strikingly delimited from the endoplasm. Ectoplasm forms a firm, clear, thin and dense outer layer. It contains the trichocysts , cilia and fibrillar structures and is bounded externally by a covering called pellicle.
Endoplasm:
The endoplasm or medulla is the more fluid and voluminous part of the cytoplasm which contains many cytoplasmic granules as well as other inclusions and structures.
The cytoplasmic inclusions are mitochondria, Golgi apparatuses, vacuole, crystals, granules and chromidia, etc. Nuclei, contractile vacuoles and food vacuoles are also found in the endoplasm.
Nuclei:
In the endoplasm near the cytostome are two nuclei, i.e., Paramecium **is heterokaryotic**, a **large ellipsoidal and granular macronucleus and other small compact micronucleus.**

Macronucleus is a conspicuous, ellipsoidal or kidney-shaped body. It is of a compact type containing fine threads and tightly packed discrete chromatin granules of variable size and embedded in an achromatic matrix. It possesses many nucleoli and much more chromatin material (DNA).
It is somatic or vegetative nucleus. It divides amitotically and controls the vegetative functions (metabolic activities) of the animal. It does undergo mitosis.
Micronucleus is small, compact and spherical. It is generally found close to the macronucleus often in a concavity. Fine chromatin granules and threads are uniformly distributed throughout the structure. The micronucleus divides mitotically and controls the reproduction.

Locomotion of Paramecium :
Paramecium caudatum performs locomotion by two methods, viz., metaboly or body contortions and by cilia. The body of *Paramecium caudatum* possesses elasticity, it can squeeze itself through a passage narrower than its body, after which the body assumes its normal shape. This temporary change of body shape is metaboly,

Nutrition of Paramecium :
In *Paramecium caudatum*, nutrition is holozoic. The food comprises chiefly bacteria and minute Protozoa. Paramecium does not wait for the food but hunts for it actively.

Respiration and Excretion of Paramecium :
The exchange of gases (oxygen and carbon dioxide) takes place through the semi-permeable pellicle by the process of diffusion

Osmoregulation in Paramecium :
Paramecium has two contractile vacuoles, one anterior and one posterior. The function of the contractile vacuoles is osmoregulation, i.e., to regulate the water contents of the body and may serve also in excretion of nitrogenous wastes such as urea and ammonia.

The responses of Paramecium to different stimuli –

Reactions to contact (Thigmotaxis):
Response to contact is varied in Paramecium. If the anterior end is lightly touched with a fine point, a strong avoiding reaction occurs.

Reactions to chemicals (Chemotaxis):
Generally Paramecia respond to a chemical stimuli by means of avoiding reaction

Reactions to temperature (Thermotaxis):
Paramecium seeks an optimum temperature of 24 to 28°C. When a temperature change occurs markedly above or below the optimal range, Paramecia show an avoiding reaction.

Reproduction in Paramecium

Paramecium caudatum reproduces asexually by transverse binary fission and also undergoes several types of nuclear re-organisation, such as conjugation, endomixis, autogamy, cytogamy and hemixis, etc.

(i) Transverse Binary Fission:

It is a distinctly unique asexual process in which one fully grown specimen divides into two daughter individuals without leaving a parental corpse.

The plane of division is through the centre of the cell and in a plane at right angles to the long axis of the body. Division of the cell body as a whole is always preceded by division of the nuclei; indeed it appears that reproduction is initiated by nuclear activity and division

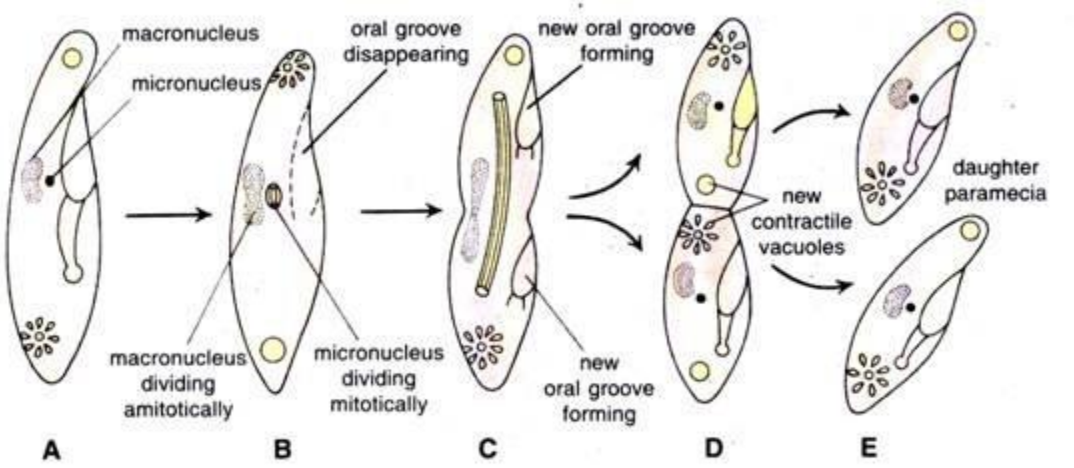


Fig. 20.20. *Paramecium caudatum*. Binary fission.

Conjugation:
Conjugation is defined as the temporary union of two individuals which mutually exchange micro nuclear material. It is unique type of a sexual process in which two organisms separate soon after exchange of nuclear material.

Conjugation Process

In conjugation two Paramecium of the opposite mating types of the same variety come together with their ventral surfaces and unite by their oral grooves; their cilia produce a substance on the surface of the body which causes adhesion of the two conjugating paramecia.

