CBCS 1ST SEM MAJOR : PAPER -1

UNIT 1: PROTISTA, PERAZOA AND METAZOA:GENERAL CHARACTERS AND CLASSIFICATION UPTO CLASS

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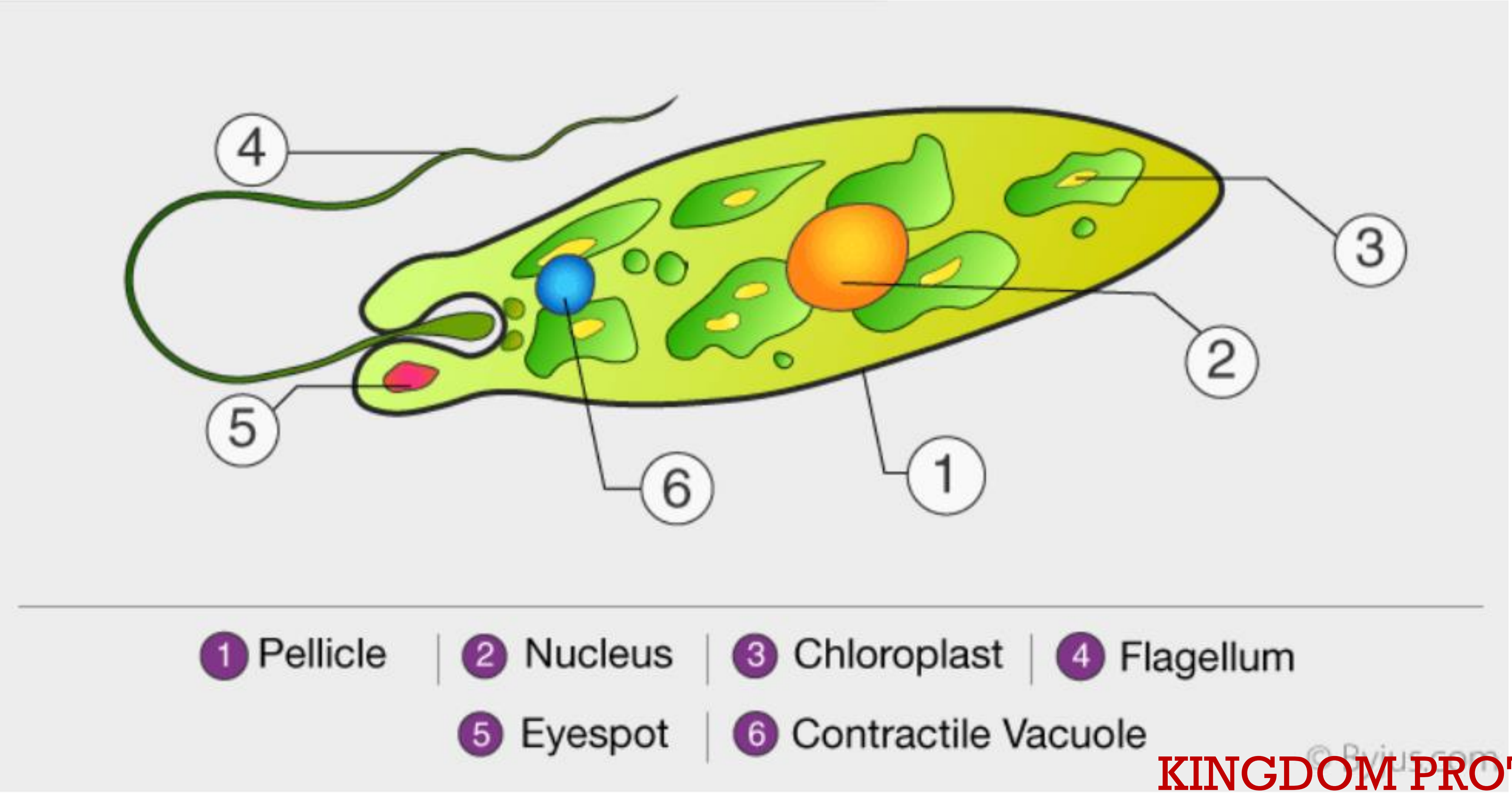
PROTISTA, CHARACTERS AND CLASSIFICATION UPTO CLASS

What are Protists?

Protists are simple eukaryotic organisms that are neither plants nor animals or fungi. Protists are unicellular in nature but can also be found as a colony of cells. Most protists live in water, damp terrestrial environments, or even as parasites.

The term 'Protista' is derived from the Greek word "protistos", meaning "the very first". These organisms are usually unicellular and the cell of these organisms contain a nucleus which is bound to the organelles. Some of them even possess structures that aid locomotion like flagella or cilia.



KINGDOM PROTISTA

Characteristics of Kingdom Protista

The primary feature of all protists is that they are eukaryotic organisms. This means that they have a membrane-enclosed nucleus. Other characteristic features of Kingdom Protista are as follows:

1. **These are usually aquatic, present in the soil or in areas with moisture.**
2. **Most protist species are unicellular organisms, however, there are a few multicellular protists such as kelp. Some species of kelp grow so large that they exceed over 100 feet in height. (Giant Kelp).**
3. **Just like any other eukaryotes, the cells of these species have a nucleus and membrane-bound organelles.**
4. **They may be autotrophic or heterotrophic in nature. An autotrophic organism can create their own food and survive. A heterotrophic organism, on the other hand, has to derive nutrition from other organisms such as plants or animals to survive.**

5.Symbiosis is observed in the members of this class. For instance, kelp (seaweed) is a multicellular protist that provides otters, protection from predators amidst its thick kelp. In turn, the otters eat sea urchins that tend to feed on kelp.

6.Parasitism is also observed in protists. Species such as Trypanosoma protozoa can cause sleeping sickness in humans.

7.Protists exhibit locomotion through cilia and flagella. A few organisms belonging to kingdom Protista have pseudopodia that help them to move.

8.Protista reproduces by asexual means. The sexual method of reproduction is extremely rare and occurs only during times of stress.

Classification of Protista

Kingdom Protista is classified into the following:

Protozoa

Protozoans are unicellular organisms. Historically, protozoans were called "animal" protists as they are heterotrophic, and showed animal-like behaviours.

Protista Single-celled eukaryotes

Features of Kingdom Protista

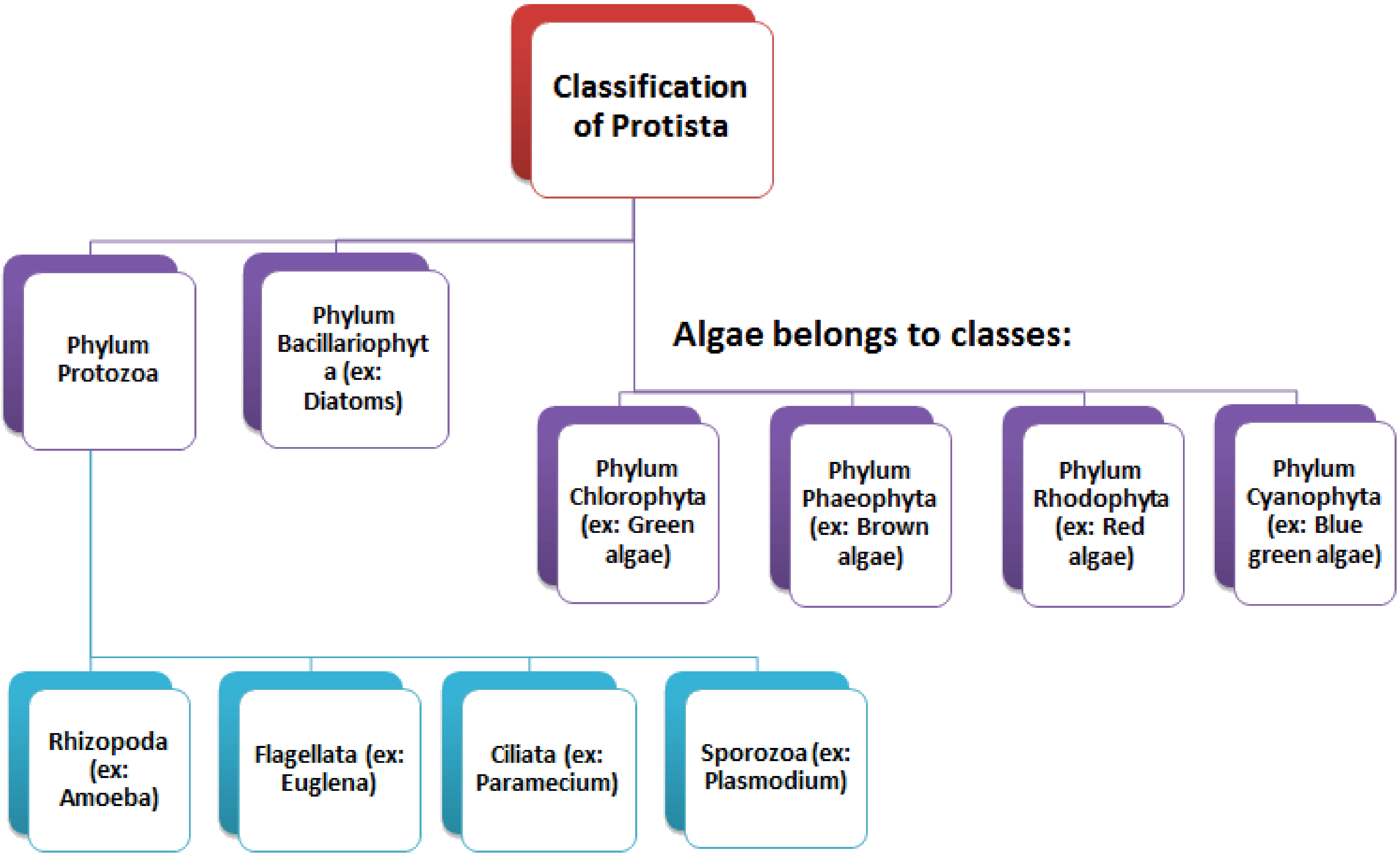
- Unicellular organisms
- Primarily aquatic
- Link between plants, animals & fungi
- Well defined nucleus & membrane-bound organelles
- Reproduction: Asexual & sexual
- Mode of nutrition: Photosynthetic, holotrophic & mixotrophic

