2. Protozoa

Protozoans are ***minute, unicellular*** (acellular) organisms without any tissue grade of organization. They are the ***first formed*** organisms and hence the name ***Protozoa.*** When man is placed at the apex of the animal kingdom, protozoans should be placed at the base.

Protozoa

The term ***Protozoa*** was used for the last 200 years to refer to the unicellular organisms like *Amoeba* , *Paramaecium*, *Euglena*, etc. The term Protozoa means ***primitive animals*** ; But plant - like organisms such as *Euglena*, *Volvox* are also included in protozoa. Hence this term becomes apperent and it is now replaced by ***Protista***.

Protista means ***first formed organisms*** such as Amoeba, Euglena and a few simple fungi.

General Characters

Phylum Protozoa is characterized by the presence of the following characters:

1. Protozoans are the ***primitive*** organisms.
2. They are ***minute*** and ***microscopic.***
3. They are ***free living*** or ***parasitic.***
4. All the free living forms are ***aquatic.***

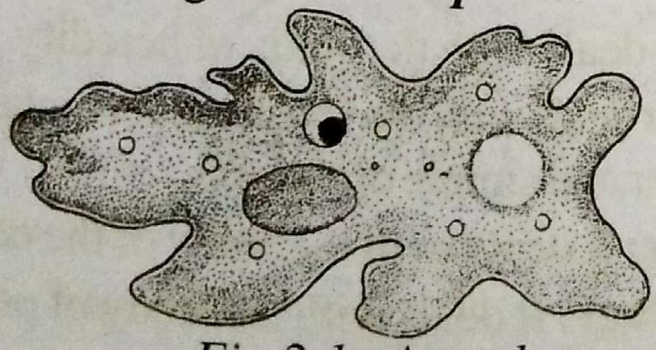

Fig.2.1: Amoeba.

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5. They are ***asymmetrical*** or ***radially symmetrical*** or ***bilaterally symmetrical.***
6. They are ***unicellular*** (acellular).
7. They have ***protoplasmic grade*** of organization.
8. All the activities are carried out by the ***cytoplasm*** of a single cell.
9. Tissues and organs are absent.
10. Locomotion is effected by ***flagella, cilia*** or ***pseudopodia.***

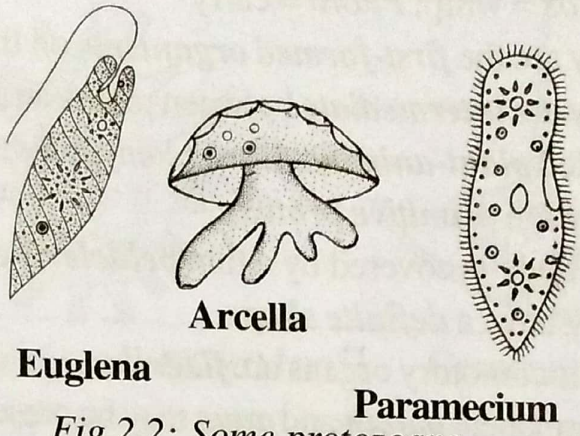

Fig.2.2: Some protozoans.

11. Nutrition is ***holophytic, holozoic, saprozoic*** or ***parasitic***.
12. Digestion is ***intracellular.***
13. Respiration occurs by ***diffusion.***
14. Excretion occurs by ***diffusion.***
15. In freshwater forms, osmoregulation is carried out by the ***contractile vacuoles.***

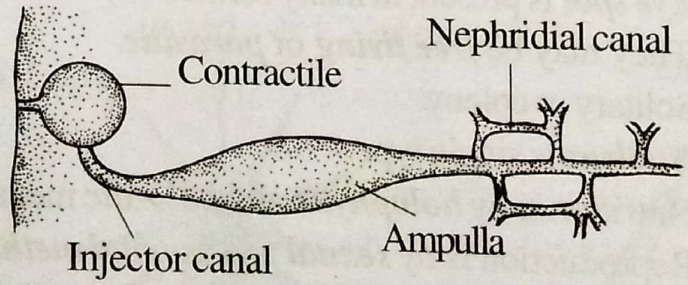

Fig.2.3: Contractile vacuole of Paramecium.

16. ***Encystment*** is a common phenomenon.
17. Reproduction occurs by ***asexual*** and ***sexual*** methods.

Classification

Protozoa includes ***unicellular, first formed organisms***.

About ***50,000*** species of protists are known. All protists are grouped into five classes, namely

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1. *Flagellata (Mastigophora)*
2. *Rhizopoda (Sarcodina)*
3. *Ciliophora*
4. *Sporozoa* and
5. *Mycetozoa.*

Class 1. Flagellata or Mastigophora

1. Flagellata or Mastigophora is a group of protozoans having ***flagella.***

Mastigos = whip; *Phoro* = carry

2. They are the ***first-formed organisms*** on the Earth.

3. They are ***intermediate*** between plants and animals. Hence they are called ***plant-animals.*** Eg. *Chlamydomonas.*

4. They are ***primitive protists.***

5. The body is covered by a thin ***pellicle*** or ***cuticle.***

6. They have a ***definite shape.***

7. The locomotory organs are ***flagella.***

8. A permanent ***mouth*** and ***anus*** may be present in most of the species.

9. The ***contractile vacuoles*** are present in freshwater forms with accessory vacuoles.

10. Some are provided with shells, cases, armours or plates of cellulose, jelly or silica.

11. ***Chloroplasts*** are found in some forms.

12. ***Eye spot*** is present in many forms.

13. They may be ***free living*** or ***parasitic.***

14. Solitary or colony.

15. ***Nucleus*** is single type.

16. Nutrition is by ***holophytic*** and ***holozoic*** methods.

17. Reproduction is by ***sexual*** and a***sexual methods***.

18. Mastigophora and the next class Sarcodina (Rhizopoda) are together called ***Sarcomastigophora.***

Common Examples for Flagellata

Euglena	*Ceratium*	*Trichonympha*
Chlamydomonas	*Leishmania*	*Chilomonas*
Volvox	*Trypanosoma*	*Cryptomonas*
Noctiluca	*Giardia*	

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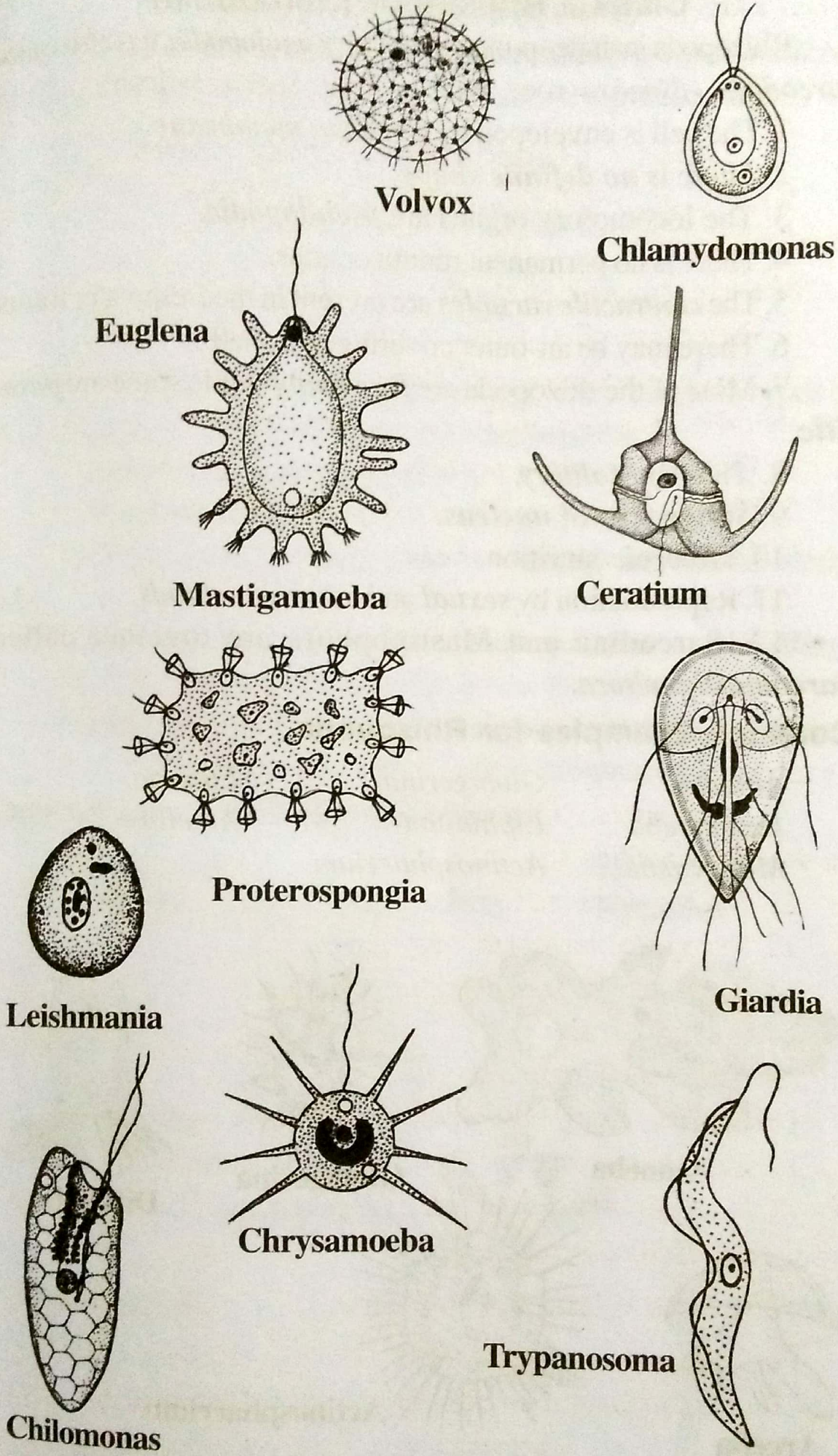

Fig.2.4: Some common flagellates.