The pellicle and ectoplasm, at the point of contact, of both break down, and a protoplasmic bridge is formed between the two animals.

The macronucleus begins to disintegrate, it becomes loose in texture and forms a complex twisted skein, during the latter half of the conjugation period it will finally disappear being absorbed in the cytoplasm.

The micronucleus of each conjugant divides twice, one of them being a reduction division.
Thus, four haploid daughter micronuclei are produced in each conjugant. Three of these four micronuclei degenerate in each, so that only one remains.
The remaining micronucleus of each conjugant divides mitotically into two unequal gametic nuclei forming a larger stationary female pro-nucleus and a smaller, active migratory male pro-nucleus.

The migratory pro-nucleus of one conjugant crosses over the protoplasmic bridge and fuses with the stationary pro-nucleus of other conjugant to form a synkaryon or conjugation nucleus in which the diploid number of chromosomes is restored and there has been an exchange of hereditary material.

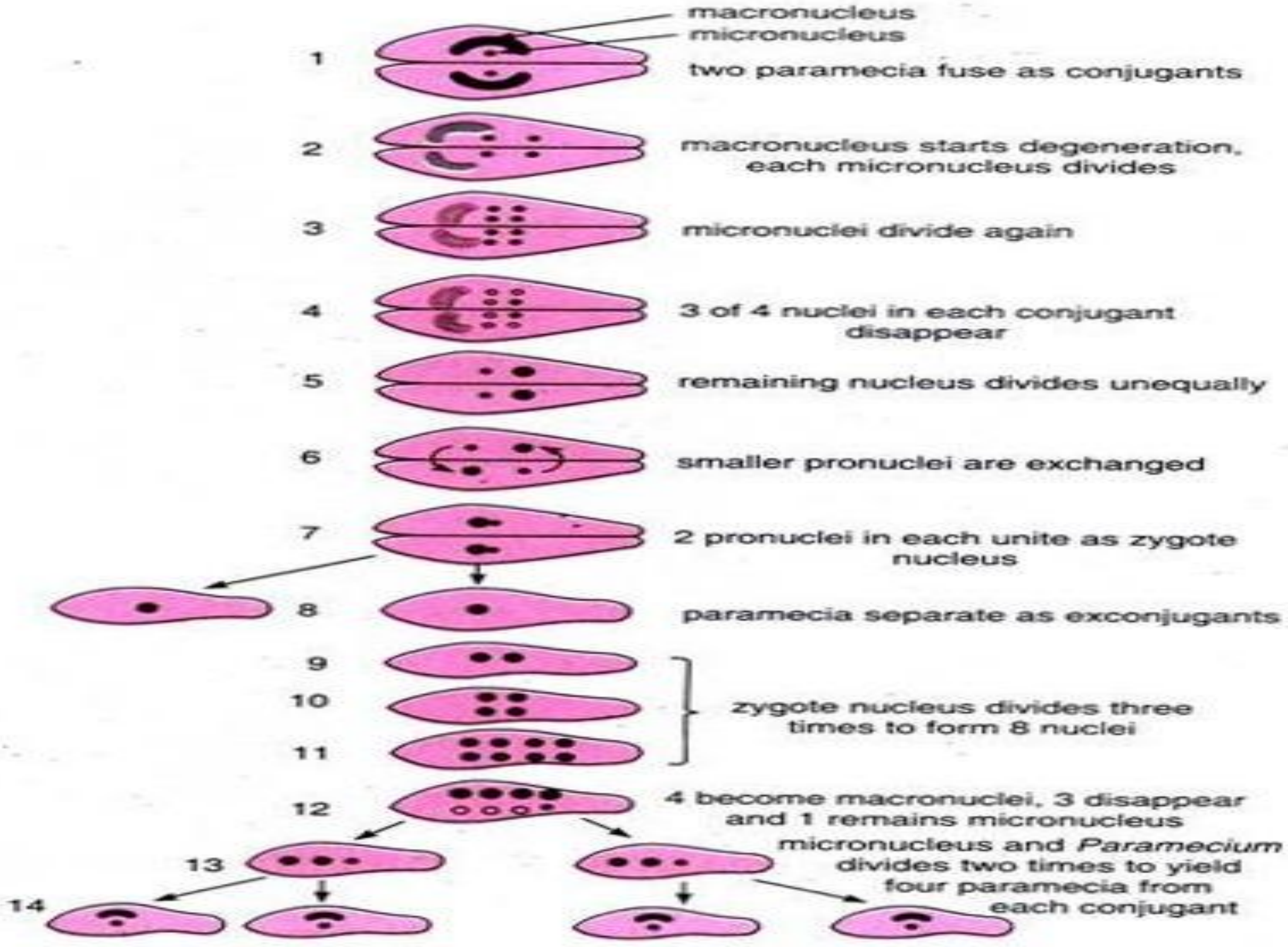


Fig. 20.21. *Paramecium caudatum.* **Stages of conjugation.**

kappa particles

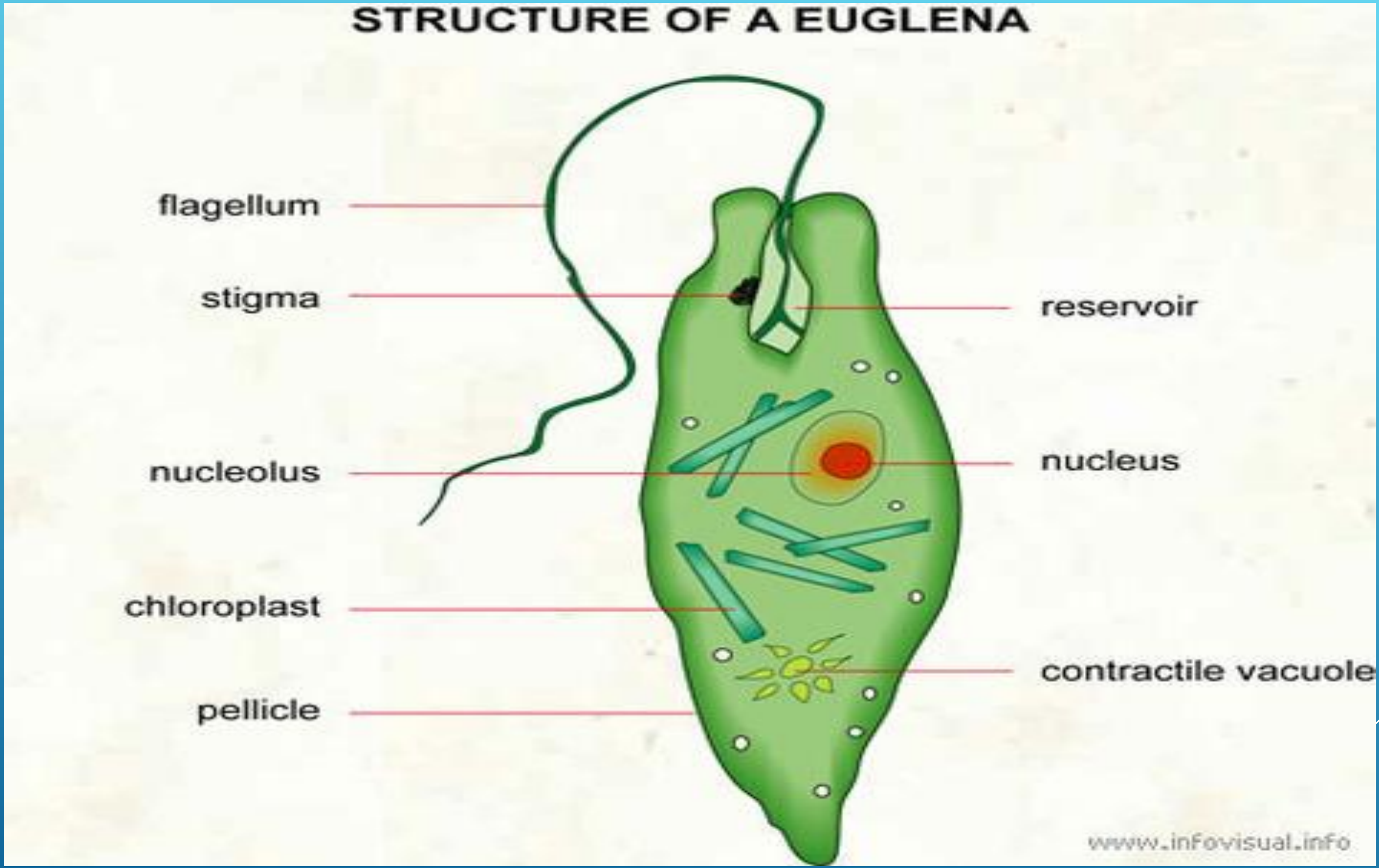
Some killer strain of Paramecium produce a poisonous substance, called paramecin which is lethal to other individuals. The paramecin is water soluble, diffusible and depends for its production upon some particles located in the cytoplasm of the Paramecium.
These particles are called kappa particles. The kappa particles have DNA and RNA.

3.Euglena

Euglena are tiny protist organisms, These single-celled eukaryotes have characteristics of both plant and animal cells. Like plant cells, some species are photoautotrophs (photo-, -auto, -troph) and have the ability to use light to produce nutrients through photosynthesis.