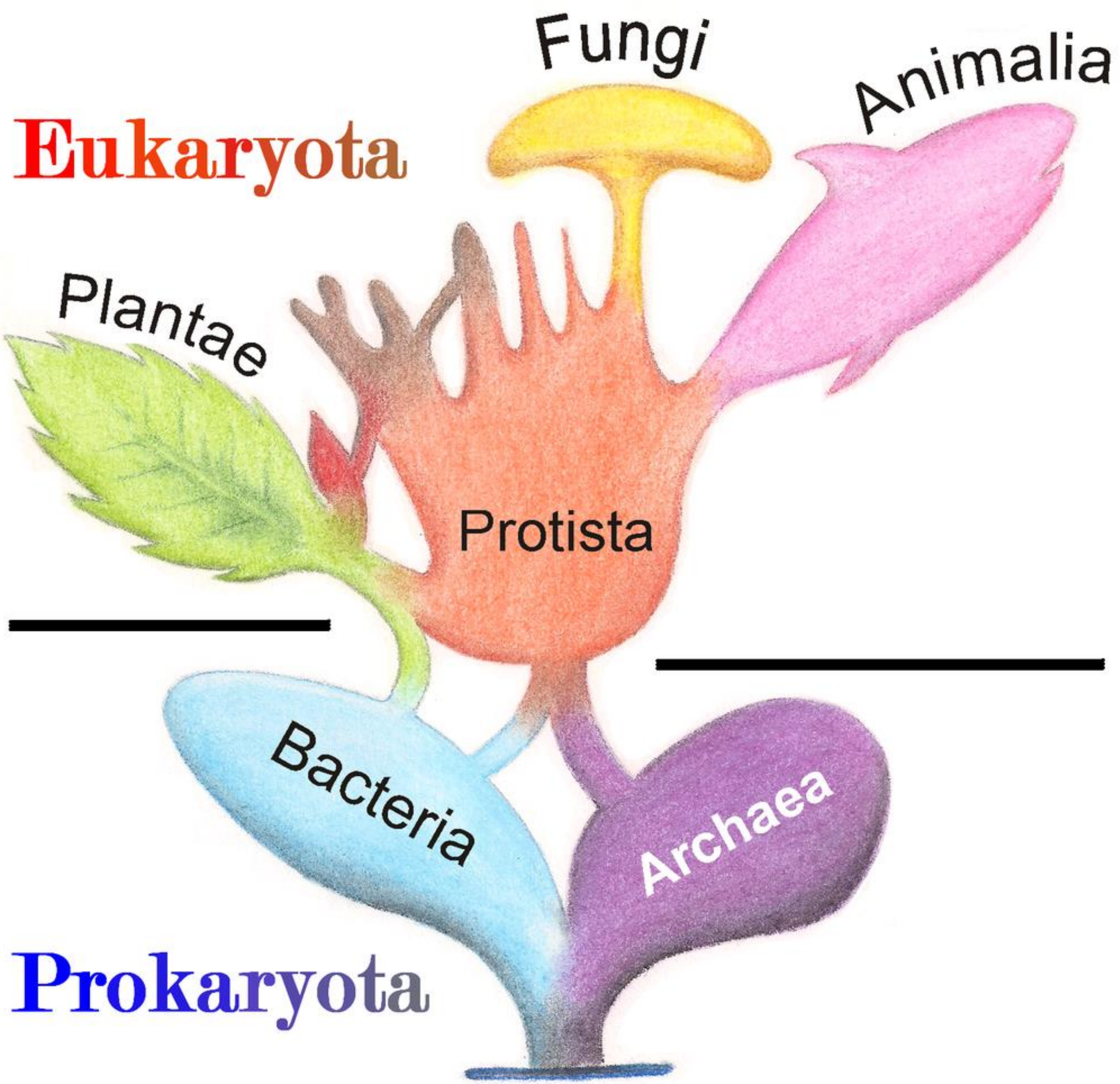
Grouping of Protists

Prokaryotic	Consumer	Protozoan
• Dinoflagellate • Diatoms • Euglenoids	• Slime moulds • Myxomycetes	• Slime moulds • Myxomycetes

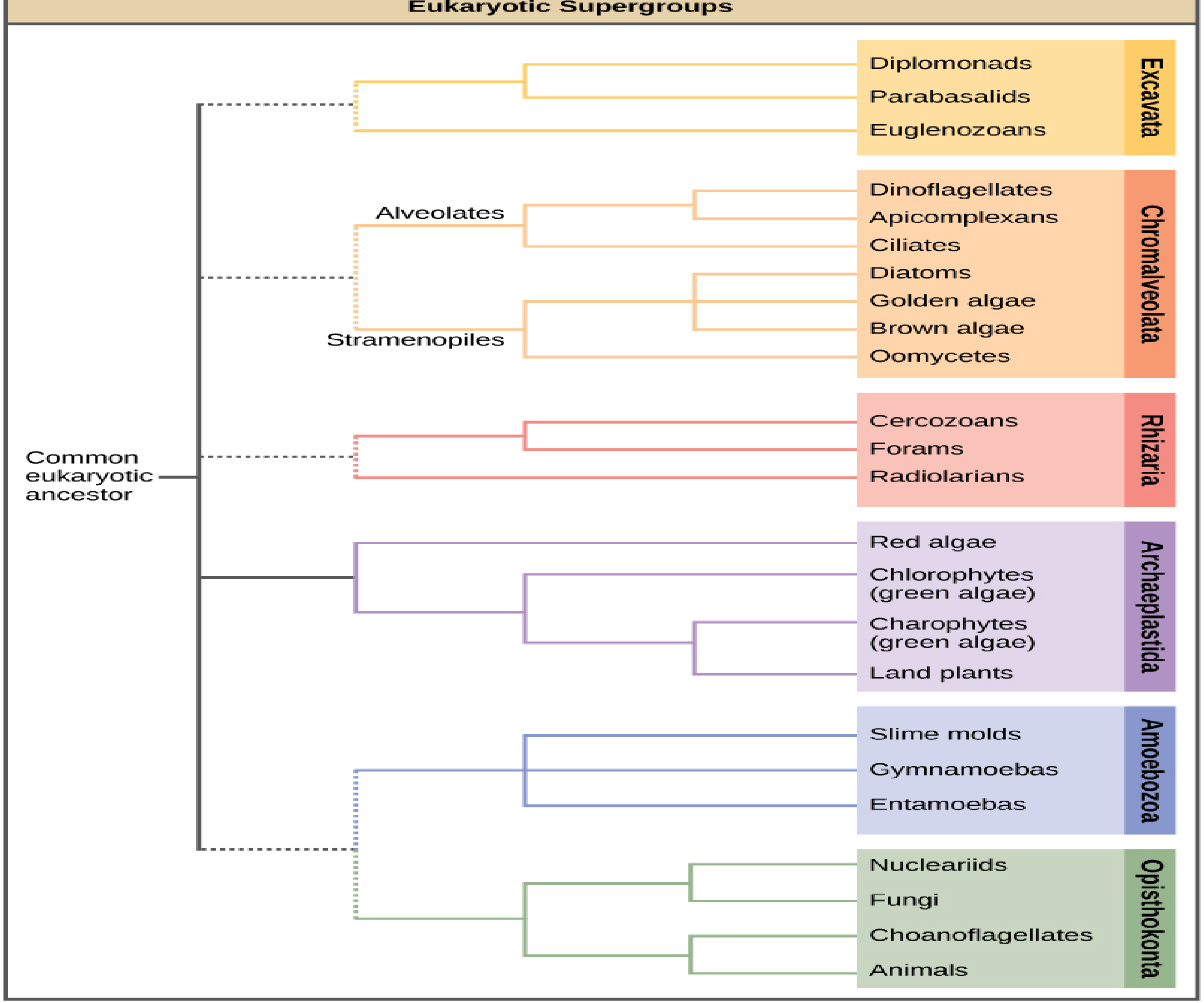
Major Protist Groups

- Chrysophytes
- Dinoflagellates
- Protozoans
  - Amoeboid
  - Flagellates
  - Sporozoans
  - Ciliates
- Euglenoids
- Slime moulds


Classification of Protista
Phylum Protozoa
Phylum Bacillariophyta (ex: Diatoms)
Algae belongs to classes:
Phylum Chlorophyta (ex: Green algae)
Phylum Phaeophyta (ex: Brown algae)
Phylum Rhodophyta (ex: Red algae)
Phylum Cyanophyta (ex: Blue green algae)
Rhizopoda (ex: Amoeba)
Flagellata (ex: Euglena)
Ciliata (ex: Paramecium)
Sporozoa (ex: Plasmodium)



PHYLOGENETIC AND SYMBIOTIC TAXONOMIC CLASSIFICATION OF PROTIST



Eukaryotic Supergroups
Diplomonads
Parabasalids
Euglenozoans
Excavata
Alveolates
Dinoflagellates
Apicomplexans
Ciliates
Stramenopiles
Diatoms
Golden algae
Brown algae
Oomycetes
Chromalveolata
Cercozoans
Forams
Radiolarians
Rhizaria
Common eukaryotic ancestor
Red algae
Chlorophytes (green algae)
Charophytes (green algae)
Land plants
Archaeplastida
Slime molds
Gymnamoebas
Entamoebas
Amoebozoa
Nucleariids
Fungi
Choanoflagellates
Animals
Opisthokonta

There are also parasitic protozoans which live in the cells of larger organisms. Most of the members do not have a predefined shape. For instance, an amoeba can change its shape indefinitely but a paramecium has a definite slipper-like shape. The most well-known examples of protozoans are amoeba, paramecium, euglena. Unlike other members of this group, euglena is a free-living protozoan that has chlorophyll, which means it can make its own food.

The protozoans can be divided into four major groups:

Amoeboid protozoans – Mostly found in water bodies, either fresh or saline. They have pseudopodia (false feet) which help to change their shape and in capturing and engulfing food. E.g. Amoeba

Flagellated protozoans – As the name suggests, the members of this group have flagella. They can be free-living as well as parasitic. E.g. Euglena

Ciliated protozoans – They have cilia all over their body which help in locomotion as well as nutrition. They are always aquatic. E.g. Paramecium

Sporozoans – These organisms are so-called because their life cycle has a spore-like stage. For example, the malarial parasite, Plasmodium.

Slime Moulds - Slime moulds are saprophytic organisms (they feed on the dead and decaying matter). These are tiny organisms that have many nuclei. Usually, Slime moulds are characterized by the presence of aggregates called plasmodium and are even visible to the naked eye.

Chrysophytes, Dinoflagellates and Euglenoids: -These form another category under kingdom Protista. These are generally single-celled or multicellular organisms. These are photosynthetic, found mostly in freshwater sources or marine lakes. They are characterized by a stiff cell wall.

Example of chrysophytes include diatoms and golden algae. They are characterised by the presence of a hard siliceous cell wall. Diatomaceous earth is formed due to the accumulation of cell wall deposits. They are photosynthetic organisms.

Dinoflagellates are photosynthetic and found in various different colours, according to the pigment present in them. They show bioluminescence and known to cause red tide.

Euglenoids are the link between plants and animals. They lack a cell wall but perform photosynthesis. In the absence of sunlight, they act as a heterotroph and feed on small organisms. The outer body covering is a protein-rich layer known as a pellicle. E.g. Euglena, Trachelomonas, etc.

Economic Importance of Protists

1. Protists serve as the foundation of the food chain.
2. Protists are symbionts – having a close relationship between two species in which, one is benefited.
3. Some protists also produce oxygen and may be used to produce biofuel.
4. Protists are the primary sources of food for many animals.
5. In some rare cases, Protists are harvested by humans for food and other industrial applications.
6. Phytoplankton is one of the sole food sources for whales
7. Seaweed is an alga, which is considered a plant-like protist.
8. Zooplankton is fed on by various sea creatures including shrimp and larval crabs.

Parazoa is a Sub-Kingdom under the Kingdom Animalia. The only surviving Parazoans are the sponges, which belong to the phylum Porifera, and the Trichoplax in the phylum Placozoa.