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Class 2. Rhizopoda (Sarcodina)

Rhizopoda includes protozoans with ***pseudopodia***. It is also called ***Sarcodina.*** (*Rhizos* = root; *Podos* = foot; *Sarcos* = flesh)

1. The cell is enveloped by a ***plasma membrane***.
2. There is ***no definite shape.***
3. The locomotory organs are ***pseudopodia.***
4. There is no permanent mouth or anus.
5. The ***contractile vacuoles*** are present in the freshwater forms.
6. There may be an outer covering or a shell.
7. Most of the rhizopoda are ***free living*** while some are ***parasitic***.
8. They are ***solitary.***
9. ***Single*** type of ***nucleus***.
10. ***Holozoic*** nutrition.
11. Reproduction by ***sexual*** and asexual ***methods***.
12. Sarcodina and Mastigophora are together called ***Sarcomastigophora.***

Common Examples for Rhizopoda

Amoeba	*Globigerina*	*Eimeria*
Entamoeba	*Elphidium*	*Arcella*
Monocystis	*Actinosphaerium*	

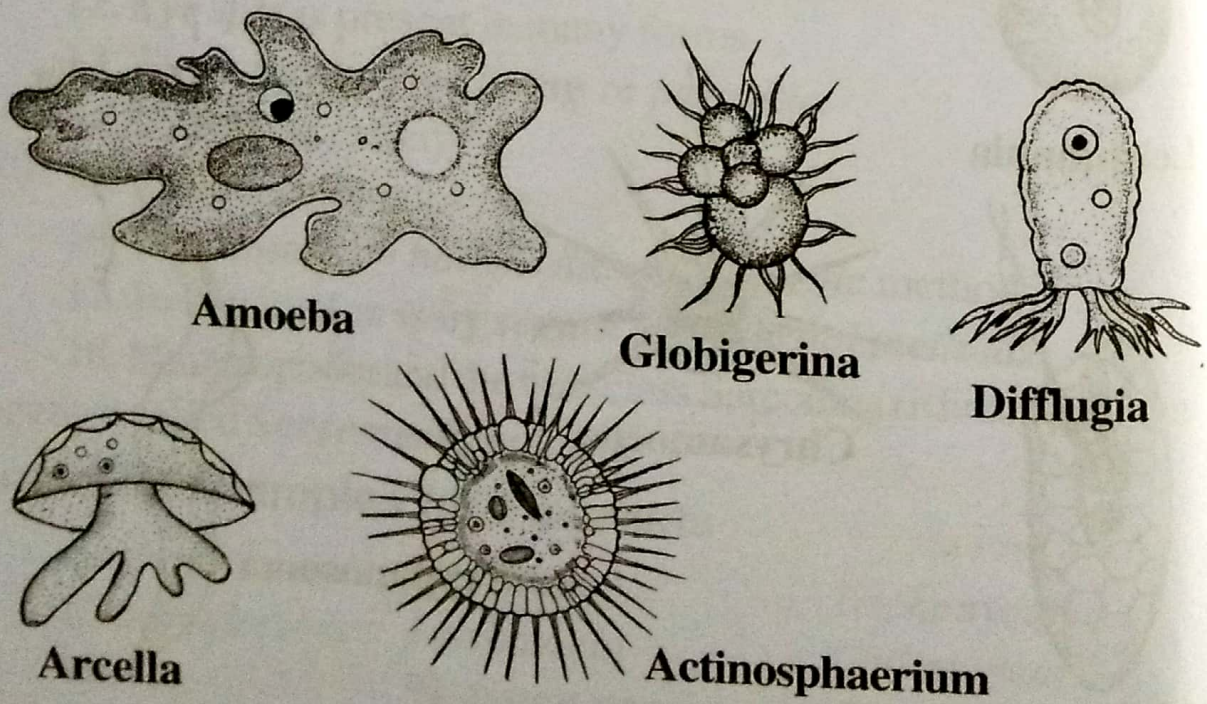

Fig.2.5: Some common rhizopods.

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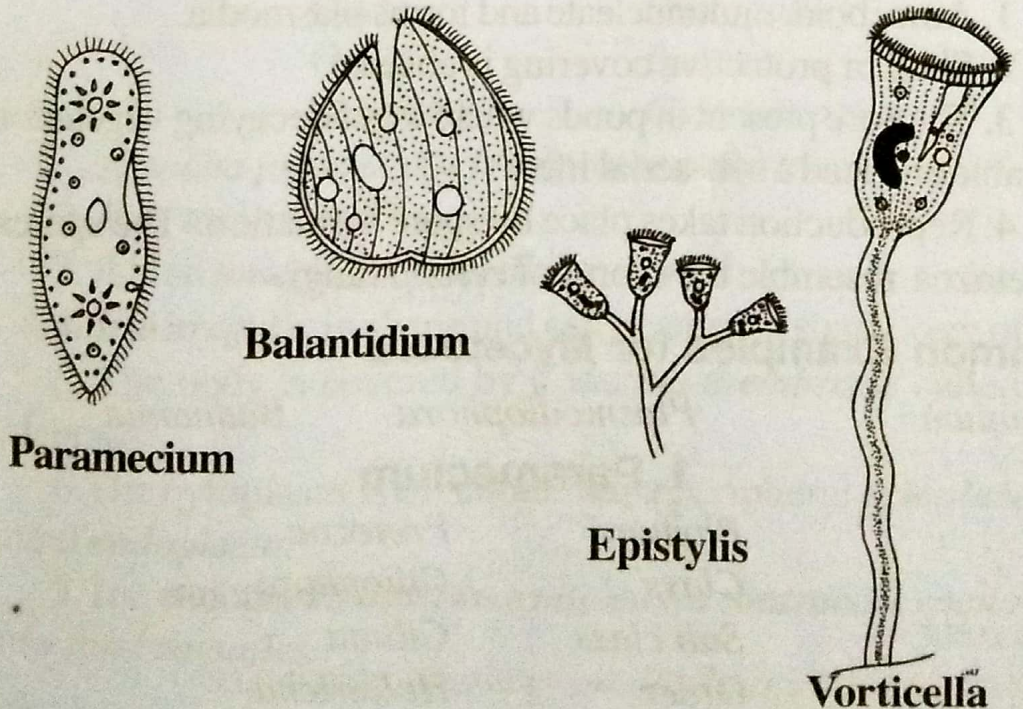
Class 3. Ciliophora (Ciliata)

Ciliophora is a group of protozoa containing ***cilia, a micronucleus*** and a ***meganucleus.*** It has the following characters:

1. They are free living or parasitic.
2. They are solitary or colonial.
3. The body is covered by a thin ***pellicle.***
4. They have a fixed permanent shape.
5. The locomotory organs are ***cilia.***
6. Tentacles are present.
7. They exhibit ***nuclear dimorphism.*** They have two types of nuclei, namely a ***micronucleus*** and a ***meganucleus.***
8. ***Mouth*** and ***gullet*** are present.
9. Nutrition is ***holozoic.***
10. Reproduction takes place by asexual and sexual methods.
11. Asexual reproduction is by ***binary fission*** and ***budding.***
12. Sexual reproduction takes place by ***conjugation.***
13. ***Contractile vacuoles*** are present in freshwater ciliates.
14. Ciliata is the advanced group of protozoans.

Common Examples for Ciliophora

Paramecium	*Stentor*	*Epistylis*
Vorticella	Balantidium	Nyctother



Balantidium

Paramecium

Epistylis

Vorticella

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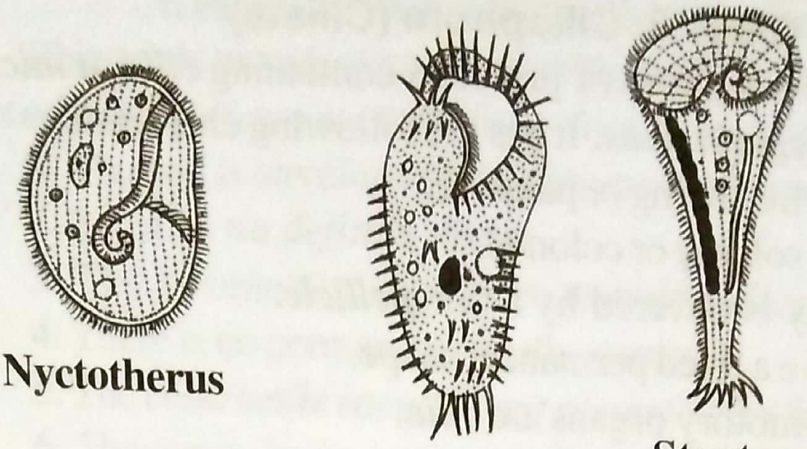

Fig.2.6: Some common ciliates.

