Phylum Protozoa: General characters and Classification

Introduction

The animals included in phylum Protozoa can be defined as microscopic and acellular animalcules without tissues and organs. They have one or more nuclei. Protozoa exist either singly or in colonies. Almost about 50,000 species are known till date.

Anton Van Leeuwenhoek was the first to observe protozoa (Vorticella convellaria) under a microscope. He called them animalcules. Gold fuss coined the term Protozoa which in Greek means first animals (Proto= first; zoans=animals). Hyman and other zoologists preferred to call them as acellular animals.

The body of protozoans is unicellular. They are generally referred to as acellular rather than unicellular as the so called single cell performs all the life activities. Though it is structurally equivalent to a single cell of the metazoan body, it is functionally equivalent to the whole metazoan animals.

General Characters of Phylum Protozoa

Protozoan animals exhibit protoplasmic grade of organization. There is division of labor among various organelles of the cell.

These are solitary (Euglena), or colonial (Proteospongia)

They may be free living (Amoeba) or symbiotic (Parasitic, mutualistic or commensalistic)

Body symmetry is symmetrical (Actinopodeans) or radial (sessile forms) or bilateral (Giardia) or absent (Amoeba)

Locomotion is brought about by pseudopodia or flagella or cilia or myonemes.

Nutrition is holozoic or holophytic or osmotrophic (Saprophytic or parasitic). Digestion is intracellular. Some forms like Euglena are mixotrophic (perform more than one type of nutrition)

Exchange of respiratory gases takes place by diffusion through the general body surface.

Respiration is anaerobic in some parasitic forms.

Excretion occurs by diffusion across general body surface or by contractile vacuoles.

Contractile vacuoles serve mainly for Osmoregulation and are common in freshwater forms.

Asexual reproduction takes place by binary fission or multiple fission or plasmotomy or budding.

Sexual reproduction takes place by syngamy or conjugation

Many forms undergo encyctment to tide over unfavorable conditions

Somotoplasm and germplasm are not differentiated. Hence they are immortal (exempt from natural death).

Classification of Phylum Protozoa

Phylum Protozoa is a large and varied group. This phylum has a number of problems in its classification. As per one of the classification given out by Hyman, Hickman and Storer, this phylum is divided into two subphyla on the basis of organs of locomotion. These two subphyla are further divided into 5 classes.

Most accepted classification of protozoa is given by BM Honigberg and others based on the scheme given by the committee on Taxonomy and Taxonomic problems of the society of Protozoologists divides this phyla into 4 subphyla.

Phylum Protozoa

The following is the classification as proposed by Honigberg and his group.

SUBPHYLUM I: SARCOMASTIGOPHORA (Gr. Sarcodes=fleshy; mastix=whip; phoros=bearing)

The locomotion in this subphylum is brought about by flagella or pseudopodia or both. Other important feature of this subphylum is the presence of monomorphic nuclei. This subphylum is further divided in to 3 super classes:

Superclass 1: Mastigophora (Gr. Mastix=whip; phoros=bearing)

The body of the animals belonging to this super class is covered by pellicle. The locomotory organelles are flagella. In this super class the asexual reproduction occurs by longitudinal binary fission. This super class includes 2 classes:

Class 1: Phytomastigophora (Gr. Phyton=plant; Mastix=whip; phoros=bearing)

They have chromatophores with chlorophyll. The nutrition in these organisms is mainly holophytic which takes place by phototrophy. These are free living organisms. The reserve food in these organisms is starch or paramylon. These organisms may have 1 or 2 flagella.

Ex: Euglena, Ceratium, Noctiluca

Class 2: Zoomastigophora (Gr. Zoon=animal; Mastix=whip; phoros=bearing)

These organisms do not have chlorophyll bearing chromatophores. These are mostly parasitic. The nutrition in these organisms is holozoic or saprozoic. The reserved food is glycogen. They may have one to many flagella.

Ex: Leishmania, Trypanosoma, Trichomonas, Trichonympha

Superclass 2: Opalinata

The organisms belonging to this super class live as commensals or parasites in the gut of anurans. Their body is covered by oblique rows of cilia-like flagella. These organisms may have 2 or many nuclei also the nuclei are monomorphic. They undergo asexual reproduction by binary fission or by syngamy. Sexual reproduction takes place by anisogamy.