PARAZOA:GENERAL CLASSIFICATION UPTO CLASS

Parazoa (pair-uh-ZO-uh) is derived from two Greek roots that mean next to [=para (παρά)] and animals [=zoa (ζώο)]. The reference is to their separation from the other animals because of their simple organization without organ systems. Both Huxley (1875) and Sollas (1884) suggested that the sponges were different enough to be separated from the rest of the animal kingdom (Thomas 1976). Sollas (1884) coined Parazoa as a formal name to distinguish them from the Metazoa (the other animals).

INTRODUCTION TO THE PARAZOA

The parazoan level of organization is a loose association of cells and structural elements that behave almost as a cellular aggregate rather than a multicellular organism. Still, the two phyla likely share only primitive characters. Furthermore, Trichoplax, the sole genus in the Phylum Placozoa, likely is secondarily simplified. Either way, this subkingdom is a paraphyletic group. The affinities between the Porifera and choanoflagellates are more clear. Please consult The Major Clades of the Animal Kingdom for some views on the relationships of the parazoan phyla with each other and with the other phyla of the animal kingdom.

PHYLUM PLACOZOA (ONE OR TWO GENERA IN A SINGLE ORDER)

PHYLUM PORIFERA

CLASS HEXACTINELLIDA (4 ORDERS DISTRIBUTED IN 2 SUBCLASSES)

SUBCLASS HEXASTEROPHORA: Aphrocallistes, Caulophacus, Euplectella, Hexactinella, Leptophragmella, Lophocalyx, Rosella, Sympagella.

SUBCLASS AMPHIDISCOPHORA: Hyalonema, Monorhaphis, Pheronema

CLASS CALCAREA (7 ORDERS DISTRIBUTED IN 2 SUBCLASSES)

SUBCLASS CALCINEA :Clathrina, Dendya, Leucascus, Leucetta, Murrayona, Soleniscus.

SUBCLASS CALCARONEA : Amphoriscus, Grantia, Leucilla, Leucoselenia, Petrobiona, Scypha (Sycon).

CLASS HOMOSCLEROMORPHA: Corticium, Oscarella, Plakina, Plakortis, Plakinolopha, Plakinastrella, Pseudocorticium.

CLASS DEMOSPONGIAE (15 ORDERS)

SUBCLASS TETRACTINOMORPHA

Acanthochaetes, Asteropus, Chondrilla, Chondrosia, Cliona, Cryptotethya, Geodia, Merlia, Polymastia, Rhabdermia, Stelletta, Superites, Tethya, Tetilla.

SUBCLASS CERACTINOMORPHA

Adocia, Agelas, Aplysilla, Aplysina (Verongia), Asbestopluma, Astrosclera, Axinella, Axociella, Calcifibrospongia, Callyspongia, Ceratoporella, Clathria, Coelosphaera, Goreauiella, Halichondria, Haliclona, Halisarca, Hispidopetra, Hymeniacidon, Ircinia, Lissodendoryx, Microciona, Mycale, Myxilla, Spongia, Spongilla, Stromatospongia, Tedania, Valceletia

Subkingdom Parazoa

Phylum Porifera

- Habitat
  - 5000 species (All aquatic, some brackish, most marine)
- Anatomy
  - Sessile
  - Two layers imbedded in a gelatinous matrix (mesohyl)
    - Outer layer of epidermal cells
    - Inner layer of choanocytes or epidermal cells
    - Amoebocytes and spicules in mesohyl
  - Skeleton
    - Spicules of Calcium carbonate or silicon
    - Spongin is a flexible skeleton
  - Cells
    - Porocytes -- Form incurrent pores in the epithelial body wall
    - Choanocytes
      - Flagellated cell
      - Contain collars
      - Create water current and trap food
    - Amoebocytes
      - Wandering cells in the mesohyl
      - Can differentiate into any other cell type
      - Functions
        - Food digestion
        - Nutrient distribution
        - Food storage
        - Gamete formation
        - Spicule formation
    - Epidermal cells
      - Line the outside and sometimes the spongocoel and canals
  - Basic body plan
    - Choanocytes on inside create a water current
    - Water enters incurrent pores
      - Pores are formed by porocytes
    - Goes into the spongocoel
      - Central cavity of the sponge
    - Exits the sponge through oscula
      - Large excurrent opening of the spongocoel
- Filter feeders
  - All cells capable of phagocytosis / intracellular digestion and absorption.
  - Feeding
    - Choanocytes
      - Collar sieve with mucous
      - Creates water current and traps food
      - Slides down and phagocytized at base
    - Amoebocytes
      - Collects, digests, distributes, and stores food
- Other physiology
  - No respiratory or excretory organs
  - Gas exchange and ammonia removed by water flow

Parazoa **is the animal sub-kingdom that includes organisms of the phyla Porifera and Placozoa. Sponges are the most well-known parazoa. They are aquatic organisms classified under the phylum Porifera with about 15,000 species worldwide. Although multicellular, sponges only have a few different types of cells, some of which may migrate within the organism to perform different functions.**

The three main classes of sponges include glass sponges (Hexactinellida), calcareous sponges (Calcarea), and demosponges (Demospongiae). Parazoa from the phylum Placozoa include the single species Trichoplax adhaerens. These tiny aquatic animals are flat, round, and transparent. They are composed of only four types of cells and have a simple body plan with just three cell layers.

Glass sponges of the class Hexactinellida typically live in deep sea environments and may also be found in Antarctic regions. Most hexactinellids exhibit radial symmetry and commonly appear pale with regard to color and cylindrical in form. Most are vase-shaped, tube-shaped, or basket-shaped with leuconoid body structure. Glass sponges range in size from a few centimeters in length to 3 meters (almost 10 feet) in length.

Calcareous sponges of the class Calcarea commonly reside in tropical marine environments at more shallow regions than glass sponges. This class of sponges has fewer known species than Hexactinellida or Demospongiae with around 400 identified species. Calcareous sponges have varied shapes including tube-like, vase-like, and irregular shapes. These sponges are usually small (a few inches in height) and some are brightly colored. Calcareous sponges are characterized by a skeleton formed from calcium carbonate spicules. They are the only class to have species with asconoid, syconoid, and leuconoid forms.

Demosponges **of the class Demospongiae are the most numerous of the sponges containing 90 to 95 percent of Porifera species. They are typically brightly colored and range in size from a few millimeters to several meters. Demosponges are asymmetrical forming a variety of shapes including tube-like, cup-like, and branched shapes. Like glass sponges, they have leuconoid body forms. Demosponges are characterized by skeletons with spicules composed of collagen fibers called spongin. It is the spongin that gives sponges of this class their flexibility. Some species have spicules that are composed of silicates or both spongin and silicates.**

phylum Placozoa contains only one known living species Trichoplax adhaerens. A second species, Treptoplax reptans, has not been observed in more than 100 years. Placozoans are very tiny animals, about 0.5 mm in diameter. T. adhaerens was first discovered creeping along the sides of an aquarium in an amoeba-like fashion. It is asymmetrical, flat, covered with cilia, and able to adhere to surfaces. T. adhaerens has a very simple body structure that is organized into three layers. An upper cell layer provides protection for the organism, a middle meshwork of connected cells enable movement and shape change, and a lower cell layer functions in nutrient acquisition and digestion. Placozoans are capable of both sexual and asexual reproduction. They reproduce primarily by asexual reproduction through binary fission or budding. Sexual reproduction occurs typically during times of stress, such as during extreme temperature changes and low food supply.

METAZOA:GENERAL CHARACTERS AND CLASSIFICATION UPTO CLASS

METAZOA

The Metazoa or the multicellular animals have achieved their structural diversity by varying their cells that have become specialized to perform different functions. These cells are normally incapable of independent existence.

Characterized metazoans.

Members of Metazoa possess a complex multicellular structural organization which may include the presence of tissues, organs and organ systems.

In the life history of metazoans, typically a fertilized egg passes through a blastula stage in the course of its early embryonic development before changing into an .

adult.

Since metazoans are multicellular they are relatively larger in size than unicellular protozoans. Naturally, their ntitritional requirements are more and they have to search for food. Consequently, locomotion in metazoans is highly developed and for this purpose they have evolved contractile muscular elements and nervous structures.

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GENERAL CHARACTERS OF METAZOA

1. Metazoans are multicellular animals.
2. Metazoans are generally seen in naked eyes.

3. Body of Metazoa is differentiated into cells which may transform into tissues, organs and systems in most cases.

4. Single animal can perform different types of functions by different systems in most groups.

5. Metazoan cells are interdependent and cannot survive in isolated condition.
6. Individual cell of Metazoa is covered by also cell membrane or plasma-lemma.

.7 Pellicle is absent in Metazoa.

8. Cytoplasm is present in Metazoa.

9. Chloroplast is present in some species (sponges).

10. Contractile vacuoles found only in freshwater sponges.

11. Many cells are mono or multi-ciliated.

12. Cilia and flagella have same ultra-structures.

13. Digestion intracellular or extracellular or both in some.

14. Food vacuole is absent in Metazoa.

15. Lower groups of metazoans do not possess circulatory, respiratory and excretory structures

16. Haemoglobin, haemocyanin, haemoerythrin, and chlorocruorin—all respiratory pigments present in many groups of Metazoa.

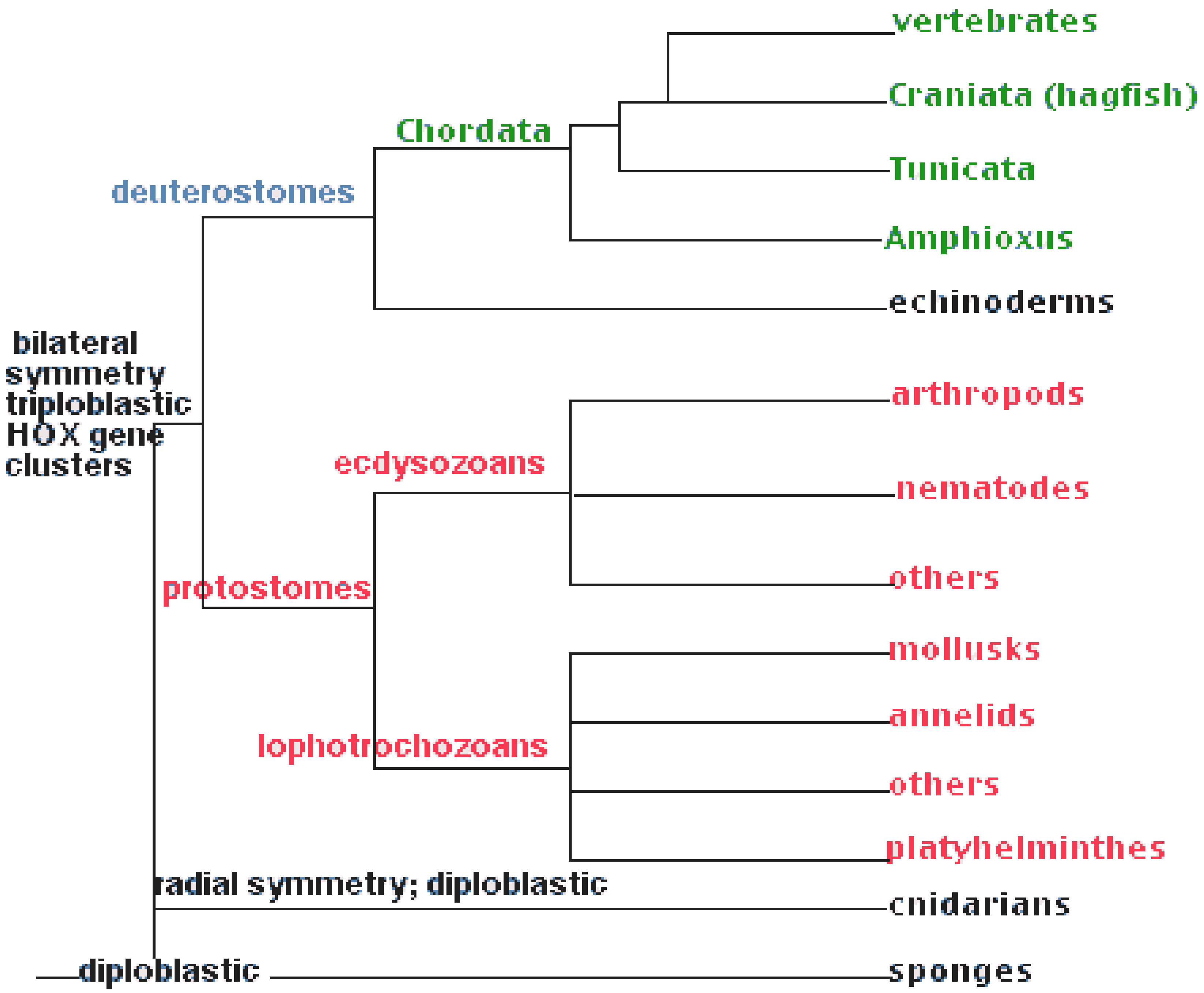
17. Gonads present except a few lower metazoan groups.