Like animal cells, other species are heterotrophs (hetero-, -troph) and acquire nutrition from their environment by feeding on other organisms.

There are thousands of species of *Euglena* that typically live in both fresh and saltwater aquatic environments. *Euglena* can be found in ponds, lakes, and streams, as well as in waterlogged land areas like marshes.


STRUCTURE OF A EUGLENA
flagellum
stigma
reservoir
nucleolus
nucleus
chloroplast
contractile vacuole
pellicle
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Euglena Cell structure

Pellicle: a flexible membrane that supports the plasma membrane
Plasma membrane: a thin, semi-permeable membrane that surrounds the cytoplasm of a cell, enclosing its contents

Cytoplasm: gel-like, aqueous substance within the cell
Chloroplasts: chlorophyll containing plastids that absorbs light energy for photosynthesis
Contractile Vacuole: a structure that removes excess water from the cell
Flagellum: cellular protrusion formed from specialized groupings of microtubules that aid in cell movement

Photoreceptor or Paraflagellar Body: This light-sensitive region detects light and is located near the flagellum. It assists in phototaxis (movement toward or away from light).

Paramylon: This starch-like carbohydrate is composed of glucose produced during photosynthesis. It serves as a food reserve when photosynthesis is not possible.

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Nucleus: a membrane-bound structure that contains DNA.

Nucleolus: structure within the nucleus that contains RNA and produces ribosomal RNA for the synthesis of ribosomes.