Class 4. Sporozoa

1. Sporozoa are spore producing protozoans.
2. They are exclusively ***endoparasitic.***
3. The body is covered by ***pellicle.***
4. They are single and nucleated.
5. Various organelles are absent due to parasitic mode of life.
6. Reproduction takes place by ***spore*** formation.
7. Nutrition is by ***parasitic*** method.
8. Life cycle may be ***simple*** or ***complicated.*** Sexual and asexual phases alternating with each other in different hosts.
9. Some of them are very important ***human parasites.***

Class 5. Mycetozoa

1. Amoeboid, multinucleate and forms plasmodia.
2. Shell or protective covering is absent.
3. They are present in ponds where lot of decaying vegetation is available and lead a sub-aerial life.
4. Reproduction takes place by spore formation. The spores of Mycetozoa resemble the spores of certain fungi.

Common Examples for Mycetozoa

Didymium *Plasmodiophora* *Badhamia*

1. Paramecium

Phylum	:	*Protozoa*
Class	:	*Ciliophora*
Sub class	:	*Ciliata*
Order	:	*Holotricha*

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1. *Paramecium* is a free swimming freshwater ***ciliate.***
2. It is commonly called ***slipper animalcule*** because, it looks like a slipper.
3. It is an ***unicellular*** or ***acellular*** animal.
4. It is ***microscopic.***
5. The body is covered by a ***pellicle.***
6. The entire body is covered by ***cilia.***
7. The cytoplasm has a peripheral ***ectoplasm*** and central ***endoplasm.***
8. The endoplasm contains ***two nuclei,*** namely a ***macronucleus*** and a ***micronucleus***, and two ***contractile vacuoles*** one at each end.
9. *Paramecium* has a ***definite symmetry*** with anterior and posterior ends and dorsal and ventral sides.
10. The ventral side has an ***oral apparatus*** consisting of ***oral groove, vestibule, cytostome*** and ***cytopharynx.***
11. The ectoplasm contains ***trichocysts***, organs of offense and de fence.
12. It exhibits ***holozoic*** nutrition.
13. It reproduces by ***binary fission, conjugation, endomixis, automixis*** and ***hemixis.***

2. Amoeba proteus

Phylum	:	*Protozoa*
Class	:	*Rhizopoda*
Order	:	*Lobosa*
Suborder	:	*Gymnamoeba*

1. *Amoeba proteus* is a ***freshwater*** protozoan.
2. It is ***microscopic.***
3. It is an ***unicellular*** or ***acellular animal.***
4. It is irregular in shape and can change its shape very often.
5. The body is covered by a ***plasma membrane*** called ***plasmalemma.***
6. The cytoplasm is divisible into a peripheral ***ectoplasm*** and central ***endoplasm.***
7. The endoplasm contains a ***nucleus***, a ***contractile vacuole*** and a few ***food vacuoles.***

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8.Locomotion is effected by outgrowths of the body called ***pseudopodia.***

9.Nutrition is ***holozoic.***

10.It undergoes ***encystment*** during unfavourable seasons.

11. It reproduces only by ***asexual*** methods such as ***binary fission*** and ***multiple fission.***

1. Euglena

Phylum : *Protozoa*
Class : *Mastigophora*
Order : *Euglenoidea*

Euglena has an unique place in taxonomy. Zoologists place it in the ***animal kingdom.*** But Botanists place it in the ***plant kingdom*** because it contains chlorophyll. Hence it is called a ***plant-animal.*** It is an ***intermediate link*** between plants and animals.

Euglena is a microscopic unicellular organism. Hence it is included in the phylum ***Protozoa.*** It moves from place to place with the help of a long whip-like structure called ***flagellum.*** Hence it is included in the class ***Mastigophora.***

Euglena is a freshwater organism. It lives in stagnant water like ponds, pools, ditches, etc. It is a free- swimming and solitary organism. The nutrition is by ***mixotrophic*** method. ie., it feeds by more than one method.

It is ***green*** in colour. It has an elongated ***spindle-shaped*** body. The anterior end is blunt and the posterior end is pointed. It shows ***radial symmetry.*** It is about 40 to 60 microns in length and 14 to 20 microns in breadth (1 micron = 0.001 mm).

Pellicle

The body is covered by a thin, flexible tough membrane called ***pellicle.*** It is formed of two layers, namely an outer ***epicuticle*** and an inner ***cuticle.*** The pellicle contains oblique fibrils called ***myonemes.***

Plasma membrane and Cytoplasm

Below the pellicle lies the ***plasma membrane.*** The body is filled with cytoplasm. It is formed of two zones, namely an outer ***ectoplasm*** and an inner ***endopla***

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4. Drinking water should be well boiled.
5. Food stuffs and water should be protected from houseflies and other insects.

Treatment

Amoebiasis is a ***curable disease***. It can be treated with the following drugs:

1. Emetine
2. Dehydroemetine
3. Chloroquine
4. Diodoquine
5. Terramycin
6. Aureomycin and
7. Erythromycin.

Other Species of Entamoeba in Man

There are many species of *Entamoeba*. A few are given below:

1. ***Entamoeba coli***: It lives in the colon (intestine) of man.
2. ***E. gingivalis***: It lives in the mouth between the teeth and gum.

5. Plasmodium

Phylum : *Protozoa*
Class : *Sporozoa*
Order : *Haemosporidia*

Plasmodium is an unicellular organism. Hence it is included in the phylum ***Protozoa***. It is a parasite reproducing by the formation of ***spores.*** Hence it is included in the class ***Sporozoa.***

It is an ***endoparasite*** living in the ***blood*** of man. It causes ***malaria*** in man. It is ***cosmopolitan*** in distribution.

Plasmodium completes its life cycle in two hosts, namely man and the female *Anopheles* mosquito. Hence it is a ***digenic parasite***. Man is the ***intermediate host**** and the mosquito is the ***primary host*****.

There are four different species of *plasmodium*. They are the following:

1. *Plasmodium vivax - benign* or *tertian* malaria or *vivax malaria.*
2. *Plasmodium malariae - quartan fever*

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3. *Plasmodium falciparum* - *malignant* or *subtertian* or *estivo-autumnal* or *falciparum malaria*.

4. *Plasmodium ovale* - similar to *P. falciparum*.

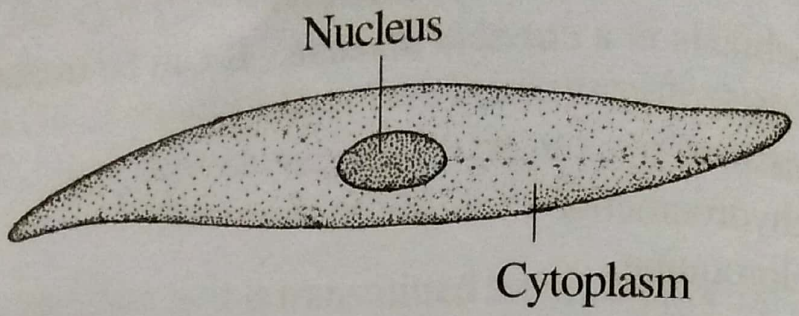

Fig.2.36: Plasmodium.

Life cycle in Man (Cycle of Golgi)

The life cycle of *Plasmodium* in man is called the ***cycle of Golgi***. It occurs in three stages. They are :

1. *Pre-erythrocytic cycle*
2. *Exo-erythrocytic cycle*
3. *Endoerythrocytic cycle.*

1. Pre-erythrocytic Cycle

This cycle occurs in the ***liver***. When a mosquito bites a man, it introduces the ***parasite*** into the blood of man.

Sporo-zoites → **Cryptos-chizont** → **Schizo-gony** → **Cryptom-erozoite**

The parasite introduced is called ***sporozoite***. It is spindle-shaped and is covered with ***pellicle***. It contains a large nucleus in the centre.

The sporozoite enters the ***liver cells***, it feeds and grows and becomes spherical in shape. The parasite in this stage is called ***cryptoschizont***.

The cryptoschizont undergoes a special kind of ***asexual reproduction*** called ***schizogony***. It divides and produces about 1000 daughter cells called ***cryptomerozoites***.

Cryptomerozoites are released into the liver by the rupture of liver cells.