18. Motile larvae in their life cycle.

19. The developmental stages possess the embryonic blastula and gastrula stages.

20. Colonial organization is prevalent in some sponges, cnidarians, lophophorates and in some lower chordates.

CLASSIFICATION OF METAZOA



ACCORDING TO PROMINENT TAXONOMIST CLASSIFICATION OF METAZOA

Clade			Phylum
Parazoans (note 1)			**Porifera:** (full of pores) sponges
"Subkingdom" Eumetazoa cells truly cooperate (note 1)	**Radiata:** radial symmetry, 2 layers of cells (diblastic). They have no head or tail and can be cut into identical halves along many lines.		**Cnidaria:** (stingers) corals, jellyfish, hydra
			Ctenophora: comb jellies
			Conulariida:
	Bilaterians bilaterally symmetrical. (triblastic) If cut in 2 from head to toe, the two halves would be mirror images of each other. Tend to move more quickly and precisely than the radially symmetrical. (note 2)	**Superphylum Lophotrochozoa:**	**Annelida:** segmented worms
			Echiura: spoon worms (note 3)
			Brachiopoda: lamp shells
			Bryozoa: "moss animals"
			Hyolitha:
			Mollusca: (soft bodies) snails, clams, squid
			Phoronida:
		Superphylum Ecdysozoa: molting animals	**Lobopodia:** (note 4)
			Onychophora: velvet worms
			Nematoda: roundworms
			Kinorhyncha;
			Arthropoda: (jointed legs) crabs, spiders, insects
		Superphylum Deuterostomia: mouth appears second (note 5)	**Vetulicolia:** (note 6) - Extinct
			Hemichordata: acorn worms, graptolites
			Echinodermata: (spiny-skinned) crinoids, starfish, sea urchins, sea cucumbers, etc.
			Chordata: (spinal cord) vertebrates and related invertebrates having a notochord

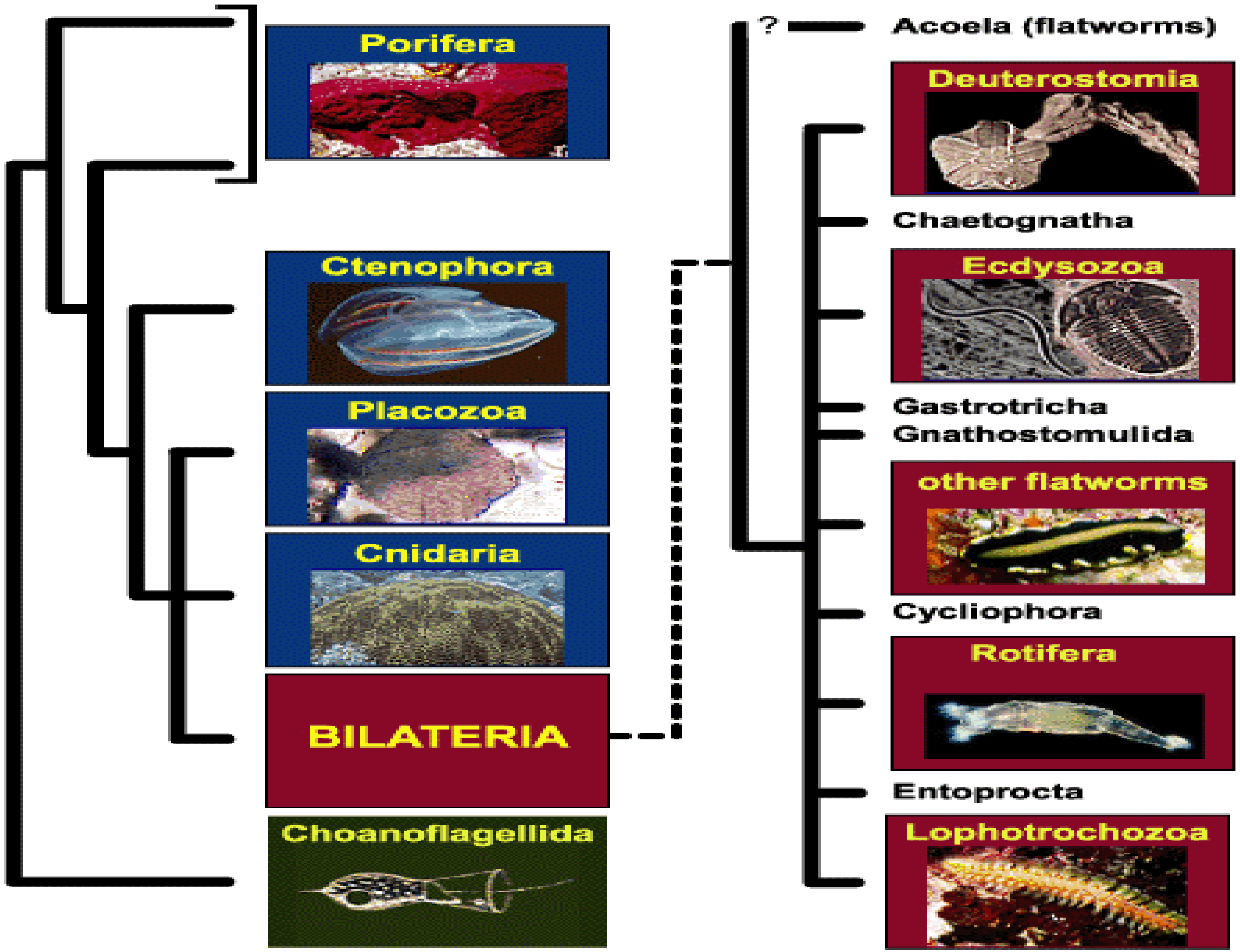
Table: Classification according to Cavalier-Smith, 1998

Classification	Characteristics
Kingdom	[meta = with, after; zoa, from zoon = animal]
Metazoa/Animalia	[radiate = symmetrical about the center]
Subkingdom Radiata	
Infrak'm Spongiaria	[porus = pore/hole] Sponges
Phylum Porifera	[coelenterata = hollow gut]
Infrak'm Coelenterata	Coelenterates, anemones, corals, jellyfish, hydra
Phylum Cnidaria	[flat animals; plakodes = laminated, flaky] simplest animals
Infrak'm Placozoa	known
Subkingdom Myxozoa	[myxo = muxa = slime, mucus] aquatic parasites
Subkingdom Bilateria	[2-sided; lateris = side; symmetrical along its length]
Protostomy Branch	[proto = first; stoma = mouth]
Infrak'm Lophozoa	[lophomore: ciliated feeding arm]
Phylum Bryozoa	[bryo- = moss] "moss animals"
Phylum Kamptozoa	
Phylum Mollusca	Snails, clams, mussels, squids, toredo worms,
P. Brachiopoda	Marine, 2-valve chalky shell; lamp shells
Phylum Sipuncula	Marine worms
Phylum Annelida	Segmented worms - garden worms
P. Nemertina	
Infrak'm Chaetognathi	[khaite = long hair = chitinous bristle; gnathos = jaw] ribbon
P. Chaetognatha	worms
Infrak'm Ecdysozoa	"Arrow worms"
Phylum Arthropoda	
P. Lobopoda	Insects, spiders, crabs, scorpions, exoskeleton molts
P. Nemathelminthes	
Infrak'm Platyzoa	
P. Acanthognatha	
P. Platyhelminthes	
Branch Deuterostomia	Flatworms, tapeworms,
Infrak'm Coelomopora	[deuteros = second; stoma = mouth] deuterostomes
P. Hemichordata	
P. Echinodermata	Acorn worms, pterobranchs, graptolites
Infrak'm Chordonia	Starfish, sea urchins, sea cucumbers,
P. Urochorda (ta)	
Phylum Chordata	Tunicates, sea squirts
Subkingdom Mesozoa	Sharks, bony fish, amphibians, reptiles, birds, mammals
	Between protozoa and metazoa.