Mitochondria: organelles that generate energy for the cell.

Ribosomes: Consisting of RNA and proteins, ribosomes are responsible for protein assembly.

Reservoir: inward pocket near the anterior of the cell where flagella arise and excess water is dispelled by the contractile vacuole.

Golgi Apparatus: manufactures, stores, and ships certain cellular molecules.

Endoplasmic Reticulum: This extensive network of membranes is composed of both regions with ribosomes (rough ER) and regions without ribosomes (smooth ER). It is involved in protein production.

Lysosomes: sacs of enzymes that digest cellular macromolecules and detoxify the cell.

Reproduction of Euglena

Most *Euglena* have a life cycle consisting of a free-swimming stage and a non-motile stage. In the free-swimming stage, *Euglena* reproduce rapidly by a type of asexual reproduction method known **as binary fission**. The euglenoid cell reproduces its organelles by mitosis and then splits longitudinally into two daughter cells.

When environmental conditions become unfavorable and too difficult for *Euglena* to survive, they can enclose themselves within a thick-walled protective cyst. Protective cyst formation is characteristic of the non-motile stage.

some euglenids can also form reproductive cysts in what is known as the palmelloid stage of their life cycle. In the **palmelloid** stage, Euglena gather together (discarding their flagella) and become enveloped in a gelatinous, gummy substance. Individual euglenids form reproductive cysts in which binary fission occurs producing many (32 or more) daughter cells.

When environmental conditions once again become favorable, these new daughter cells become flagellated and are released from the gelatinous mass.

Stigma(Eye-spot):

Near the inner end of the cytopharynx close to the reservoir is a red eye spot or stigma. It consists of a plate of lipid droplets, a carotenoid pigment as red granules of haematochrome which stains blue with iodine. Stigma is cup-shaped with a colourless mass of oily droplets in its concavity which function as a lens. The stigma is sensitive to light.

Nutrition of *Euglena viridis*:

The mode of nutrition in Euglena, **is mixotrophic**, i.e., the nutrition is accomplished either by holophytic or saprophytic or by both the modes.

(i) Holophytic or Autotrophic Nutrition:

In Euglena, the chief mode of nutrition is holophytic or plant-like. The food is manufactured photosynthetically, as in plants, with the aid of carbon dioxide, light and chlorophyll present in the chromatophores. The chlorophyll decomposes the carbon dioxide into carbon and oxygen in the presence of sunlight.

The oxygen is set free and carbon is retained and combined with the elements of water to form carbohydrate (polysaccharide) like paramylum. The paramylum differs from starch because it does not become blue with iodine solution.

(ii) Saprophytic or Saprozoic Nutrition:

In the absence of sunlight, Euglena derives its food by another mode of nutrition known as saprophytic, osmotrophic or saprozoic. In this mode, the animal absorbs through its general body surface some organic substances in solution from decaying matter in the environment of animal

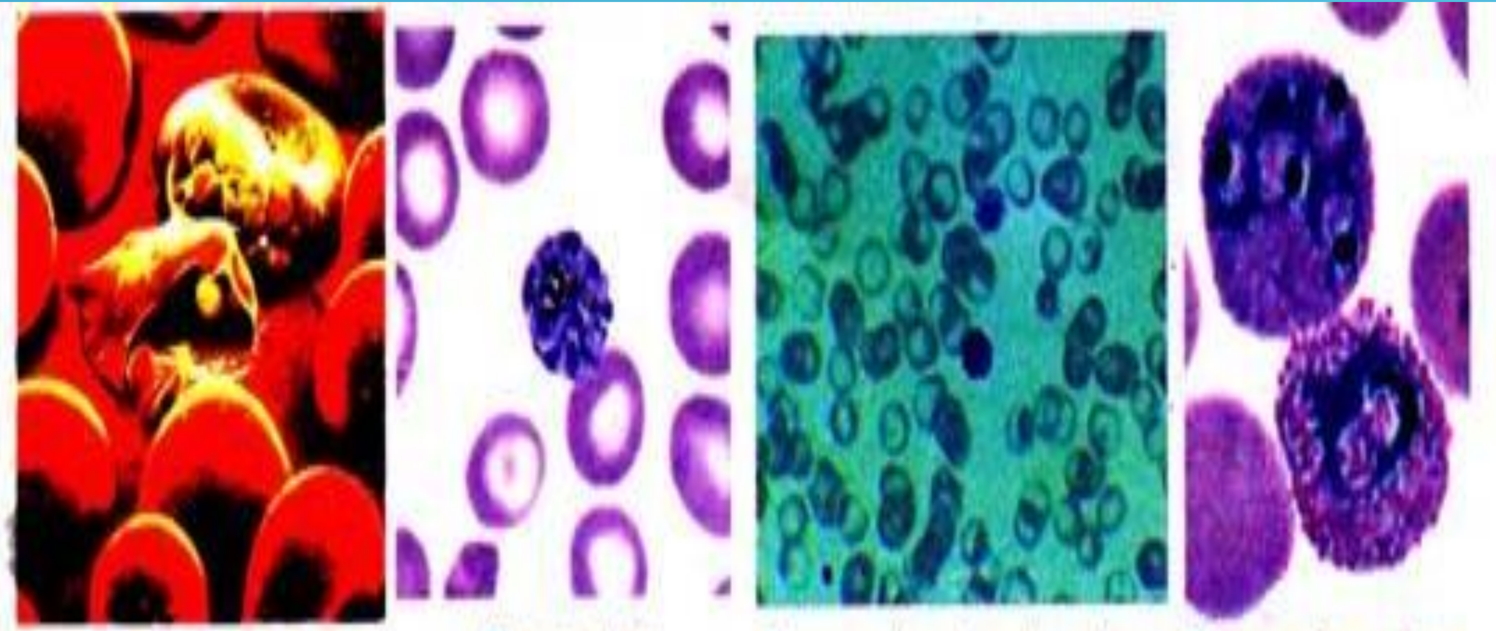
Respiration

In *Euglena viridis*, the exchange of gases (intake of O_2 and giving out of CO_2) takes place by diffusion through the body surface. It absorbs dissolved oxygen from the surrounding water and gives out carbon dioxide by diffusion.