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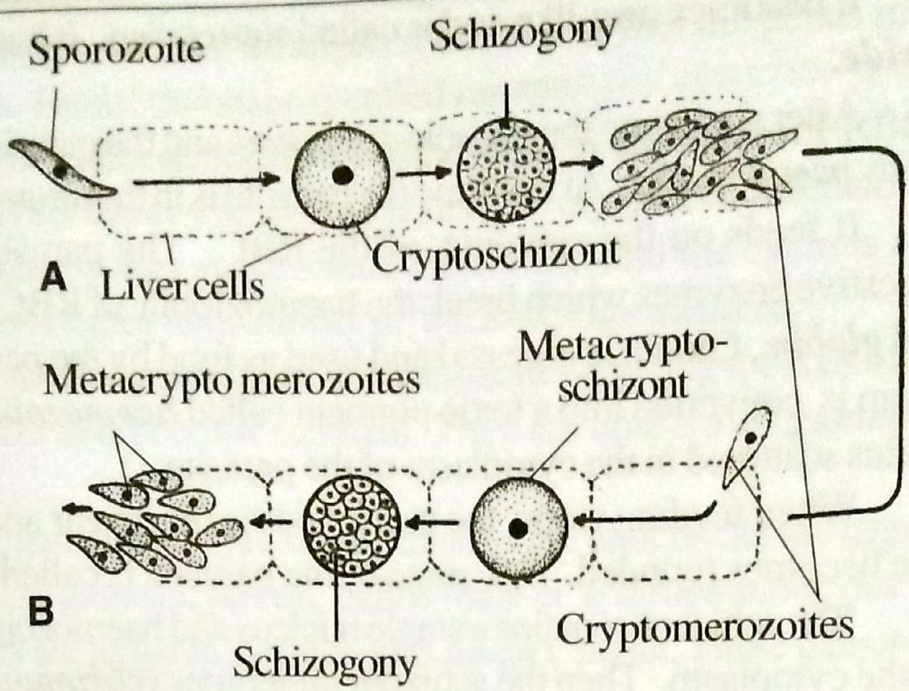

Fig.2.37: Plasmodium-Life history: A. Pre-erythrocytic cycle B. Exo-erythrocytic cycle.

2. Exo-erythrocytic Cycle

This cycle occurs in the ***liver.*** The cryptomerozoites enter fresh liver cells. Here they grow and increase in size and become spherical in shape. The parasite in this stage is called ***metacryptoschizont.***

Cryptom-erozoites → ***Metacryp-toschizont*** → ***Schizo-gony*** → ***Metacrypto-merozoites***

The metacryptoschizont undergoes ***schizogony*** resulting in thousands of daughter individuals called ***metacryptomerozoites.*** The metacryptomerozoites are released by the rupture of liver cells.

The pre-erythrocytic cycle and the exo-erythrocytic cycle are completed within 8 days. After this period the metacryptomerozoites, enter the blood. Until this time there will not be any symptom of malaria.

3. Erythrocytic Cycle or Endoerythrocytic Cycle

This cycle occurs within the ***RBC.***

The ***metacryptomerozoite*** penetrates the RBC. Inside the RBC the parasite becomes rounded. This stage of the parasite is called ***trophozoite.***

It grows and increases in size.

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It becomes ring-like and is called ***signet ring.*** It has a ***vacuole inside.***

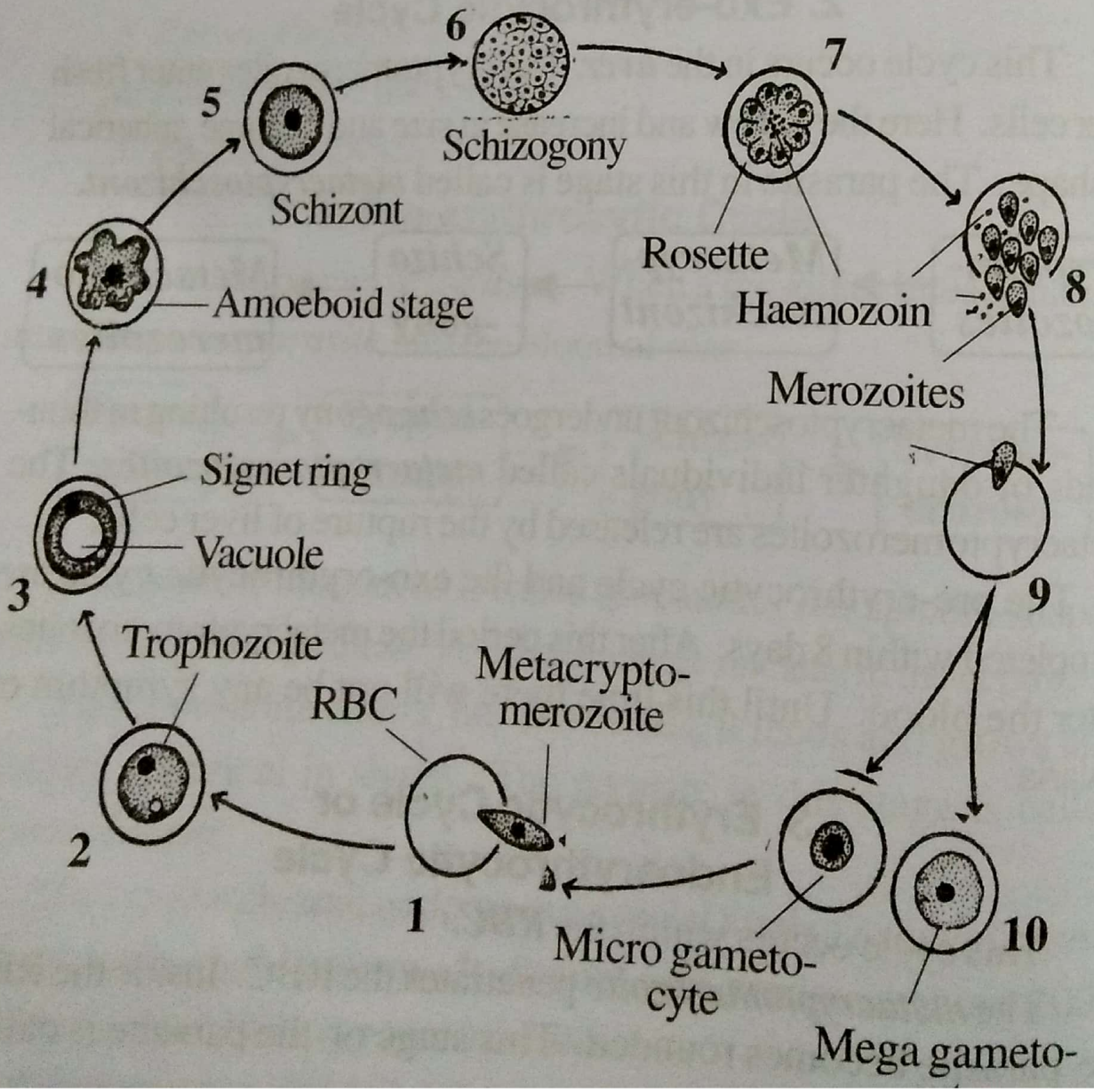
After sometime the vacuole disappears and the parasite develops many ***pseudopodia.*** At this time the parasite is in the ***amoeboid stage.***

It feeds on the contents of the RBC. The parasite secretes digestive enzymes which break the haemoglobin of RBC into ***haem*** and ***globin.*** Globin is digested and used as food by the parasite. The haem is converted into a toxic pigment called ***haemozoin*** which remains scattered in the cytoplasm of the parasite.

When feeding stops, the pseudopodia disappear and the parasite becomes rounded. This stage of the parasite is called ***schizont.***

The schizont contains a single nucleus and haemozoin pigments in the cytoplasm. Then the schizont undergoes ***schizogony.***

In schizogony, the nucleus and cytoplasm divide into 12 to 24 daughter parasites called ***merozoites.***



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The merozoites are arranged more or less like the petals in a rose flower. Hence this stage is called ***rosette.***

The merozoites are released into the blood by the rupture of RBC.

The erythrocytic cycle takes 48 hours (two days) for completion.

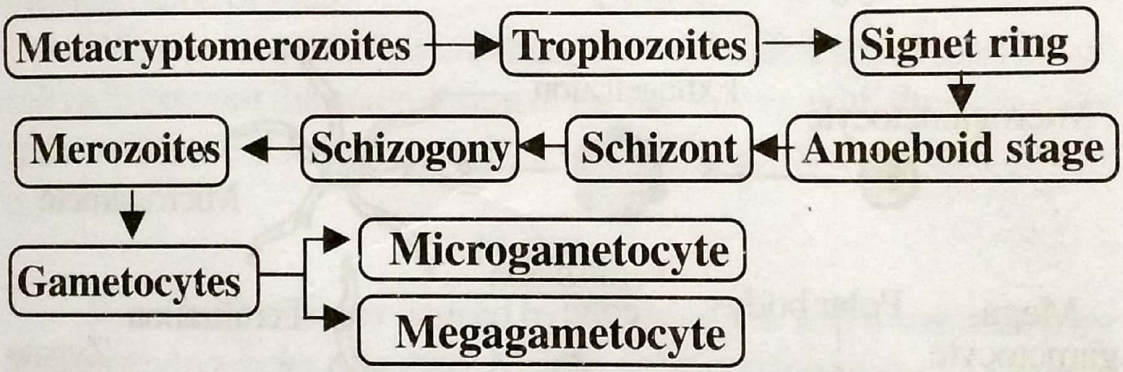
The merozoites again attack fresh RBC and the cycle is repeated several times until almost all the RBCs are attacked.