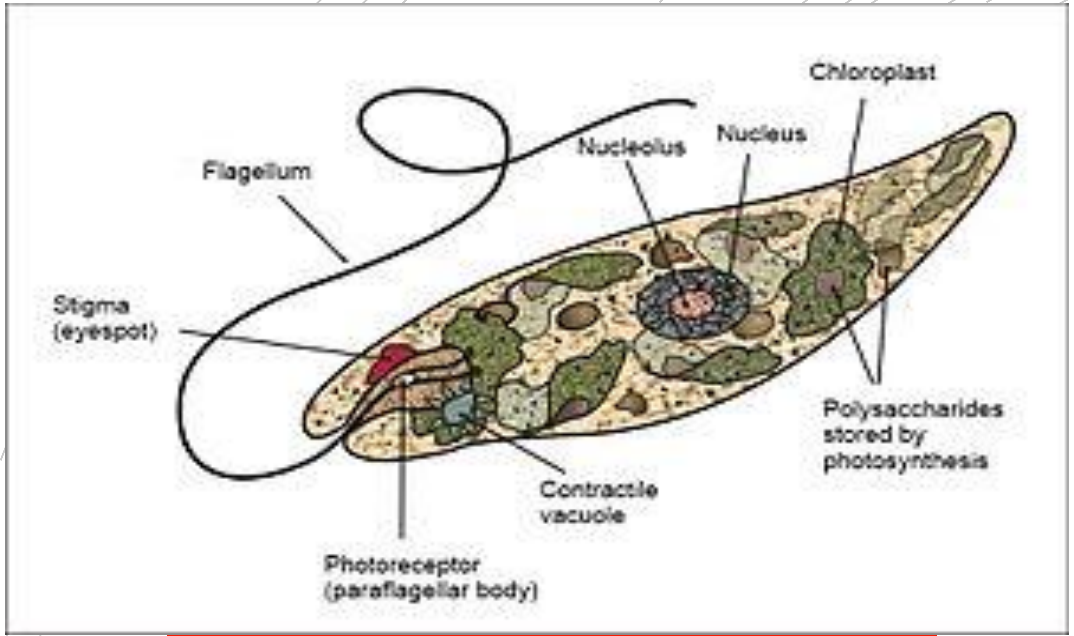
CLASSIFICATION OF METAZOA

ANCESTRAL UNICELLULAR ORGANISM

- **Unicellular (Protozoa)**
- **Multicellular (Metazoa)**
  - **Cell Aggregate**
    No germ layer,
    no true tissue or organs
    asymmetrical, intracellular digestion
    (Mesozoa, sponges)
  - **Eumetazoa**
    Germ layers, true tissue,
    mouth, digestive system
    - **Radiata**
      Radial symmetry
      tissue level organisation
      (Ctenophora, Cnidaria)
    - **Bilateria**
      Bilateral symmetry
      organ-system level
      organisation
      - **Protostomia**
        Blastopore forms mouth
        and the anus is a new formation.
        Spiral cleavage.
        Determinate type of development
        - **Acoelomata**
          (Eg. Platyhelminthes
          Nemertea
          Gnathostomulida)
        - **Pseudocoelomata**
          Cavity derived from
          blastocoel
          No peritoneal lining
          (Eg. Nematoda, Rotifers)
        - **Schizocoelomata**
          Coelom derived
          from splitting of
          mesodermal bands
          (Eg. Annelida,
          Arthropoda,
          Mollusca)
      - **Deuterostomia**
        Blastopore does not form mouth
        but anus. Mouth formed later
        from independent opening of
        body wall.
        Radial cleavage.
        Indeterminate type of development.
        - **Enterocoelomata**
          Coelom from fusion
          of enterocoelous pouches.
          (Eg. Echinoderms to Chordates)


Porifera
Ctenophora
Placozoa
Cnidaria
BILATERIA
Choanoflagellida
?
Acoela (flatworms)
Deuterostomia
Chaetognatha
Ecdysozoa
Gastrotricha
Gnathostomulida
other flatworms
Cycliophora
Rotifera
Entoprocta
Lophotrochozoa

STUDY OF EUGLENA,AMOEBA AND PARAMECIUM



EUGLENA

Euglena is a genus of single cell flagellate eukaryotes. It is the best known and most widely studied member of the class Euglenoidea, a diverse group containing some 54 genera and at least 800 species. Species of Euglena are found in freshwater and salt water.

Euglena Characteristics

- Euglena has an elongated cell measuring 15-500 micrometres
- Mostly green in colour due to the presence of chlorophyll pigment
- Some of the species of euglena contain carotenoid pigments, which give it distinct colour like red
- Euglena is unicellular having one nucleus
- Euglena lacks the cellulose cell wall present in a plant cell
- There is a presence of a flexible outer membrane known as a pellicle, which supports the plasma membrane. The pellicle is composed of a proteinaceous strip and supporting microtubules. The pellicle gives flexibility to the cell and an ability to contract and change its shape

- A thin plasma membrane is present, which encloses the cytoplasm and cell organelles
- It contains a contractile vacuole which removes excess water
- There is inward pocket near the base of flagella called a reservoir, where contractile vacuole dispels excess water
- Various cell organelles such as mitochondria, endoplasmic reticulum and Golgi bodies are present

Most species of Euglena have photosynthesizing chloroplasts within the body of the cell, which enable them to feed by autotrophy, like plants. However, they can also take nourishment heterotrophically, like animals. Since Euglena have features of both animals and plants, early taxonomists, working within the Linnaean two-kingdom system of biological classification, found them difficult to classify. It was the question of where to put such "unclassifiable" creatures that prompted Ernst Haeckel to add a third living kingdom (a fourth kingdom in toto) to the Animale, Vegetabile (and Lapideum meaning Mineral) of Linnaeus: the KingdProtista

Euglena Classification

Classification of Euglena is contentious. They are kept in the phylum Euglenozoa or in the phylum Euglenophyta with algae due to the presence of chlorophyll.

Since all the species of Euglena do not contain chloroplasts, they are kept in the phylum Euglenozoa. The class Kinetoplasteae in the phylum Euglenozoa contains non-photosynthetic flagellates known as Trypanosomes, which are parasitic and cause serious diseases in humans such as African sleeping sickness, leishmaniasis

Classification of Euglena:

Domain	Eukaryota
Kingdom	Protista
Superphylum	Discoba
Phylum	Euglenozoa
Class	Euglenoidea
Order	Euglenales
Family	Euglenaceae
Genus	Euglena

Habit and Habitat of Euglena Viridis:

Euglena viridis (Gr., eu = true; glene = eye-ball or eye-pupil; L., viridis = green) is a common, solitary and free living freshwater flagellate. It is found in freshwater pools, ponds, ditches and slowly running streams. It is found in abundance where there is considerable amount of vegetation.

Structure of Euglena Viridis:

Shape:

Euglena viridis is elongated and spindle-shaped in appearance. The anterior end is blunt, the middle part is wider, while the posterior end is pointed.

Size:

Euglena viridis is about 40-60 microns in length and 14-20 microns in breadth at the thickest part of the body.

Pellicle:

The body is covered by a thin, flexible, tough and strong cuticular periplast or pellicle which lies beneath the plasma membrane. It has oblique but parallel striations called myonemes all round. But according to Chadefaud (1937), the pellicle is made of an outer thin layer epicuticle and inner thick layer cuticle.

Both the layers of pellicle are present all over the body but only the epicuticle ends into an anteriorly placed cytopharynx and reservoir.

The pellicle is composed of fibrous elastic protein but not of cellulose. The pellicle maintains a definite shape of the body, yet it is flexible enough to permit temporary changes in the body shape, these changes of shape are spoken of as metabody or euglenoid movements.

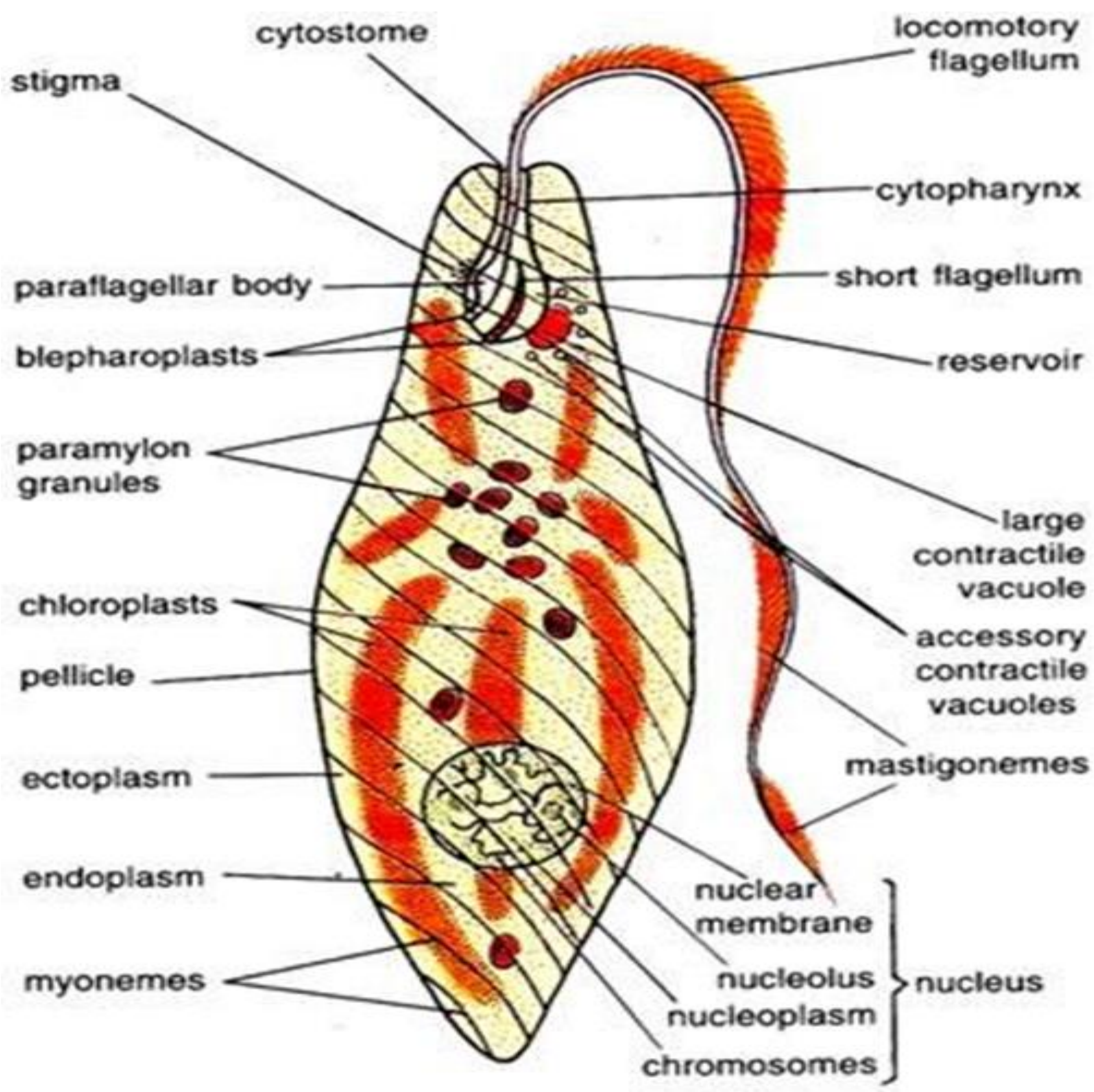


Fig. 12.1. *Euglena viridis.*

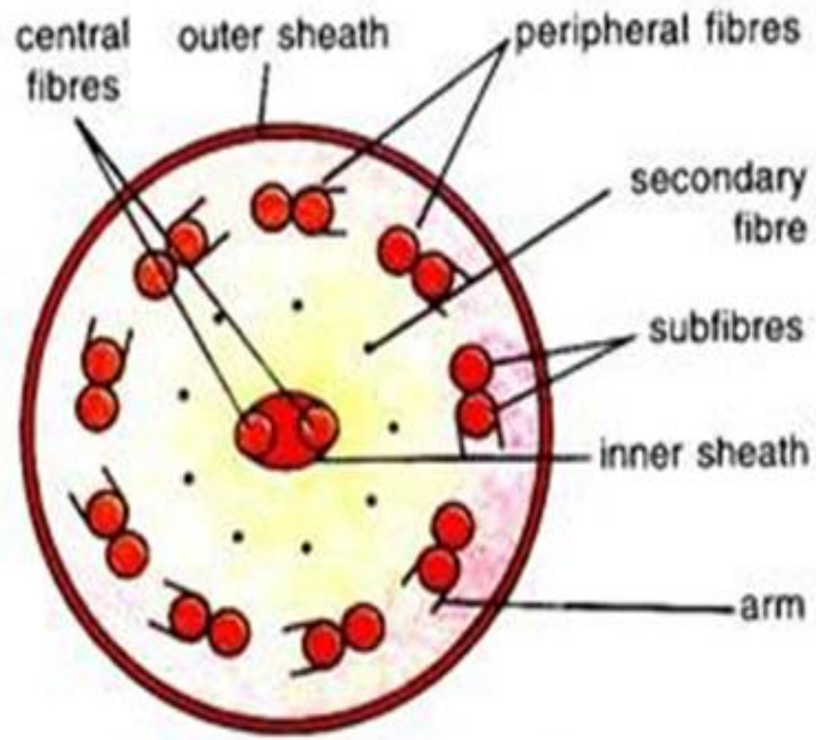


Fig. 12.2. *Euglena.* T.S. flagellum
(diagrammatic).