Ex: Opalina, Zelleriella

Superclass 3: Sarcodina (Gr. Sarcode=fleshy)

The locomotion in the organism belonging to this superclass is brought about by pseudopodia. Their body is amoeboid without definite pellicle. The nutrition is holozoic or saprozoic. This super class is further divided into 3 classes:

Class 1: Rhizopodea (Gr. Zoon=animal; Mastix=whip; phoros=bearing)

The pseudopodia of the animals in this class are in the form of lobopodia, filopodia or reticulopodia without axial filaments. This class includes amoebas, foraminiferans and mycetozoans. These animals are mostly free living and a few are also parasitic. In amoebas, the body is naked; in foraminiferans the body is covered by porous calcareous shell.

Ex: Amoeba, Entamoeba, Elphidium
Class 2: Piroplasmea

The animals belonging to this class are parasitic. Locomotory structures are absent in this class. Spores are also absent. These are the small parasites in the red blood cells of vertebrates.

Ex: Babesia

Class 3: Actinopodea (Gr. Actis=ray; podos=foot)

The pseudopodia of the animals belonging to this class are in the form of axopodia with axial filaments, radiating from the spherical body. These are planktonic. This class includes Heliozoans, Radiolarians and acanthareans. Radiolarians and acanthareans are marine forms whereas heliozoans are both marine and fresh water forms. Skeletons of radiolarians have siliceous shells. The shells of dead radiolarians accumulate on the ocean floor to form radiolarian ooze.

Ex: Collozoum, Actinophrys, Acanthometra

SUBPHYLUM II: SPOROZOA (Gr. Actis=ray; podos=foot)

The animals belonging to this subphylum are exclusively endoparasites. Special locomotory organelles are absent in these animals. Sometimes pseudopodia are present which are useful only for ingestion of food. Sporozoites are merozoites bear anterior apical complex that helps penetrate host cells. This subphylum includes 3 classes:

Class 1: Telosporea

The Sporozoites are long in these animals. Reproduction is both asexual and sexual. They are blood and gut parasites of vertebrates. Sexual reproduction is by isogamy or anisogamy.

Ex: Monocyctis, Eimera, Plasmodium

Class 2: Toxoplasmea

In this class reproduction is only asexual type which takes place by internal budding where two daughter cells are produced within the mother cell and the mother cell is finally destroyed in the process of reproduction. Spores are absent.

Ex: Toxoplasma

Class 3: Haplosporea

The spores in this class are amoeboid. Also reproduction is only asexual type taking place through multiple fissions.

Ex: Haplosporidium, Ichthyosporidium

SUBPHYLUM III: CNIDOSPORA (Gr. Knide=nettle; spora=seed)

The animals belonging to this subphylum are parasitic. Special kind of locomotory organelles are absent in these animals. Spores are present with one or more polar filaments. Polar filaments are special and unique features of these animals. When these spores infect a host, the polar filament is discharged and it gets attached to the host tissue. This subphylum includes 2 classes:

Class 1: Myxosporidea

The spores of the animals of this class are large and develop from several nuclei. These are generally extracellular parasites. The spores of this class have two polar filaments and have two to three valves

Ex: Myxobolus

Class 2: Microsporidea

The spores of the animals of this class are small and are developed from only one nucleus. These spores have single valve. These are generally intracellular parasites. Many of the animals of this class have a single polar filament.

Ex: Nosema bombycis

SUBPHYLUM IV: CILIOPHORA (La. Cilium=eye lid with lashes; phoros=bearing)

Ciliophorans are complex of all the protozoans. The locomotory organelle of all the animals of this subphylum is cilia. These cilia also help in feeding at some stage of the life cycle of the animals. The nuclei of these organisms are dimorphic. Macronucleus is vegetative and polyploid. Micronucleus is reproductive and diploid. Asexual reproduction takes place by binary fission. Sexual reproduction takes place by conjugation. Only one class is included in this subphylum:

Class 1: Ciliatea

The locomotory organelles of these animals are numerous hair-like cilia. One or more contractile vacuoles are present in these forms. The nucleus is dimorphic including both macro nucleus and micronucleus.