After several generations, the merozoites entering the RBC, increase in size and become rounded. They are now called ***gametocytes.***

Some gametocytes are smaller in size and their nuclei are larger in size. These gametocytes are called male or ***microgametocytes.***

Others are larger in size but with smaller nuclei. These gametocytes are called female or ***megagametocytes.***

For further development the gametocytes must be taken into the body of the female Anopheles mosquito.



Life cycle in Mosquito (Cycle of Ross)

The life cycle of *Plasmodium* in mosquito was first studied by ***Sir Ronald Ross.*** Hence this cycle is called the ***cycle of Ross.***

Plasmodium undergoes ***sexual reproduction*** in *Anopheles*. Hence *Anopheles* is the ***primary host.*** As it transmits the parasite from one man to another, it is called a ***vector.***

When a female *Anopheles* mosquito sucks the blood of man, the gametocytes enter the gut. The RBCs are digested and the gametocytes are released.

The megagametocyte is reorganized and becomes a ***female gamete*** or ***megagamete.***

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In microgametocyte, the nucleus divides into 6 to 8 daughter nuclei. The daughter nuclei are arranged in the periphery of the gametocyte. The cytoplasm grows out into 6 to 8 long thin flagella-like structures. Each nucleus moves into a flagellum-like structure. Each flagellum-like structure is now called a ***microgamete***.

The microgametes break off from the microgametocyte by violent movements. The formation of microgametes from microgametocyte is called ***exflagellation.***

The microgametes exhibit gliding movement inside the lumen of the gut. The megagametocyte gives out a small cytoplasmic projection. It is called ***fertilization cone.***

When a microgamete comes into contact with the megagamete, it penetrates through the fertilization cone. Now the two gametes fuse together. This is called ***fertilization*** or ***syngamy***. The resulting structure is called ***zygote*** or ***synkaryon.***

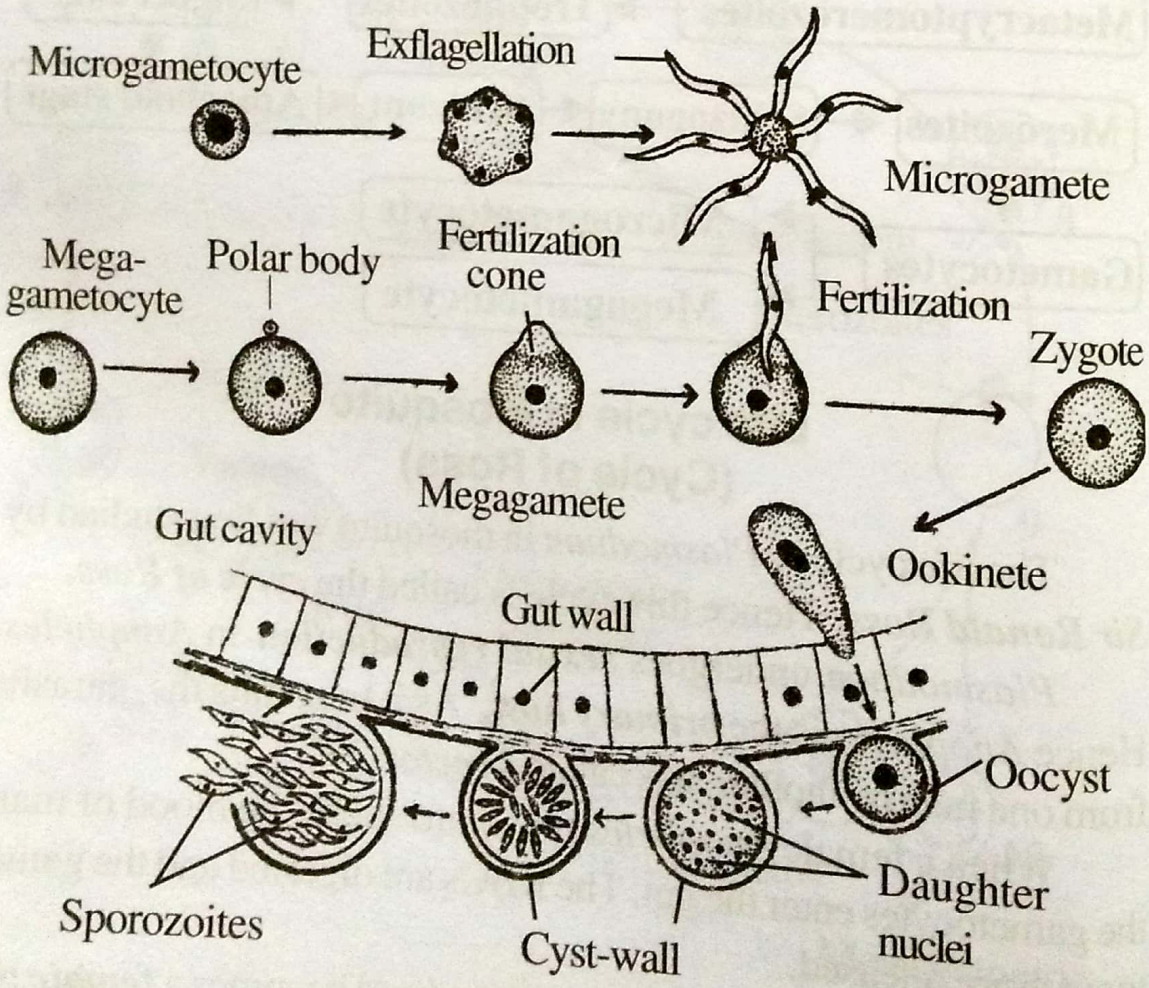

Fig.2.39: Plasmodium: Life history(Cycle of Ross).

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The zygote is spherical in shape. It is a diploid cell. It is non-motile. Soon it becomes elongated and spindle-shaped; it exhibits gliding movement. At this stage the parasite is called an ***ookinete.***

The parasite penetrates the wall of the gut and comes to lie beneath the outer layer of the gut wall. Here it becomes spherical and secretes a ***cyst wall*** around it. Now the parasite is called ***oocyst.***

It grows by absorbing nutritive materials from the mosquito through the cyst wall. As a result it increases in size. The fully grown oocysts are seen as projections on the surface of the gut.

The oocyst now undergoes a special kind of sexual reproduction called ***sporogony.*** During sporogony the nucleus and cytoplasm divide into about 1000 parasites called ***sporozoites.***

Each sporozoite is spindle-shaped. They are released into the body cavity of the mosquito by the rupture of the oocyst and the outer layer of the gut wall. They then enter the salivary gland.

For further development, the sporozoites must be introduced into the blood of man.

When a mosquito bites a man, it introduces a small amount of saliva to prevent the coagulation of blood. Along with the saliva the sporozoites are also introduced into the blood of man and the cycle is repeated.

Malaria

It is a kind of fever caused by *Plasmodium* and transmitted by the female *Anopheles* mosquito. Malaria shows the following symptoms:

1. Loss of appetite
2. Nausea
3. Constipation
4. Headache
5. Muscular pain and ache in joints
6. Shaking chillness
7. Sweating
8. Rise in body temperature as high as 106^0F at an interval of 48 hours and
9. Anaemia.

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Kinds of Human Malaria

There are four different kinds of human malaria caused by four different types of *Plasmodium* :

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1. *Plasmodium vivax* - causing *benign* or *tertian* malaria or *vivax malaria*, producing fever every 48 hours and causing relapses.

2. *Plasmodium malariae* - causing *quartan* fever, producing fever every 72 hours.

3. *Plasmodium falciparum* - causing pernicious, *malignant* or *subtertian* or estivo-autumnal or *falciparum* malaria, characterised by irregular temperature, often with continuous fever. It has a 40 to 48- hour cycle.

4. *Plasmodium ovale* - causing sudden action constantly at night. It causes the same effect as *P. falciparum*, but its attacks are milder. This species is very rare. It is found widely distributed in many parts of the world.

Control and Prevention of Malaria

Malaria can be controlled and prevented by the following methods:

1. Destruction of mosquito and its larva.
2. Spraying DDT in and around the houses.
3. Sterilization of mosquito.
4. Rearing the enemies of mosquito and its larvae like larvivorous fishes (stickle backs, minnows and trouts), ducks, dragon flies, etc. This method is called ***biological control.***
5. Constructing mosquito proof houses.
6. Using mosquito nets.
7. Applying anti mosquito creams on the surface of the body.

Treatment

Malaria can be treated with the following drugs: ***Quinine, Daraprim, Chloroquine, Paludrine, Plasmoquine***, etc.

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4. Hemixis

Hemixis is a kind of reproduction where the macronucleus alone undergoes reorganization. The ***micronucleus*** remains inert. The ***macronucleus*** divides into many fragments. Certain fragments are absorbed into the cytoplasm. The remaining fragments become the macronuclei. This is followed by the binary fission.