Electron Microscopic structure of pellicle:

Electron microscopic study of pellicle reveals that it is made of helically disposed strips. These strips are fused at both the endof the cell body and each has a groove along one edge and a groove along the other. The edges of neighbouring strips overlap and articulate in away that the ridge of one strip fits into the groove of the other.

In fact, the articulating ridges give the pellicle striated appearance. Just beneath and parallel to the strips, a row of mucus-secreting muciferous bodies and bundles of microtubles are found arranged with style.(Fig. 12.3).

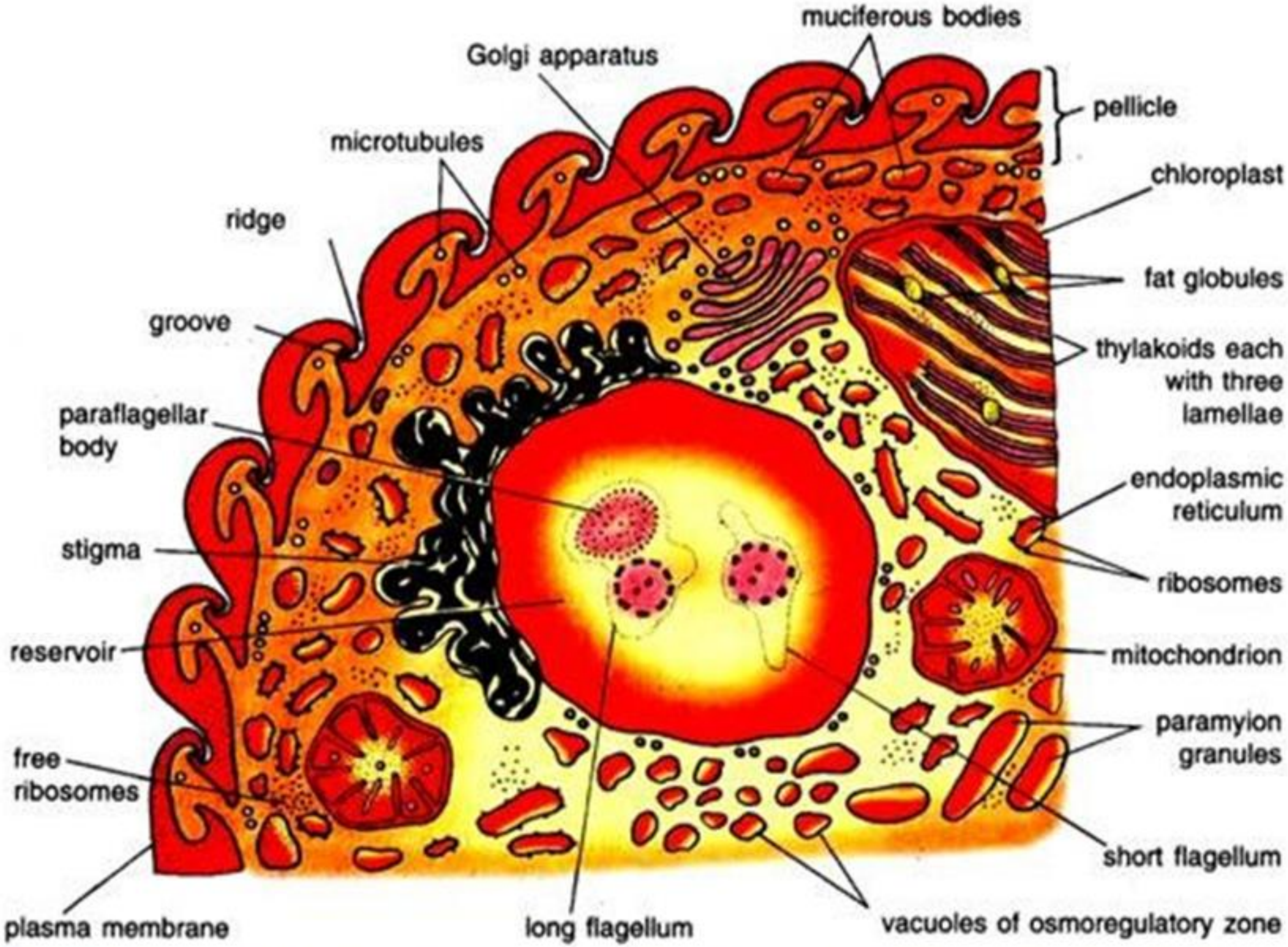


Fig. 12.3. *Euglena*. Diagrammatic representation of electron structure of a portion of body in T.S. passing through the reservoir.

Cytostome and cytopharynx:

At the anterior end is a funnel-shaped cytostome or cell mouth slightly to one side of the centre. Cytostome leads into a short tubular cytopharynx or gullet which, in turn, joins a large spherical vesicle, the reservoir or flagellar sac. The cytostome and cytopharynx are not used for ingestion of food but as a canal for escape of fluid from the reservoir.

Contractile vacuole:

A large osmoregulatory body, the contractile vacuole lies near the reservoir on one side. It is surrounded by several minute accessory contractile vacuoles, which probably fuse together to form the larger vacuole. The contractile vacuole discharges the excess of water and some waste products of metabolism into the reservoir from where it goes out through the cytostome.

Flagellum:

A single, long, whip-like flagellum emerges out of the cytostome through cytopharynx. The length of flagellum differs in different species of Euglena but in Euglena viridis it is as long as the body of the animalcule. It arises by two roots from the base of the reservoir from the side opposite to the contractile vacuole.

Each root springs from a blepharoplast (Gr., blepharon = eyelid; plastos = formed) or basal granule which lies embedded in the anterior part of the cytoplasm.

According to some workers, there are two flagella, one long and other short, each arising from a basal granule located in the cytoplasm at the base of the reservoir.

The short flagellum does not extend beyond the neck of the reservoir and it often adheres to the long flagellum producing the appearance of bifurcation.

The flagellum consists of an outer contractile protoplasmic sheath and an inner elastic axial filament, the axoneme. The distal portion of the flagellum contains numerous minute fibres known as mastigonemes which project along one side of the sheath and, therefore, the flagellum is stichonematic type.

Electron structure of flagellum:

Electron microscopic study of the flagellum reveals that it consists of two central and nine peripheral fibrils. Each central fibril is single, while the peripheral fibrils are paired having two sub-fibrils in each. One of the two sub-fibrils of each peripheral fibril bears a double row of short projections called arms; all the arms being directed in the same direction.

The two central fibrils are found enclosed in an inner membranous sheath. All the fibrils are enclosed within an outer protoplasmic sheath continuous with the cell membrane. There are nine secondary fibrils between central and peripheral fibrils.

All these fibrils fuse to join the blepharoplast or basal granule. Manton (1959) has suggested that mastigonemes, hair-like contractile fibres, arise from two of the nine peripheral fibrils.

Stigma:

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.

Paraflagellar body or photoreceptor:

A small swelling known as paraflagellar body lies either on one root or at the junction of two roots of the flagellum. The paraflagellar body is sensitive to light and it is regarded to be photoreceptor. RRecent studies of Chadefaud and Provasoli have shown that the stigma and paraflagellar body together form the photoreceptor apparatus.

Cytoplasm:

The cytoplasm of Euglena Viridis is differentiated into an outer layer of ectoplasm and inner layer of endoplasm. The ectoplasm is thin, clear or non-granular, while the endoplasm is more fluid-like and granular. The endoplasm contains nucleus, chromatophores and paramylum bodies.

Nucleus:

Euglena has a single, large, round or oval and vesicular nucleus lying in a definite position usually near the centre or towards the posterior end of the body. There is a distinct nuclear membrane. The nucleus contains a central body known as endosome (which is also known as nucleolus or karyosome).

Chromatin forms small granules in the space between nuclear membrane and the endosome. There is a large amount of nucleoplasm.

Chromatophores or chloroplasts:

Radiating from the centre of the body of Euglena, there are several, slender, band like elongated chromatophores. The chromatophores contain the green pigment, chlorophyll a and b, along with β-caroteneand are also known as chloroplasts.

Euglena Viridis derives its green colour from these chromatophores. Chloroplasts are arranged in a stellar fashion or like the rays of the stars. Each chromatophore or chloroplast consists of a very thin central part known as pyrenophore which is enclosed by a pyrenoid.

The pyrenoid is enclosed between a pair of hemispherical structures made of paramylum. Paramylum is a polysaccharide (β-1, 3 glucan) starch which gives no colour with iodine. A careful observation of chloroplasts suggests the presence of groups of chlorophyll bearing lamellae or thylakoids in them.

Each thylakoid bears three lamellae; the thylakoids are placed in the stroma or matrix of the chloroplasts and also contain ribosomes and fat globules. A chloroplast is bounded by a triple membrane envelope.

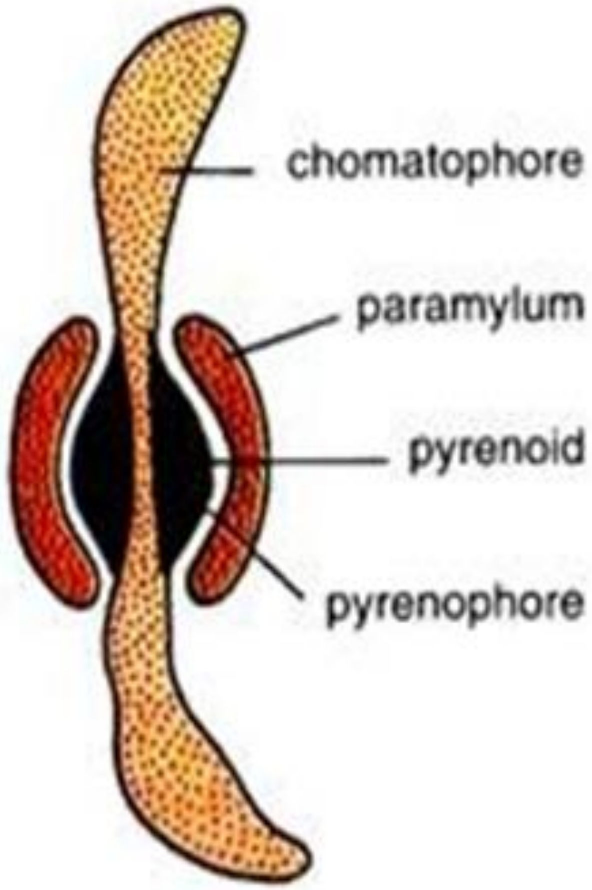


Fig. 12.4. Chromatophore of *Euglena*.

Paramylum bodies:

Paramylum bodies of various shapes and sizes are found scattered throughout the endoplasm. These are refractile bodies and contain stored food material in the form of paramylum which is a product of photosynthesis.