Ex: Paramoecium, Vorticella, Balatidium

Phylum Protozoa: Locomotary Organs (Pseudopodia, Myonemes, Flagella and Cilia)

Protozoan movement in water
Protozoans in water are subjected to forces of water resistance like pressure drag and viscous drag. Pressure drag is due to the difference of pressure between two ends of the body. Viscous drag is due to the water molecules attached to the surface of the body.

For protozoans which are small in size, viscous drag is of much importance. These organisms are not streamlined to minimize the pressure drag.

Locomotory Organs in Protozoa
Locomotion is the movement of the animals from place to place. It is performed in search of food, mate, and shelter or to escape from predators etc. it is influenced by external and internal stimuli.

Protozoans are very primitive, single celled animals which show great adaptability in their locomotion. They exhibit slowest locomotion like amoeboid locomotion and also the fastest locomotion like ciliary locomotion.

In protozoans, locomotion is brought about by

Cellular extensions like Pseudopodia (Eg: Amoeba)
Pellicular contractile structures like Myonemes (Eg: Euglena and Sporozoans)
Locomotory organelles like Flagella (Eg: Paramecium) and Cilia (Eg: Euglena)
PSEUDOPODIA (CELLULAR EXTENSION)
They are also known as false feet. These are the temporary outgrowths of the cell. They are formed on the surface of the body by the movement of the cytoplasm.

Depending on number of pseudopodia formed on the surface:
Polypodia- Several pseudopodia formed on the surface of the body.

Eg: Amoeba proteus

Monopodia- Only single pseudopodia is formed on the surface of the body.

Eg: Entamoeba histolytica

Depending on the structure of the pseudopodia:
Lobopodia: These are lobe like and blunt structures with broad and rounded ends. These structures composed of endoplasm and ectoplasm. Lobopodia move by pressure flow mechanism.

Eg: Amoeba proteus, Entamoeba histolytica

Filopodia: These are slender filamentous pseudopodia tapering from base to tip. Sometimes these may be branched out but they are not fused to form a network. They are composed of only ectoplasm.

Eg: Euglypha, Lecithium

Reticulopodia: They are also known as rhizopodia or myxopodia. They are filamentous, profusely interconnected and branched. They form a network. The primary function of these pseudopodia in ingestion of food and the secondary function is locomotion. They exhibit two way flow of the cytoplasm. They are commonly found in foraminifers.

Eg: Elphidium, Globigerina

Axopodia: These are fine needle like, straight pseudopodia radiating from the surface of the body. Each Axopodia contain a central axial rod which is covered by granular and adhesive cytoplasm. The main function of these axopodia is food collection. Axopodia also exhibit two-way flow of cytoplasm. Axopodia are mainly found in Heliozoans and radiolarians.

Eg: Actinosphaerium, Actinophrys, Collozoum

MYONEMES (PELLICULAR CONTRACTILE EXTENSIONS)

Many protozoans have contractile structures in the pellicle or ectoplasm called as myonemes. These may be in the form of,

* Ridges or grooves (Eg: Euglena)

* Contractile myofibrils (Eg: Larger ciliates)

* Microtubules (Eg: Trypanosoma)

FLAGELLUM (LOCOMOTORY ORGANELLES)

Flagella are the locomotory organelles of flagellate mastigophoran protozoans. They are mostly thread like projection on the cell surface. A typical flagellum consists of an elongated, stiff axial fiber called as axial filament or axoneme enclosed by an outer sheath. The axoneme arises from basal granule called as blepharoplast or kinetosome which is further derived from Centrioles. Blepharoplast lies below the cell surface in the ectoplasm. The region around blepharoplast is called microtubular organizing center that controls the assembly of microtubules.

When the axial filament is viewed under an electron microscope 9 + 2 arrangement can be observed. The 2 central longitudinal fibers are enclosed by membranous inner sheath. The 2 central longitudinal fibers are surrounded by 9 longitudinal peripheral doublets (each with microtubules A and B) which form a cylinder between the inner and the outer sheath. Each peripheral paired fiber is connected to the internal membranous sheath by radial spokes. Each peripheral doublet also has pairs of arms directed towards neighboring doublet. These arms are made of the protein called as dynein. The arms create the sliding force. The peripheral doublets are surrounded by an outer membranous sheath called as protoplasmic sheath, which is an extension of the plasma membrane. Some flagella also bear lateral appendages called as flimmers or mastigonemes along the length of the axoneme above the level of the pellicle.