5. Cytogamy

It is a kind of sexual reproduction where two individuals temporarily fuse and then separate without any nuclear exchange. It occurs in *Paramecium caudatum.* In cytogamy, two *Paramecia* come together by their ventral surfaces. But the pellicle does not break. The micronucleus divides thrice to form eight micronuclei. Six micronuclei disintegrate. The remaining two nuclei fuse together to form a ***synkaryon.*** The two *Paramecia* now separates.

General Topics

1. Locomotion in Protozoa

Locomotion is the displacement of animals from one place to another. Protozoa exhibits four types of locomotion. They are as follows:

1. *Amoeboid movement*
2. *Flagellar movement*
3. *Ciliary movement*
4. *Metabolic movement.*

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1. Amoeboid Movement

Movement by means of ***pseudopodium*** is called ***amoeboid movement***. Amoeboid movement is a characteristic feature of *Amoeba*. But it is also exhibited by certain flagellates and sporozoans.

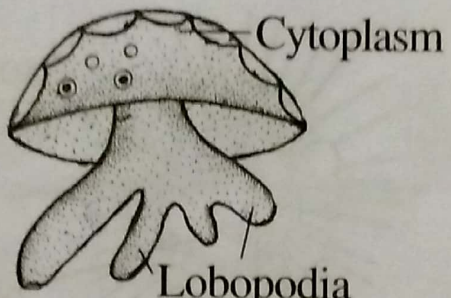
Pseudopodium

Pseudopodium is a temporary projection of cytoplasm formed on the body. There are four types of pseudopodia, namely

1. Lobopodia
2. Filopodia
3. Reticulopodia and
4. Axopodia

1. Lobopodia

These are lobe-like pseudopodia with rounded tips. Eg. *Amoeba, Arcella*, etc.

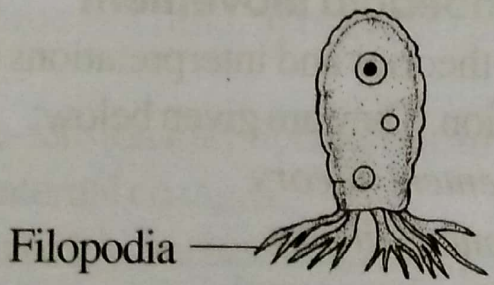


Arcella

Fig.2.54: Lobopodia.

2. Filopodia

Filopodia are filamentous pointed pseudopodia. They are formed exclusively of ectoplasm. They may be branched. Eg. *Euglypha.*



Euglypha

Fig.2.55: Filopodia.

3. Reticulopodia *(Rhizopodia)*

These are filamentous pseudopodia. They are highly branched and the branches anastomose to form a network Eg.*Globigerina, Chlamydophrys,* etc.

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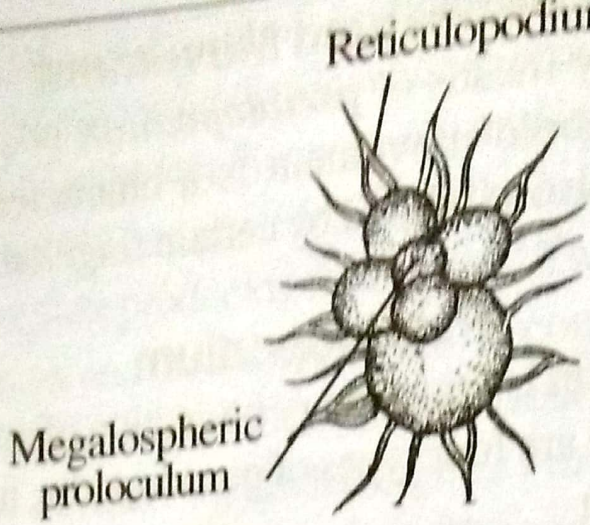
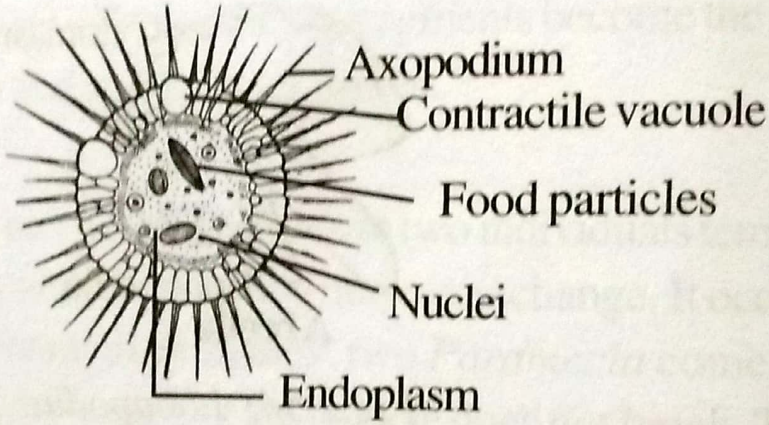


Fig.2.56: Reticulopodia in Globigerina.

4. Axopodia

These are stiff, straight, pointed pseudopodia radiating from the circular body in all directions. Each axopodium has a cytoplasmic ***sheath*** and an ***axial rod***. Eg. *Actinophrys, Actinosphaerium*, etc.



Actinosphaerium

Fig.2.57: Axopodia.

Mechanism of Amoeboid Movement

There are many theories and interpretations on the mechanism of amoeboid locomotion. They are given below:

1.Walking movement theory
2.Rolling movement theory
3.Surface-tension theory and
4.Sol-gel theory.

1.Walking Movement Theory

This theory was proposed by ***Dellinger*** (1906). According to this theory, *Amoeba* walks on the substratum using ***pseudopodia*** as legs. During its movement, the ***pseudopodium***

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end is firmly attached to the substratum. It contracts and pulls the body forwards. Another pseudopodium is formed and it is attached to the substratum infront of the previous one and the process is repeated.

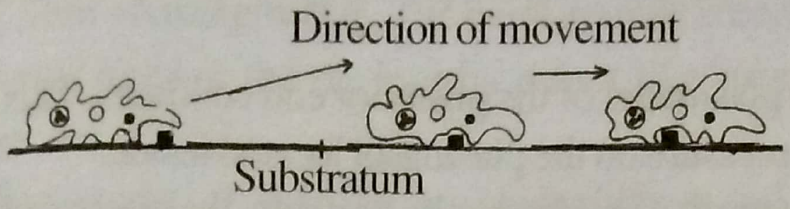

Fig.2.58: Walking movement in Amoeba.

2. Rolling Movement Theory

This theory was proposed by ***Jennings.*** According to this theory, the *Amoeba* moves by the rolling of the body on the substratum. This is brought about by the streaming movement of the cytoplasm. This type of movement is exhibited by *Amoeba verrucosa.*

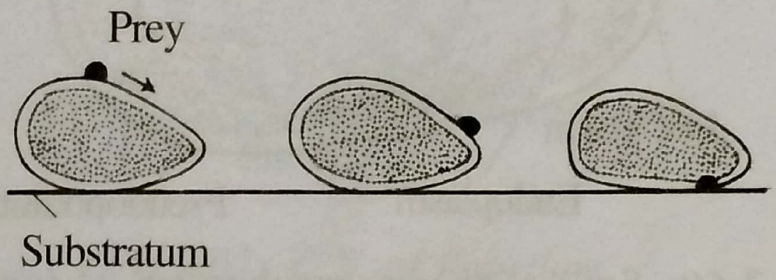

Fig.2.59: Rolling movement in Amoeba verrucosa.

3. Surface-tension Theory

This theory was proposed by ***Berthold.*** This theory says that the pseudopodium is formed from the surface of the body by a change in surface tension. It occurs in the following methods:

1. As protoplasm is a fluid, it remains spherical due to surface tension.
2. The surface-tension may decrease at any point on the surface due to external or internal changes.
3. At the point of low surface tension, the protoplasm flows out in the form of ***pseudopodium.***
4. The *Amoeba* now moves in the direction of ***pseudopodium.***

4. Sol-gel theory or Changes of Viscosity Theory

This theory was proposed by ***Hyman*** (1917). It is the most accepted theory. This theory says that the pseudopodium is formed by the

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change of cytoplasm from ***gel*** to ***sol*** and ***sol*** to ***gel.*** It occurs in the following methods:

1. The plasmalemma is attached to the substratum.
2. At the anterior end, the plasmagel is converted into plasmasol.
3. The plasmagel of the posterior end contracts. This produces a hydraulic pressure on the plasmasol located inside.
4. As a result of the hydraulic pressure, the plasmasol is pushed forwards as a small projection.