Excretion

The elimination of carbon dioxide and nitrogenous waste product (ammonia) takes place through the general body surface by diffusion.

4. Plasmodium



Plasmodium falciparum. *Plasmodium malariae.* *Plasmodium trophozoite.* *Plasmodium vivax.*

Plasmodium vivax lives as an intracellular parasite in the red blood corpuscles (R.B.Cs) of man in the form of its mature adult condition, called trophozoite

Plasmodium is widely distributed in tropical and temperate countries of the world but they are no longer a problem in the colder countries of the world. Countries like India, Sri Lanka, Bangladesh, Nepal, Pakistan, etc., are worst affected.

Hosts of of *Plasmodium Vivax* :

Plasmodium vivax has two hosts; man and female Anopheles mosquito. Man is considered to be the primary host and female Anopheles mosquito, the secondary or intermediate host.

The common species of Anopheles, which transmit malaria parasite in India, are A. maculatus, A. stephensi, A. fluvialitis and A. culicifacies.

Structure of *Plasmodium vivax* :

As referred to, the parasite, **in its mature adult condition, is called trophozoite**. The trophozoite is amoeboid, uninucleated having vacuolated and granular cytoplasm.

Ultra structure of trophozoite:

According to electron microscopic studies, the Plasmodium in a red blood corpuscle possesses a double membrane, the plasma lemma closely applied to the cytoplasm. The cytoplasm of *Plasmodium vivax* contains small dense particles probably containing ribo-nucleoproteins.

The endoplasmic reticulum is not well developed and appears as vesicles of variable shapes. The vesicles are either smooth surfaced or rough surfaced and are loosely scattered in the cytoplasm.

The mitochondria possess double membrane and show peripheral cristae and a structure less central region.The number of mitochondria varies with the age, the merozoite has only one mitochondrion, while the trophozoite has several mitochondria.

The Golgi apparatus is composed of small vesicles arranged in rows. A double layered concentric body is also found in the cytoplasm attached with the plasma lemma of Plasmodium Vivax.

The nucleus is large and its nucleoplasm is composed of granular and fine fibrillar material. The nuclear membrane is double, to which RNA particles are attached. The nucleolus lies centrally in the nucleus.

Pinocytosis vacuoles are common in the cytoplasm and serve as food vacuoles. The food vaculoes may also contain hemozoin depending upon the species of Plasmodium.