Types of Flagella

Number and arrangement of flagella vary in Mastigophora from one to eight or more. Free living species usually have one to eight flagella whereas the parasitic forms may have one to many flagella. Flagella are classified based on the arrangement of lateral appendages and the nature of the axial filament.

Stichonematic: Only one row of lateral appendages occurs on the axoneme up to tip.

Eg: Euglena, Astasia

Pantonematic: Two or more rows of lateral appendages occur on the axoneme

Eg: Peranema, Monas

Acronematic: Lateral appendages are absent and axoneme ends as a terminal ‘naked’ axial filament

Eg: Chlamydomonas, Polytoma

Pantacronematic: Flagellum is provided with two or more rows of lateral appendages and the axoneme ends in a terminal naked axial filament.

Eg: Urceolus

Anematic: In some cases the flagella is simple without any lateral appendages and a terminal naked filament.

Eg: Chilomonas, Cryptomonas

CILIA (LOCOMOTORY ORGANELLES)
Cilia are short hair like structures present all over the surface of the body. They may be also confined to specific regions of the ciliate protozoan. Cilia help in locomotion as well as in food collection.

Cilia greatly resemble the flagella in the basic structure. The major difference between the flagella and the cilia is that cilia are smaller compared to the flagella. Cilia arise from the kinetosome. Cilia consist of an axial filament called as axoneme surrounded by the protoplasmic outer sheath.

Electron microscopic studies of axoneme reveal 9 + 2 organization of the peripheral doublet fibrils and central singlet fibrils. The details of the 9 + 2 organization and the presence of the dynein arms are similar to that of the flagellum. All these fibrils are embedded in a matrix. The central fibrils are enclosed within a delicate sheath.

The infraciliary system is located just beneath the pellicle. It consists of kinetosomes at the bases of cilia, kinetodesmos or kinetodesmal fibrils that are connected to the kinetosomes and running along the right side of each row of kinetosomes as cord of fibers known as kinetodesmata. A longitudinal row of kinetosomes, kinetodesmal fibrils and their kinetodesmata form a unit called kinety. All the kineties together form an infraciliary system that lies in the ectoplasm. The infraciliary system is connected to the motorium, a neuromotor center neat the cytopharynx and forms the neuromotor system. This neuromotor system controls and coordinates the movement of cilia.

Types of cilia
* In some primitive forms like holotrichs (Eg: Paramecium) cilia are present all over the body

* In some forms like peritrichs (Eg: Vorticella) cilia are present only in the peristomial region In Suctorians (Eg: Acineta) cilia are present in only in the young ones which are later replaced by sucking tentacles in the adults

Compound ciliary organelles
* Cilia in compound ciliary organelles do not fuse, but their basal granules are sufficiently close to introduce a sort of coupling.

* A group of cilia that forms a bundle is called as cirrus. An undulating membrane is a row of adhering cilia forming long sheet.

* The smaller rows of adhering cilia form the membranelles

Q1. Name the locomotory organelle of the following Animals.
Ans

a. Nereis	Parapodia
b. Star Fish	Tube Feet
c. Amoeba	Pseudopodia
d. Paramecium	Cilia
e. Euglena	Flagella
f. Pila & UNio	Foot
g. Fasciola	Absent
h. Sycon	Absent
i. Prawn	Walking Legs, Pleopods & Uropods

Q2. What is locomotion? Write the significance of locomotion.
Ans. Locomotion is the movement of an animal as a whole from one place to another. It is the characteristic feature of the animals. It helps in nutrition, reproduction, respiration, excretion, protection and distribution of the species.
Q3. What is kinesiology?
Ans. Study of movements is called kinesiology.
Q4. How many modes of locomotion are found in Protozoa? Ans: Protozoans have different locomotory organs and their presence or absence is one of the main bases of their classification. Different types of locomotory organs found in different classes are as follows: Rhizopoda: Peudopodia Flagellata: Flagella Ciliata: Cilia Sporozoa: Absent
Q5. Describe the pseudopodial locomotion or amoeboid movement in detail.
Ans: Pseudopodia means false feet derived from a greek word(pseudos, false + podos, foot). Amoeboid movement is typically found in amoeba, a unicellular animal. As Amoeba moves by producing pseudopodia, such locomotion is