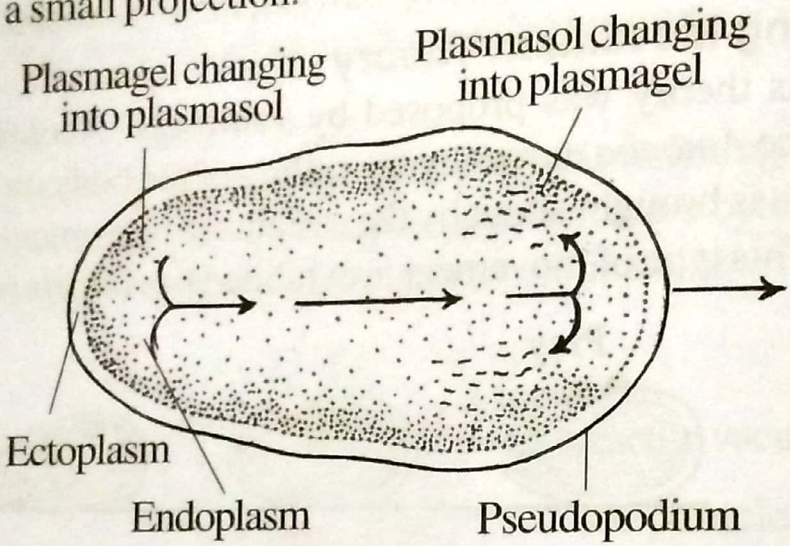

Fig.2.60: Sol-gel theory-mechanism of locomotion in Amoeba.

5. By the continuous ***accumulation*** of plasmasol, the ***pseudopodium*** is formed.
6. At the periphery of the pseudopodium the plasmasol is converted into the plasmagel.
7. The plasmagel of the posterior end is continuously changed into plasmasol and it flows forwards.
8. This results in the withdrawal of pseudopodium from the posterior end and helps the continuous supply of the plasmasol to the developing pseudopodium at the anterior end.
9. By producing pseudopodia continuously in one direction in the above manner, *Amoeba* slowly moves.

2. Flagellar Movement

Flagellar movement is *the swimming brought about by the beating of flagella.* It is exhibited by flagellates. Eg. *Euglena.*

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Flagellum

Flagellum is a whip-like structure. Each flagellum has a central axis called ***axoneme*** and a ***protoplasmic sheath***. The axial filament originates from a ***basal granule***. The basal granule is connected with the ***parabasal body*** or the nucleus by a root-like structure called ***rhizoplast.***

Each axoneme is formed of two ***central fibres*** and nine paired ***peripheral fibres***. Each peripheral pair bears a pair of ***short arms.*** All the fibres are embedded in the ***matrix.***

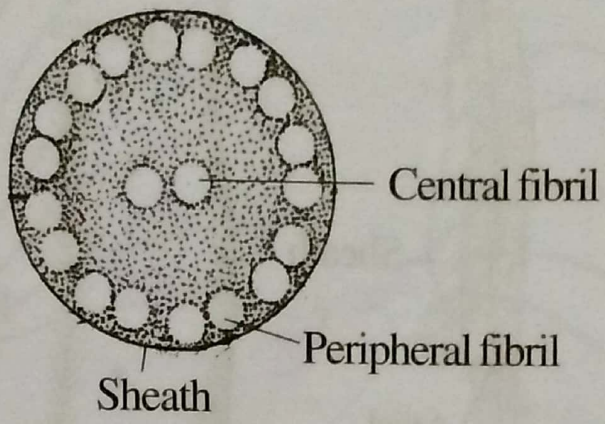

Fig.2.61: T. S. of flagellum.

The flagella bear small fibres on the sides. These fibres are called ***mastigonemes***. Based on the arrangement of mastigonemes, the flagella are classified into the following types:

1. Stichonematic flagellum: This type of flagellum contains a single row of mastigonemes. Eg. *Euglena.*

2. Partonematic flagellum: In this flagellum, mastigonemes are arranged in two or more rows. Eg. *Paranema.*

3. Pentacronematic flagellum: This type of flagellum has two or more rows of mastigonemes and a terminal filament.

4. Acronematic flagellum: Here mastigonemes are absent; but a ***terminal filament*** is seen.

5. Simple flagellum: In this type, mastigonemes and ***terminal filament*** are lacking. Eg. *Chlamydomonas.*

6. Flagellum with undulating membrane: In *Trypanosoma,* the flagellum is provided with an ***undulating membrane.***

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Number of Flagellum

The number of flagellum in an animal may be one or two or more. Of these many flagella, one flagellum pulls the body forwards.

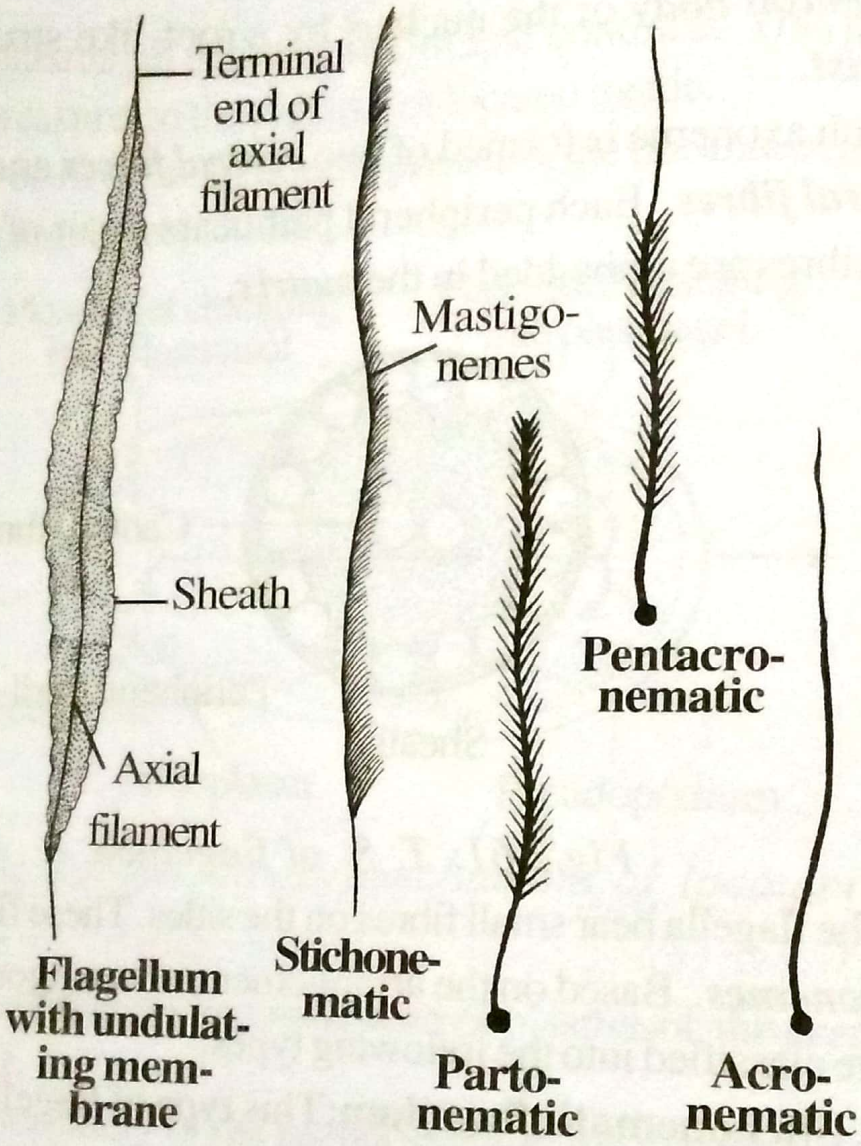

Fig.2.62: Types of flagella.

This flagellum is called ***tractellum.*** It is directed forwards. The flagella which are directed backwards are called ***trailing flagella.*** Certain flagella situated at the posterior end of the body are used to push the body forwards. These flagella are called ***pulsellum.***

Types of Flagellar Movement

The flagellum causes the animal to swim in the water. The swimming is brought about by the oscillation of the flagellum. There are two types of oscillation of the flagellum. They are as follows:

1. Rowing and
2. Undulations.

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1. Rowing: During normal locomotion, the flagellum beats. Each beat consists of an ***effective stroke*** and a ***recovery stroke***. *(Fig.2.63).* During effective stroke, the flagellum is held rigidly with a slight concavity in the direction of the stroke. The effective stroke pushes the water backwards. This draws the body forwards. During recovery stroke, the flagellum is relaxed and well curved and is brought to its original position passively. The flagellum beats obliquely. Hence when the animal moves, it ***rotates*** on its longitudinal axis.

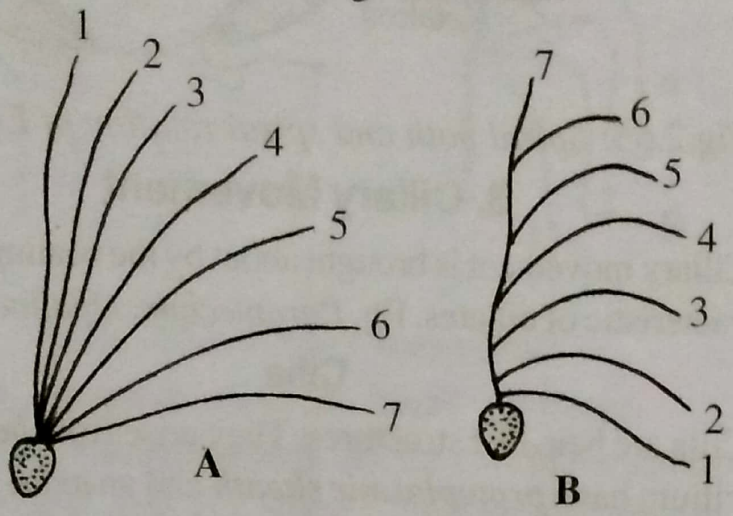

Fig.2.63: Rowing: A. Effective stroke; B. Recovery stroke.