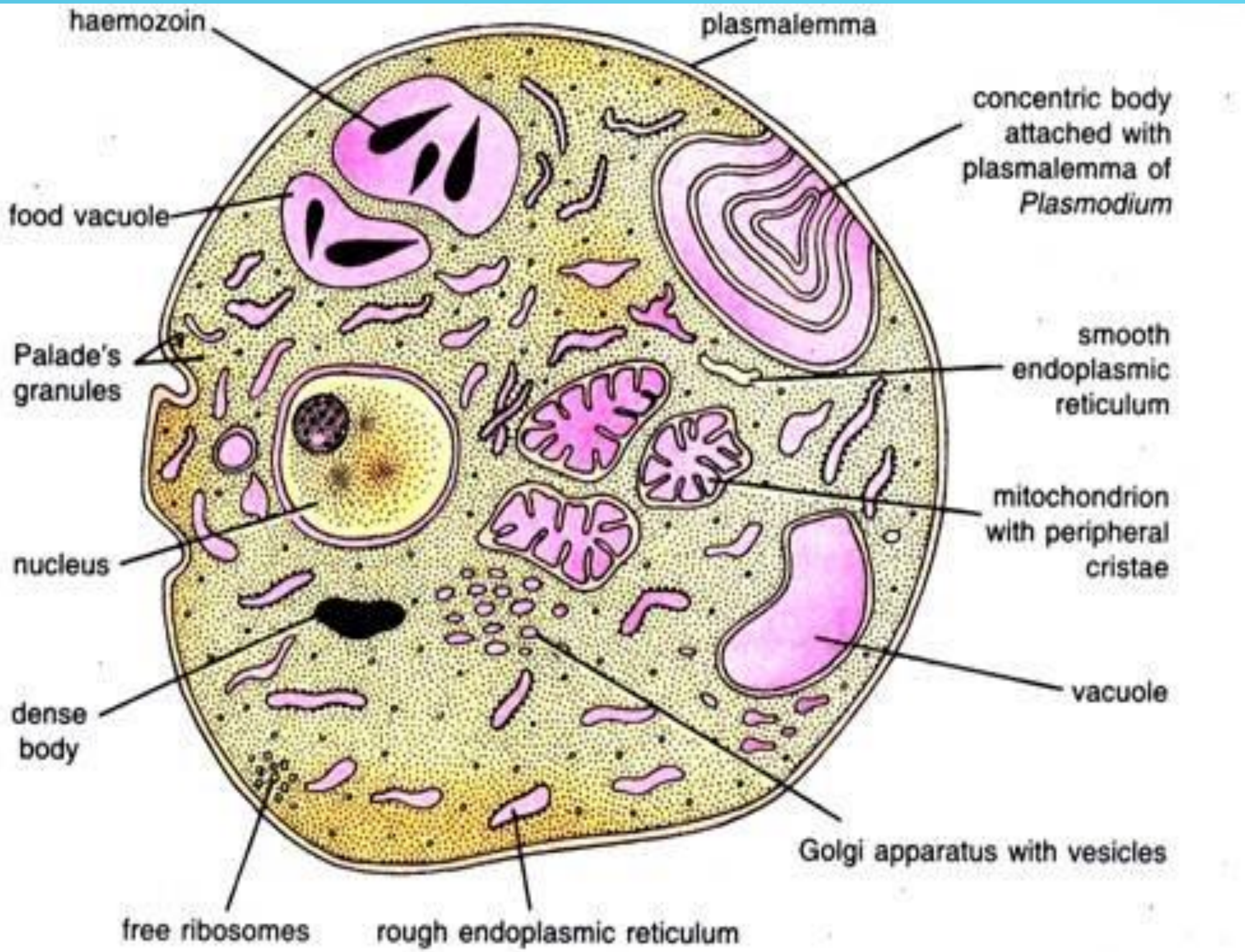


Fig. 19.1. *Plasmodium*. Ultrastructure of trophozoite in R.B.C. as seen in electron microscope.

The mode of nutrition is saprozoic, occurs by osmotrophy.

Organ of locomotion, contractile vacuole, etc., are not found.
Respiration takes place anaerobically.

Reproduction occurs both by sexual and asexual methods.

Life Cycle and *Plasmodium vivax*:

The life cycle of *Plasmodium vivax* is digenetic involving two hosts. Its life cycle is completed both by asexual and sexual phases.

Asexual phase of its life cycle is completed in man by schizogony (differentiated into exo-erythrocytic schizogony involving pre- and post-erythrocytic schizogonic cycles, and erythrocytic schizogony) and sexual phase of its life cycle is completed in female Anopheles mosquito by gametogony, syngamy and sporogony.

(a) Part of Life-Cycle of *P. vivax* in Man (Asexual Cycle):

Inoculation:

When an infected female Anopheles bites a man to suck his blood, then along with its saliva it injects the sporozoite stage of Plasmodium into the human blood. The parasite remains always in the body of one of the two hosts, hence, the sporozoites do not possess any protective covering.

The sporozoite, infective stage, is minute measuring about 11 to 12 microns in length and 0.5 to 1 micron in width, sickle-shaped cell with an oval nucleus; mosquito inoculates sporozoites in thousands.

The sporozoites are capable of slight gliding movement. In about half an hour the sporozoites disappear from the blood stream, and **they enter the parenchymatous cells of the liver** where they undergo at least two schizogonic cycles.

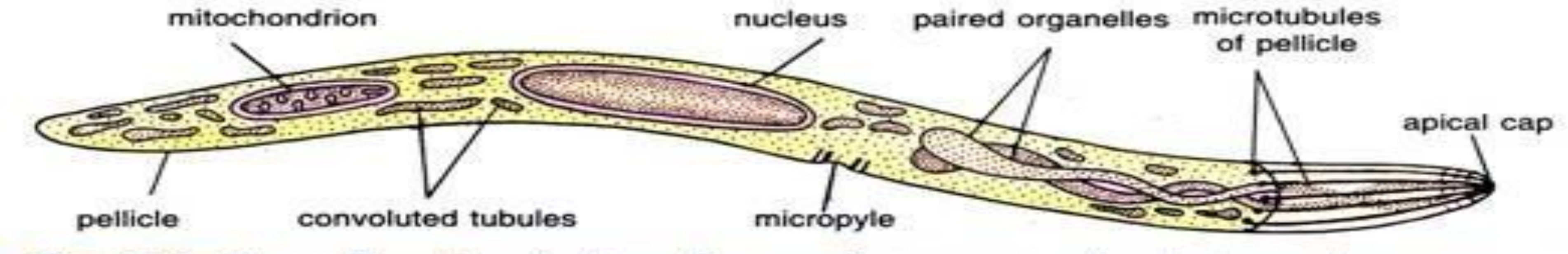


Fig. 19.2. *Plasmodium*. Ultrastructure of sporozoite as seen under electron microscope.

Ultra Structure of Sporozoite:

The sickle-shaped body of the sporozoite is covered externally by an elastic, firm pellicle having longitudinally arranged contractile microtubules. These microtubules help in the gliding movements shown by the sporozoite. Its anterior end bears an apical cup being made of three or more concentric rings.

A pair of elongated reservoir like secretory organelles, comparable to roptries of the sporozoite of Monocystis, open into the apical cup.

These organelles are supposed to secrete some secretion which facilitates its penetration into the liver cells.

Nucleus is single and vesicular having a nucleolus in its centre. There is a single mitochondrion and a large number of convoluted tubules of unknown function. However, the micropyle represents the cytostome of other protozoans.

Schizogony in Liver Cells:

In the liver cells, the sporozoite grows to form a large, round schizont.

The schizont divides by multiple fission to form about one thousand to several thousand small spindle-shaped cells called merozoites; this multiple fission is called schizogony.