called as the pseudopodial locomotion. Pseudopodia are cytoplasmic projections. This involves change in the shape of the cell body and streaming movement of cytoplasm into the pseudopodium. The movement due to pseudopodia in amoeba is termed as amoeboid movement. Amoeboid movement is characteristic of certain cells in other organisms. For example, the movement of white blood cells or leucocytes, in human blood.
This was discovered by Rossenhoff. The rate of speed of amoeba is .02– .03 mm /minute. At freezing point no pseudopodia are formed.
In general, Protozoans have four types of pseudopodia. Lobopodia,; filopodia; reticulopodia, and axopodial. Pseudopodial locomotion can be classed as either axial or appendicular, depending upon the definition of the pseudopodium. Outwardly, pseudopodial locomotion appears to be the extension of a part of the body that anchors itself and then pulls the remainder of the body forward.
Internally, its cytoplasm (the living substance surrounding the nucleus) is divided into two parts: a peripheral layer, or ectoplasm of gel enclosing an inner mass, and endoplasm, of sol. As a pseudopodium is formed, part of the ectoplasmic gel is converted to sol, whereupon endoplasm begins flowing toward this area, the cell wall expands, and the pseudopodium is extended forward. When the endoplasm, which continues to flow into the pseudopodium, reaches the tip, it extends laterally and is transformed to a gel. Basically, the movement is one of extending an appendage and then emptying the body into the appendage, thereby converting the latter into the former. The energy required for amoeboid locomotion is available from - ATP by the action of ATPase

Q4. Describe various theories regarding formation of pseudopodia and pseudopodial locomotion or. Ans. Several theories have been given for the formation of pseudopodia and pseudopodial locomotion. 1. Contraction theory – Proposed by Schultuz. 2. Walking theory – Given by Dellinger. 3. Rolling movement theory – Given by Jenning by doing experiment on A. verucosa using charcoal.
4. Surface Tension theory – Given by Berthold. The point where surface tension is low, pseudopodia is formed. 5. Adhesion theory – Given by Jenning amoeba moveslike drop of water. 6. Fountain zone theory – Given by Allen. 7. Folding and unfolding theory – Given by Goldacre and Lorch. 8. Hydraulic pressure theory – Given by Renoldi and Jaun. 9. Sol–gel theory – Given by Hyman and supported by Mast and Pentin.
1. Surface Tension Theory:

It was put forward by Butschli and was widely accepted for long. According to this view locomotion in amoeba is essentially like the movement of a globule of mercury or other liquid produced by local reduction of surface of the fluid protoplasm that makes the mass spherical. From such a sphere an outflow will occur wherever the surface tension is locally lowered, either by internal or external changes. In such a projection the fluid will flow forward and the centre and backward along the sides. Such streaming movement can be seen in active pseudopods of some amoeboid forms. It is very simple and attractive theory which has been extended in its application to various types of activity in amoeba (by Rhumbler). There are, however, a number of fully established facts which show conclusively that surface tension as applied in this theory plays but a very insignificant role in the process of movement and locomotion in amoeba. The objections to this theory are as follows: 1. The upper surface in many species moves forward in places of backward. That is, it moves in a direction opposite to that produced in a globule of liquid by local reduction in surface tension. 2. Many amoebae are so rigid that local reduction in surface tension cannot produce movement. 4. According to this view the surface is assumed to be liquid whereas in most amoeboid forms it is gelatinized. This theory is consequently untenable.

2. Sol–gel theory :

The sol-gel theory was first advocated by Hyman (1917) and has been adopted, among other, by Pantin (1923-1926) and Mast (1925). This is the most accepted theory of pseudopodial formation. This theory is based upon the fact that the plasmasol changes into the plasmagel and vice versa. The cytoplasm inside the cell is capable of changing into different forms i.e. from fluid to solid and vice versa. When the cytoplasm is in fluid state, it is known as plasma sol, and the more solid or gel like state is called the plasma-gel. The plasmasol changes into rigid plasmagel (gelates) at the anterior end and at the posterior end the plasmagel changes into plasmasol (solates) causing a forward streaming of the more fluid plasmasol). The interchange of plasma sol to plasmagel is known as Sol- Gel theory and is responsible for amoeba movement. Pseudopodial formation basically consists of some steps which are as follows:-

When the cytoplasm is in solid or gel like state, there is no locomotion. Movement takes place only when the cytoplasm is in fluid state. This way the amoeba "drags" itself and this movement is known as amoebic movement.