Other cytoplasmic contents:

The cytoplasm also contains other cellular components like Golgi apparatuses, endoplasmic reticulum, mitochondria whose number is more near the reservoir and the ribosomes which are found scattered in the endoplasm, on the endoplasmic reticulum and in the chloroplasts.

4. Locomotion in Euglena Viridis:

There are two methods of locomotion in Euglena Viridis, viz,:

(i) Flagellar movement

(ii) Euglenoid movement

(i) Flagellar Movement:

Vickerman and Cox (1967) have suggested that the flagellum makes direct contribution to locomotion. However, several theories have been put forth to explain the mechanism of flagellar movement. Butschli observed that the flagellum undergoes a series of lateral movements and in doing so, a pressure is exerted on the water at ripressure is exerted on the water at right angles to its surface.

This pressure creates two forces one directed parallel, and the other at right angles, to the main axis of the body. The parallel force will drive the animal forward and the force acting at right angles would rotate the animal on its own axis

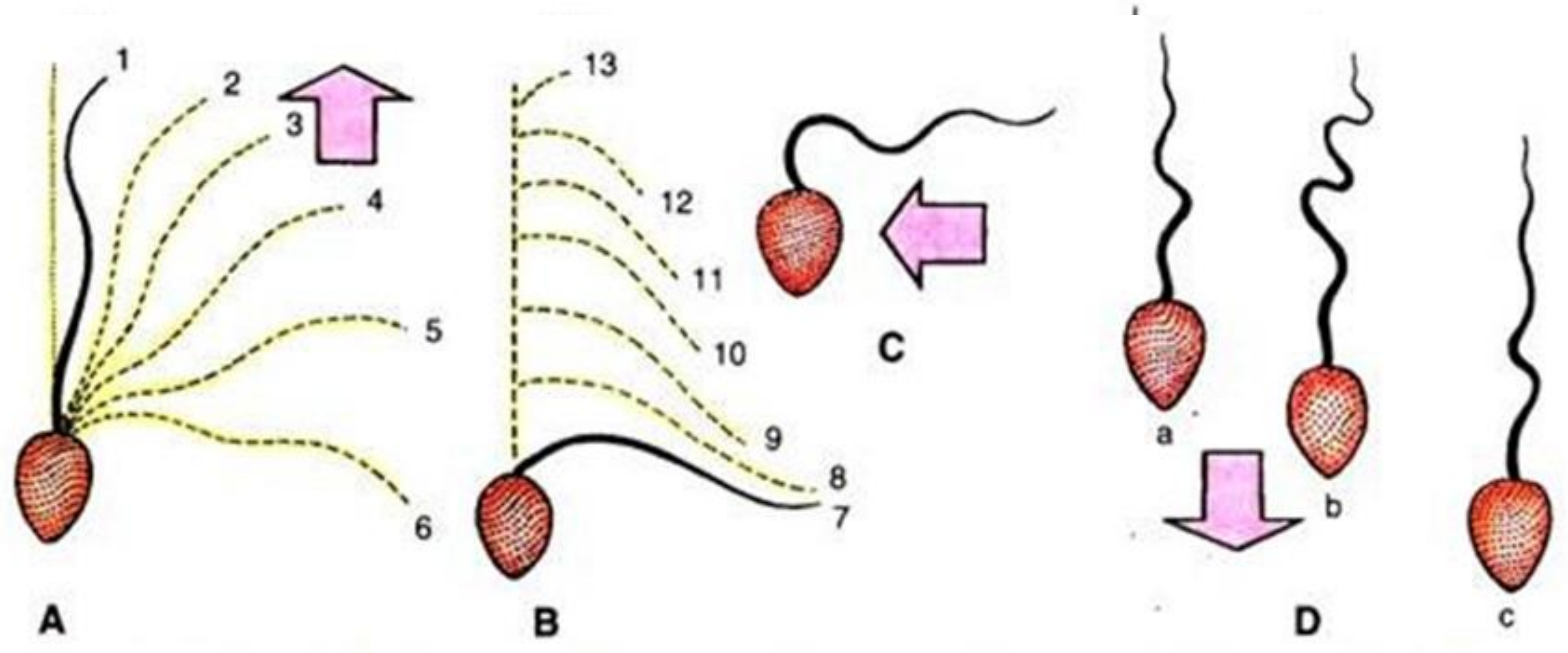


Fig. 12.5. Action of flagellum. A—Recovery stroke, successive stages from 1 to 7; B—Effective stroke, successive stages 8 to 13.

Gray (1928) suggested that a series of waves pass from one end of the flagellum to the other. These waves create two types of forces, one in the direction of the movement and the other in the circular direction with the main axis of the body. The former will drive the animal forward and the latter would rotate the animal.

For quite a long time it was generally presumed that the flagellum is directed forwards during flagellar movement but now it is generally agreed that the flagellum is straight and turgid in effective stroke and dropped backwards in the recovery stroke.

Recently Lowndes (1941-43) has pointed out that the flagellum is directed backwards during locomotion. According to Lowndes, a series of spiral waves pass successively from the base to the tip of the backwardly directed flagellum at about 12 per second with increasing velocity and amplitude.

The waves proceed along the flagellum in a spiral manner and cause the body of Euglena to rotate once in a second. Thus, in its locomotion, it traces a spiral path about a straight line and moves forward. The rate of movement is 3 mm per minute.

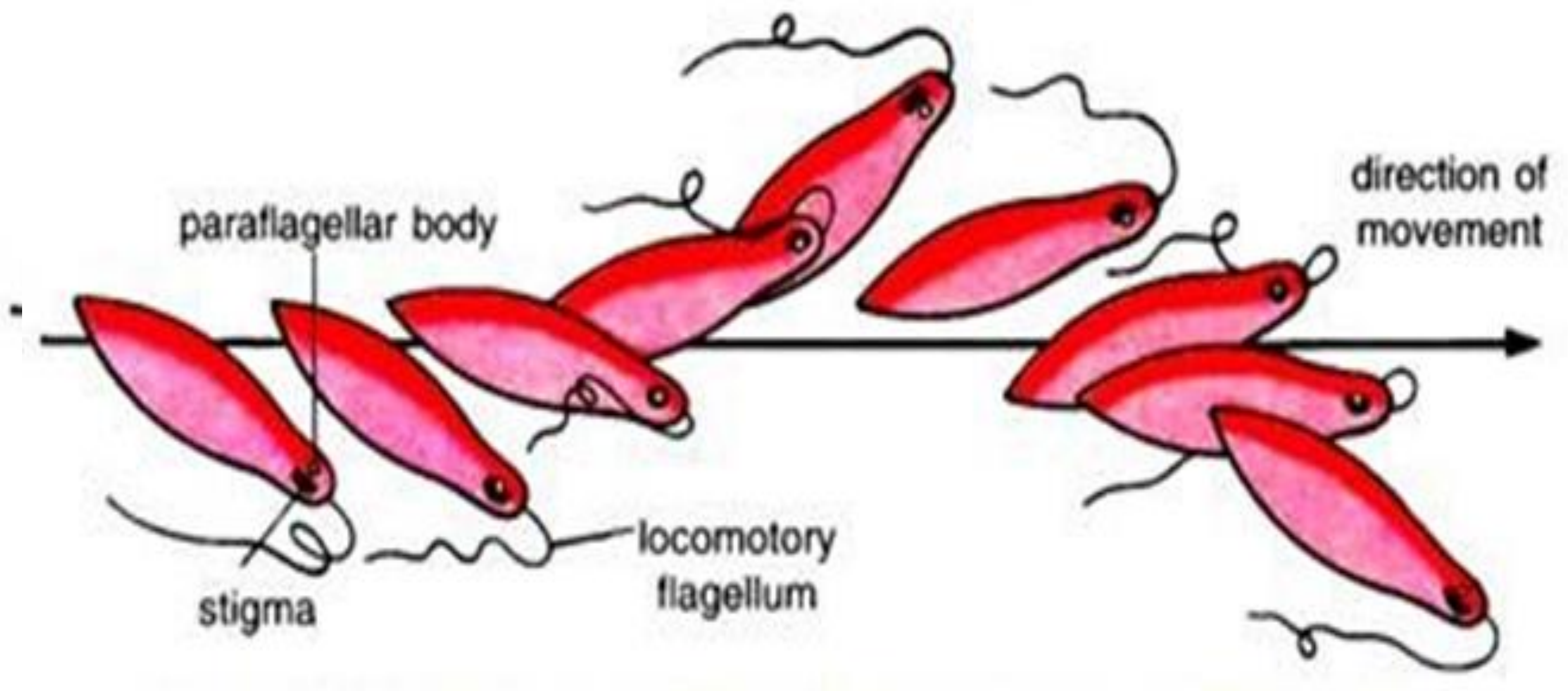


Fig. 12.6. *Euglena*. Successive stages in flagellar movement.

However, movement of flagellum is related to the contraction of its all fibrils.

The energy for the contraction of these fibrils is derived from ATPs formed in the mitochondria of blepharoplasts.

(ii) Euglenoid Movement or Metaboly:

Euglena sometimes shows a very peculiar slow wriggling movements. A peristaltic wave of contraction and expansion passes over the entire body from the anterior to the posterior end and the animal moves forward. The body becomes shorter and wider first at the anterior end, then in the middle and later at the posterior end. This type of movement is called euglenoid movement by which slow and limited movement occurs. Euglenoid movements are g brought about by the contractions of cytoplasm or by the contractions of myonemes present in the cytoplasm below the pellicle.

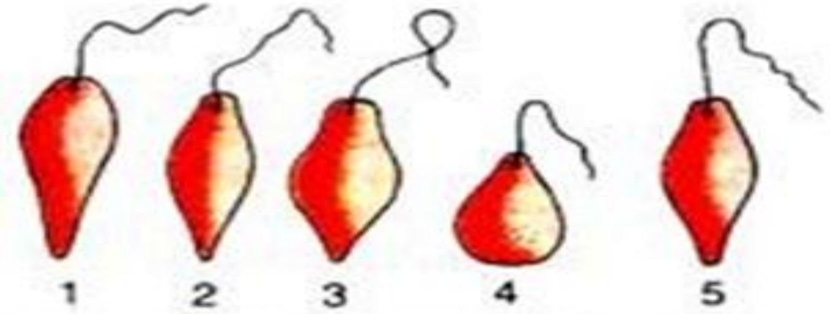


Fig. 12.7. *Euglena*. Stages of euglenoid movement.

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. In Euglena the reserve food is stored in the form of refractile paramylum bodies and their number is abundant in a well fed Euglena.

(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. They require ammonium salts, instead of nitrates, for their sources of nitrogen.

Euglena can subsist on saprozoic nutrition when it loses its chlorophyll in complete darkness. Usually, the chlorophylls lost in darkness are regained in light. But in forms like E. gracilis, the change is permanent, i.e., the chlorophylls once lost are not regained. The saprophytic nutrition may also supplement the normal holophytic nutrition.

Pinocytosis has also been reported to occur at the base of the reservoir for the intake of proteins and other large molecules. When an organism exhibits by using more than one method, then it is said to exhibit mixotrophic mode of nutrition. Euglena exhibits both holophytic and saprozoic nutrition, therefore, it exhibits mixotrophic mode of nutrition. Digestion is carried on by enzymes secreted into the food vacuoles by the surrounding cytoplasm.