The schizont ruptures and merozoites are liberated into the sinusoids or venous passages of the liver.

This phase of asexual multiplication is pre-erythrocytic schizogony and the merozoites produced by it are also called cryptozoites or cryptomerozoites; these cryptozoites are immune to medicines and the resistance of the host.

A second phase of asexual multiplication known as an exo-erythrocytic schizogony occurs in the liver cells in which the cryptozoites enter into new liver cells and grow into schizonts, the schizont divides to form merozoites; the merozoites of the second generation are termed metacryptozoites or phanerozoites.

The exo-erythrocytic schizogony may continue in more liver cells to form a reservoir of merozoites, or some merozoites after at least two cycles of schizogony may re-enter the blood stream when they invade erythrocytes.

It is supposed that the merozoites of second generation, i.e., metacryptozoites are of two types; the more numerous and smaller are micro-metacryptozoites, while larger and less in number are macro-metacryptozoites.

In fact, the micro-metacryptozoites invade the R.B.Cs and start erythrocytic schizogony, while the macro-metacryptozoites enter fresh liver cells to continue the exo-erythrocytic schizogony. The merozoites attack only the young and immature corpuscles, (the merozoites of P. malariae attack only old corpuscles, while those of P. falciparum attack all kinds of corpuscles indiscriminately).

Pre-patent and Incubation Periods:

The pre-patent period is the duration between the initial sporozoite infection and the first appearance of parasite in the blood. In case of *P. vivax*, it is about 8 days on an average. The incubation period is the time taken from the infection of man by sporozoites till the appearance of first malarial symptom.

In case of *P. vivax*, it is about 14 days on an average ranging from 10 to 17 days. Of course, during the incubation period the host shows no symptoms of malaria.

Schizogony in Erythrocytes:

In the erythrocytes, a third multiplication phase of schizogony occurs which is known as erythrocytic schizogony. The micro-metacryptozoite feeds on erythrocytes, a vacuole appears in it, the nucleus is pushed to one side, and the micro-metacryptozoite is changed into what is called as the ring-shaped trophozoite, the signet ring stage, which is 1/3 to 1/2 the size of the erythrocyte.

The signet ring stage is not found in P. falciparum. The trophozoite grows to become rounded and amoeboid, this is the full grown trophozoite and is known as a schizont. The large schizont makes the erythrocyte to become very large. The schizont shows yellowish-brown pigment granules of haemozoin derived from the iron of haemoglobin of erythrocyte; the enlarged erythrocyte acquires granules called Schuffner's dots.

The schizont now undergoes multiple fission to form 12 to 24 oval-shaped merozoites; this phase of asexual multiplication is erythrocytic schizogony. The much weakened erythrocyte bursts and the merozoites are liberated into the plasma from where they enter new erythrocytes, then they repeat the erythrocytic schizogony once every 48 hours.