2.Undulations: Some times the flagellum does not beat. But wave-like movements pass along the flagellum. These movements are called ***undulating movements*** *(Fig.2.64).* When the

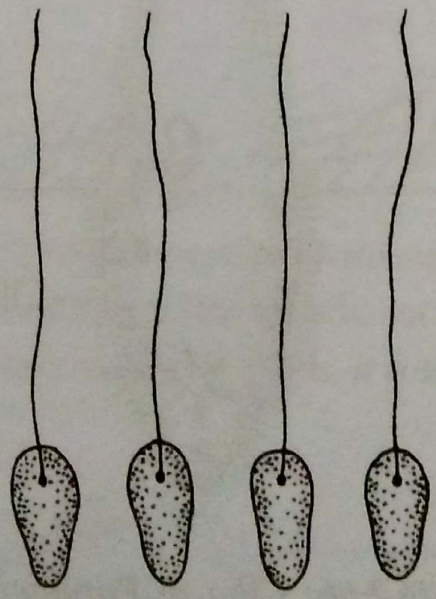

Fig.2.64: Undulating movements of flagellum from the tip to the base.

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undulations pass from the base to the tip, the animal moves ***forwards***. When the undulations pass from the tip to the base, the animal moves ***backwards***. As these undulations are spiral, the organism moves in a ***spiral*** path around a central axis. At the same time the body ***rotates*** on its own axis.

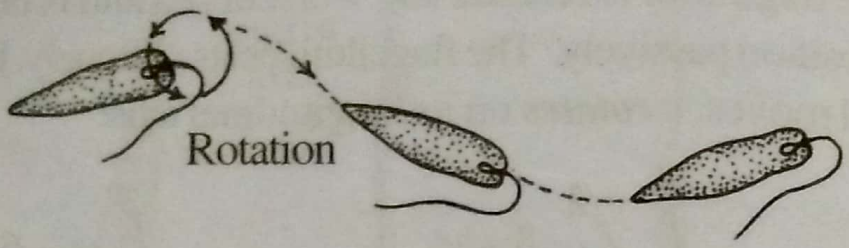

Fig.2.65: Spiral path and spiral rotation of Euglena.

3. Ciliary Movement

Ciliary movement is brought about by the beating of the cilia. It is characteristic of ciliates. Eg. *Paramecium, Opalina,* etc.

Cilia

Cilia are hair-like structures. They arise from ***basal granules***. Each cilium has a ***protoplasmic sheath*** and an ***axial filament***. The axial filament has same structure as that of the flagellum.

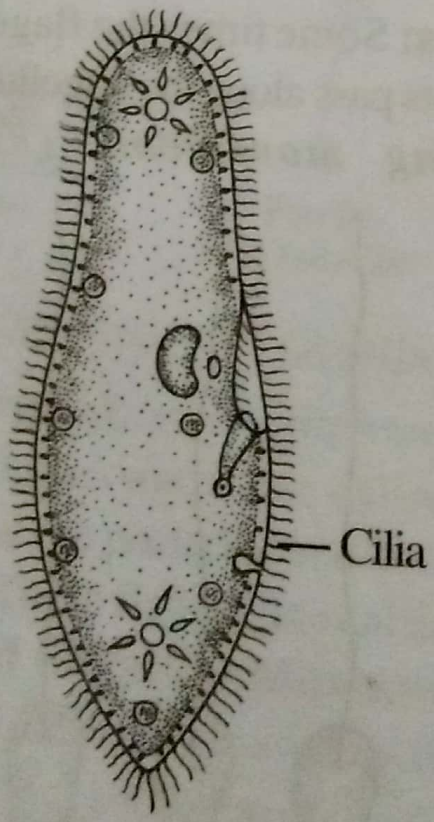

Fig.2.66: Cilia in Paramecium.

The cilia are arranged in longitudinal rows. They may be arranged all over the body uniformly or in restricted areas.

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Mechanism of Ciliary Movement

Ciliary movement is very similar to that of flagellar movement. It has also an ***effective stroke*** and a ***passive recovery stroke***.

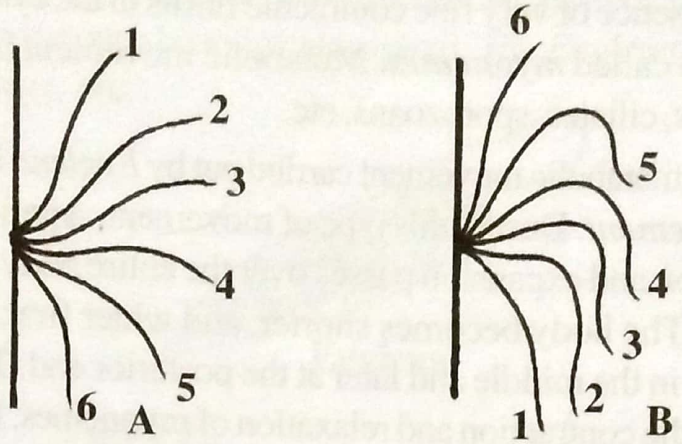

Fig.2.67: Ciliary movement:
A. Effective stroke; B. Recovery stroke.

The cilia beat ***independently***. All the cilia of the same body do not beat at the same time. But all the cilia of a transverse row beat at the same time. The cilia of a longitudinal row beat one after another. This causes a wave-like movement of cilia which is exactly like the movement of paddy in a paddy field. This type of movement of cilia is called ***metachronal rhythm.***

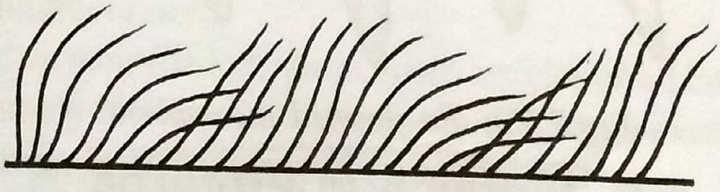

Fig.2.68: Metachronal rhythm.

The cilia do not beat directly backwards; but they beat ***obliquely***. Hence when the animal moves forwards, ***it rotates spirally like a rifle bullet.***

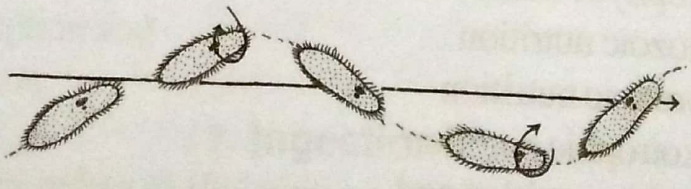

Fig.2.69: Spiral path and rotation of Paramecium.

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4. Metabolic Movement

The metabolic movement is brought about by the contraction and relaxation of the ***body.*** This type of movement is brought about by the presence of very fine contractile fibrils in the cytoplasm. These fibrils are called ***myonemes.*** Metabolic movement is exhibited by flagellates, ciliates, sporozoans, etc.

The metabolic movement carried out by *Euglena* is called ***euglenoid movement***. During this type of movement, a peristaltic wave of contraction and expansion passes over the entire body from the anterior end. The body becomes shorter and wider first at the anterior end, then in the middle and later at the posterior end. This is brought about by the contraction and relaxation of myonemes. Myonemes are situated longitudinally or transversely or spirally in the cytoplasm.

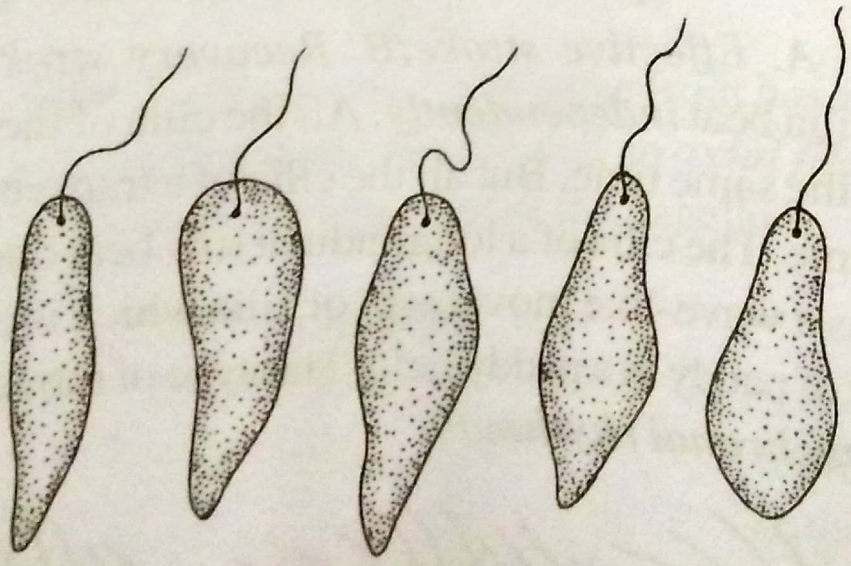

Fig.2.70: Euglenoid movement.

2. Nutrition in Protozoa

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