The protoplasm which is thick, less in quantity, non granular transparent and contractile is - Plasmagel. The protoplasm which is more in quantity less viscous, fluid like more granular and opaque is plasmasol.

The change of Sol into Gel, and Gel into Sol is a Physico - Chemical change.

The first stage in the formation of pseudopodia is - Hyaline cap formation. Hyaline cap contains thickened ectoplasm at the advancing end. The point of weakness in the elasticity of plasmagel develops below the Hyaline cap.

Conversion of plasma gel into plasma sol by taking water is called - Solation.

Conversion of plasma sol into plasma get by losing water is called - Gelation.

During amoeboid locomotion amoeba has - Two ends,

The smooth round end is - advancing end and The trailing or retractile or wrinkled ends is Uroid end.

Ectoplasm is - Plasma gel, and the Endoplasm is Plasma sol.

The outer region of plasma sol produces Plasmagel tube.

During pseudopodial formation conversion of sol into gel takes place near (gelation zone) at the

advancing end. The protein molecules present in the cytoplasm that are involved in the amoeboid locomotion are actin and myosin.

During pseudopodial formation, conversion of Gel into Sol takes place near the (Solation zone) i.e.

"Uroid”. Gelation and solation occur simultaneously at the same rate.

3. Hydraulic pressure theory – Given by Renoldi and Jaun

Contraction of plasmagel tube at the trailing end exerts Hydraulic pressure on plasma sol, this results in the continuous flow of plasma sol forwards in the plasmagel tube and forms the pseudopodium.

4. Folding and unfolding theory
According to this view on sol gel theory was explained the basis of action of protein molecules by Goldacre and Lorsch.
When the protein molecules of Amoeba are in Folded or Contracted condition the endoplam is said to be in - 'Sol State".
When the protein molecules are in relaxed or unfolded condition, the endoplasm is said to be in – Gel State".
Folded protein molecules unfold at the gelation point of the advancing end by - losing water.
Relaxed proteins at the solation point below the uroid surface fold due to - The absorption of water

5. Rolling movement theory
It was given by Jenning by doing experiment on A. verucosa using charcoal. In some specimens locomotion is accompanied with „rolling movement‟ of the surface. With the help of carbon particle Jennings stated that A.verucosa moves like a rolling ball. This generally occurs in the monopodal specimens. Structure and Function of Invertebrates 11

Q.5 Describe different types of pseudopodia found in various species of protozoa.
Ans. The temporary outgrowths of the cell formed on the surface of the body are Pseudopodia. Pseudopodia are the characteristic of the classes- Rhizopodia and Actinopodia but they also occur in few mastigophorans - Mastigamoeba
Based on number of pseudopodium organisms can be monopodium or polypodium.
Organisms with many pseudopodia are called Polypodial organisms Eg: Amoeba. Organisms with a single pseudopodium are called Monopodial organisms Eg: Entamoeba.

Based on their form and structure pseudopodia are - 4 types, Lobopodia, Filopodia, Reticulopodia and Axopodia or Actinopodia
Lobopodia are blunt and finger like tubular pseudopodia containng ectoplasm and endoplasm with round tip Eg : Amoeba, Entamoeba.
Filopoda are slender filamentous, pseudopodia with pointed tips. Eg : Euglypha, Lecithium.
Reticulopodia are - Filamentous branched, net like pseudopodia chiefly meant for food collection Eg : Elphidium, Globigerina. Recticulopodia are also called Myxopodia. Primary function of Recticulopodia is - Ingestion of food. Retculopodia are common in – Foraminifers
Axopodia or Actinopodia are needle like pseudopodia, which develop radially on the body surface with a central axial filament. These are pseudopodia with adhesive cytoplasm. The main function of Axopodia is Food collection. Axopodia occur in Helozoans (Actinosphaerium, Actinophrys) and Radiolarians (Collozoum).