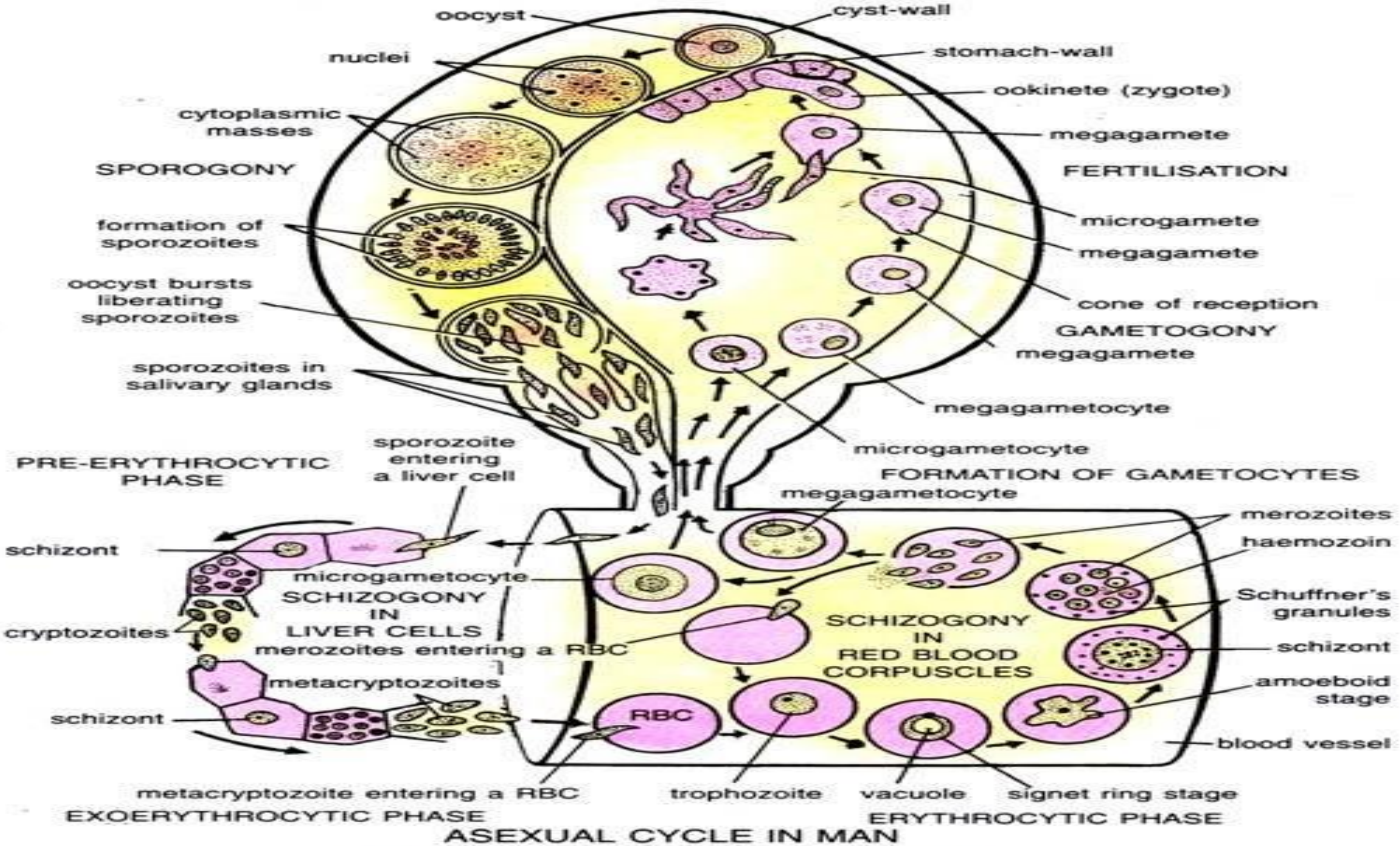


Fig. 19.3. *Plasmodum vivax.* **Life cycle.**

However, the merozoites may again go from the blood to the liver cells and invade them to undergo another phase of asexual multiplication which is called post-erythrocytic schizogony

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Formation of Gametocytes:

After many generations of schizogony in the blood, some of the merozoites slowly grow large producing much haemozoin, these are inside erythrocytes and do not change in schizonts but they grow and are transformed into two types of gametocytes called macro gametocytes and microgametocytes.

The condition which brings about the formation of gametocytes is not known. Gametocytes appear in the peripheral blood at various intervals after the onset of fever, they remain inactive while in the human blood. The macro gametocytes are female, they are round with the food laden cytoplasm and a small eccentric nucleus.

The microgametocytes are male, they have a clear cytoplasm and a large central nucleus. Both gametocytes contain large amounts of haemozoin; they enlarge the erythrocytes. Gametocytes remain in the human blood for several weeks, but are unable to develop any further, it is necessary for them to be taken into the body of an Anopheles', if this does not happen they degenerate and die.

(b) Part of Life-Cycle of *P. Vivax* in Mosquito (Sexual Cycle):

Many species of Anopheles, but not all species, act as intermediate hosts. If the gametocytes are sucked up along with human blood by a female Anopheles then they reach the stomach where corpuscles are dissolved and the gametocytes are set free.

Gametogony:
The microgametocytes, after release in the stomach of mosquito, undergo the process of ex-flagellation. The cold-bloodedness of the mosquito is said to stimulate this process. However, the nucleus of microgametocytes divides into 6-8 haploid daughter nuclei.

These nuclei migrate towards the periphery of microgametocyte. The cytoplasm pushes out forming long flagellum like structures having one daughter nuclei in each. Thus, 6-8 flagellum like male gametes or microgametes measuring from 20-25 microns in length are formed. Soon these gametes separate and start moving actively in the stomach of mosquito.

On the other hand, the macro gametocytes undergo maturation process, thereby two polar bodies are pushed out and a female gamete or macrogamete is formed. The female gamete is non-motile and develops a cytoplasmic or receptive cone.

Fertilization:

If microgamete happens to reach the macrogamete, then it enters into the female gamete at the point of cytoplasmic cone and finally complete fusion of nucleus and cytoplasm of the two gametes occurs. This results in the formation of rounded zygote.

Several microgametes may approach a macrogamete but only one of them enters the macrogamete and others shed off. The fusion of male and female gametes is called syngamy. Here, the gametes are dissimilar (anisogametes), hence, their fusion is called anisogamy.

Ookinete and Encystment:

The zygotes, thus, formed remain rounded and motionless for 24 hours but soon they elongate to become worm-like having pointed ends and motile. The zygotes are now called ookinetes or vermicules.

The ookinete moves and bores through the wall of the stomach of mosquito and comes to lie beneath the outer epithelial layer. (The ultrastructure of ookinete shows the presence of a central, irregular nucleus, dense cytoplasm, brown pigment granules, many mitochondria and ribosomes in it. It also shows the presence of contractile fibrils, the microtubules).

However, here they become spherical and secrete a thin elastic membranous cyst. The cyst is also partly secreted by the surrounding tissues of the stomach. Thus, the ookinetes become encysted and in this condition it is referred to as the oocyst. The oocyst grows in size and sometimes called sporont.

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Sporogony:

The nucleus of oocyst first divides by meiosis and then by mitosis several times and its cytoplasm develops vacuoles forming faintly-outlined cells called sporoblasts.

Particles of chromatin arrange themselves around the periphery of each sporoblast. Then the cytoplasm forms slender spindle-shaped haploid cells known as sporozoites.

Each oocyst may have ten thousand sporozoites, and group of sporozoites gets arranged around the vacuoles. This phase of **asexual multiplication in which sporozoites are formed is called sporogony which is completed in 10-20 days from the time the gametocytes are taken in by the mosquito, the time depending on the temperature.**

The oocyst bursts and sporozoites are liberated into the haemolymph of the mosquito, from where they reach its salivary glands and enter the duct of the hypopharynx. The sporozoites will infect a human host when the mosquito bites and the life cycle is repeated again.

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