6. Respiration in Euglena Viridis:

In Euglena Viridis, the exchange of gases (intake of O2 and giving out of CO2) takes place by diffusion through the body surface. It absorbs dissolved oxygen from the surrounding water and gives out carbon dioxide by diffusion.

There is every reason to believe that during the day time, tThere is every reason to believe that during the day time, the oxygen released during the photosynthesis is utilised for the purpose of respiration and carbon dioxide given out in respiration can be utilised for photosynthesis.

7. Excretion in Euglena Viridis:

The elimination of carbon dioxide and nitrogenous waste product (ammonia) takes place through the general body surface by diffusion. At least some excretion, however, is carried out by the contractile vacuole.

Osmoregulation:

Since Euglena Viridis has a semi-permeable pellicle and lives in water so that water continuously enters in its body by endosmosis. The removal of excess of water from the body is known as osmoregulation. The elimination of excess of water is done by the contractile vacuole.

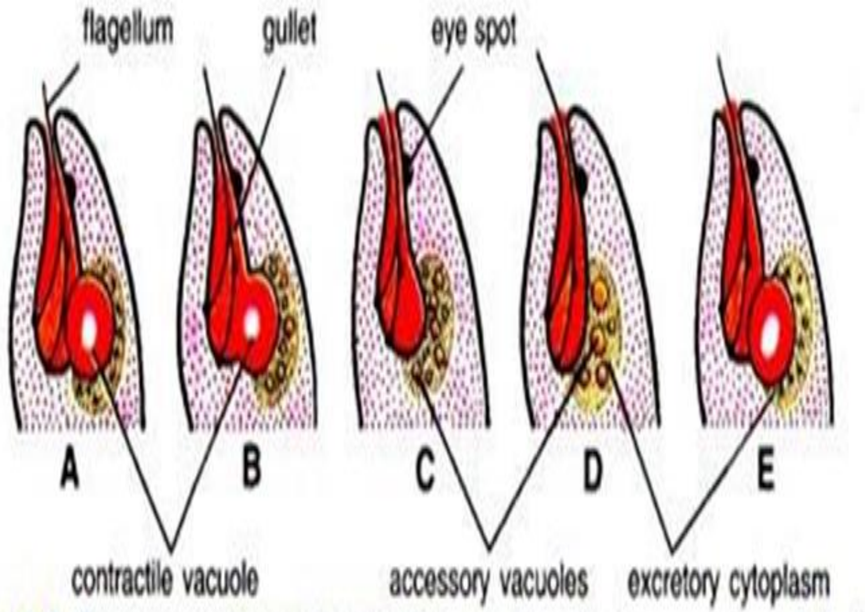


Fig. 12.8. Successive stages of contractile vacuoles showing systole and diastole.

The accessory contractile vacuoles collect excess of water from the surrounding cytoplasm and liberate their contents into the main contractile vacuole which gradually increases in size and finally bursts and forces the water into the reservoir. From the reservoir water, escapes out by cytosome through the cytopharynx. Along with this, water soluble wastes are also thrown out of the body.

Recently Chadefaud has pointed out that the contractile vacuole is surrounded by a specialised granular and excretory cytoplasm. The contractile vacuole periodically attains its maximum size and collapses to discharge its contents into the reservoir (i.e., systole).

Simultaneously, several small accessory vacuoles appear in the excretory cytoplasm. These vacuoles then fuse together to form a new large vacuole (i.e., diastole) which attains the maximum size and collapses to discharge the water like the former one.

8. Behaviour of Euglena Viridis:

Euglena Viridis responds to a variety of stimuli and is very .sensitive to light. It swims towards an ordinary light such as that from a window and avoids strong light. If a culture of Euglena is examined, most of the animals will be found on the side towards the light. This is of distinct advantage to the animal, because light is necessary for the assimilation of carbon dioxide by means of its chlorophyll.

Euglena will swim away from the direct rays of sun. Direct sunlight will kill the organism if allowed to act for a long time. If a dish containing Euglenae is placed in the direct sunlight and then one half of it is shaded, the animals will avoid the shady part and also the direct sunlight and will remain in a small band between the two in the light best suited for them (Fig. 12.9), that is, their optimum.

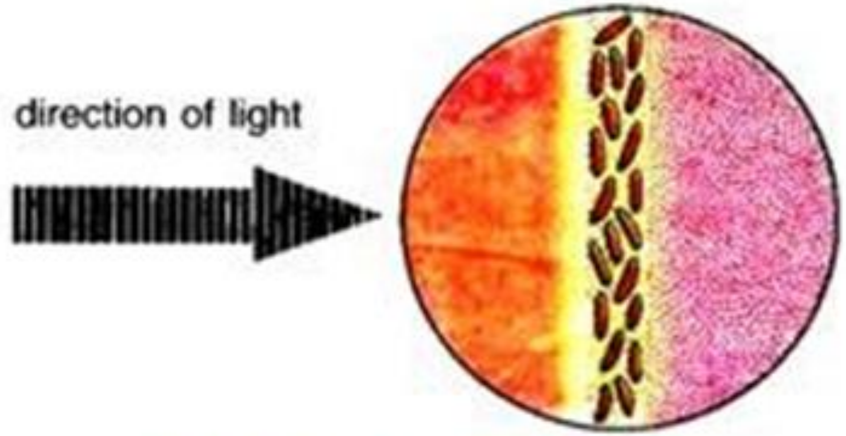


Fig. 12.9. *Euglena* showing reaction to light.

A swimming Euglena moves in a spiral manner rotating and gyrating around its own axis but it shows a shock reaction whenever the direction of light is changed.

It has been found that the region in front of the eye spot is more sensitive to light than any other part of the body. Euglena orientates itself parallel to rays of light whenever the paraflagellar body (photoreceptor) is shaded by the stigma or eyespot. The animal adjusts its position to the direction of light moving either towards or away from it.

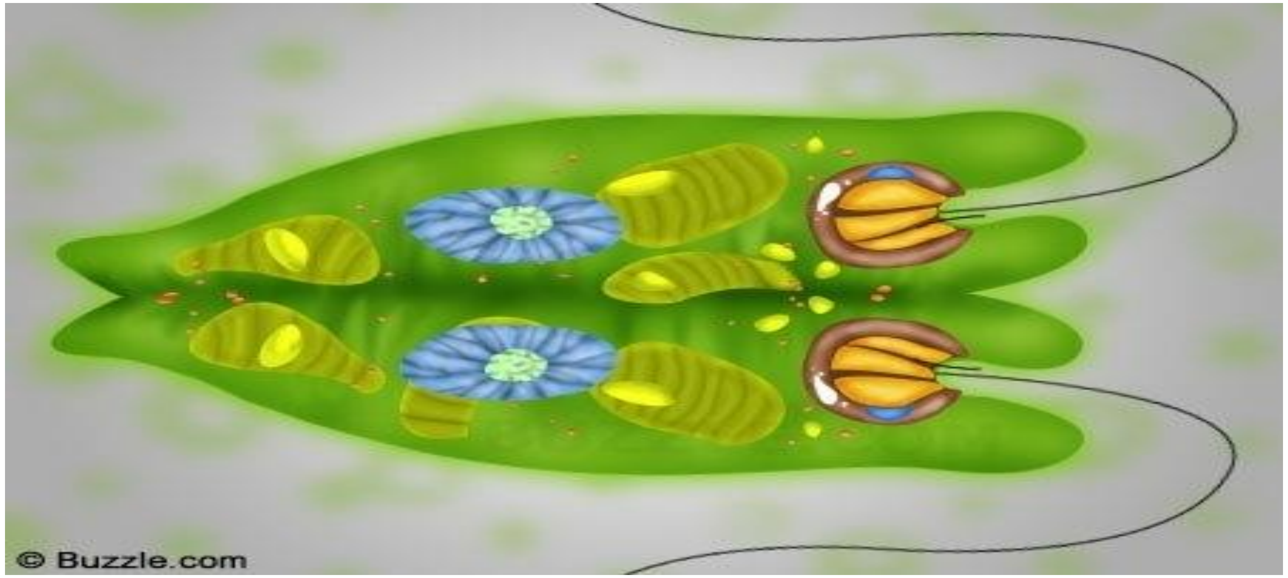
When the animal rotates, the stigma acts as a screen, the paraflagellar body is alternately exposed or shielded when light falls on it from the side. The animal adjusts itself until the paraflagellar body is continuously exposed, this happens when the source of light is either straight in front or behind.

Euglena gives avoiding reaction to mechanical, thermal and chemical stimuli on a trial and error pattern (phabotaxis). When stimulated by a change, Euglena, in majority of cases, stops or moves backward, turns strongly towards the dorsal surface, but continues to revolve on its long axis.

The posterior end then acts as a pivot, while the anterior end traces a circle of wide diameter in the water. The animal may swim forward in a new direction from any point in this circle. This is avoiding reaction.

9. Reproduction in Euglena Viridis:

Euglena Viridis reproduces asexually by longitudinal binary fission and multiple fission. Encystment also takes place. Sexual reproduction does not occur, although a primitive form of it is reported in some species.



(i) Longitudinal Binary Fission:

During active periods, under favourable conditions of water, temperature and food availability, Euglena reproduces by longitudinal binary fission. The fission is always symmetrogenic, i.e., the parent Euglena divides into two daughter euglenae, which are exactly identical to one another.

The nucleus divides by mitosis. The endosome elongates transversely and becomes constricted into two approximately equal parts. Nuclear division takes place within nuclear membrane.

The organelles at the anterior end such as stigma, blepharoplasts, reservoir, cytopharynx and chromatophores and paramylum bodies are also duplicated. The body begins to divide lengthwise, from the anterior end downwards to the posterior end resulting in the formation of two daughter individuals.

The old flagellum is retained by one half, whereas a new flagellum is developed by the other, contractile vacuole and paraflagellar body do not divide but they disappear and are made again in the daughter individuals.

(ii) Multiple Fission:

Multiple fission usually takes place in encysted condition. Sometimes during resting or inactive periods, encystment occurs in Euglena. The mass of cytoplasm and the nucleus inside the cyst undergo repeated mitotic divisions giving rise to 16 or 32 small daughter individuals.

On the return of favourable conditions, the cyst breaks and the daughter individuals escape out from the cyst. Each daughter individual develops the various organelles and starts the normal life. Some workers considered the daughter individuals as the spores and this process as sporulation.

(iii) Palmella Stage:

Sometimes,usually under unfavourable conditions, large number of euglenae come close together, lose their flagella and become rounded. They secrete gelatinous covering or mucilaginous matrix within which they remain embedded. This condition is called palmella stage which is often seen as green scum on the water surface of ponds.

Individuals of palmella stage carry on metabolic activities and reproduce by binary fission. On the arrival of favourable conditions, the gelatinous covering swells by the absoprtion of water and the euglenae are released. They regenerate their flagella and start normal active life.

(iv) Encystment:

During unfavourable conditions such as drought, extreme cold or extreme hot, scarcity of food and oxygen Euglena undergoes encystment. First of all Euglena becomes inactive, loses its flagellum and secretes a cyst around it. The cyst is secreted by the muciferous bodies lying below the pellicle.

The cyst is thick-walled, rounded and red in colour due to the presence of a pigment called haematochrome. This cyst is of the protective type.

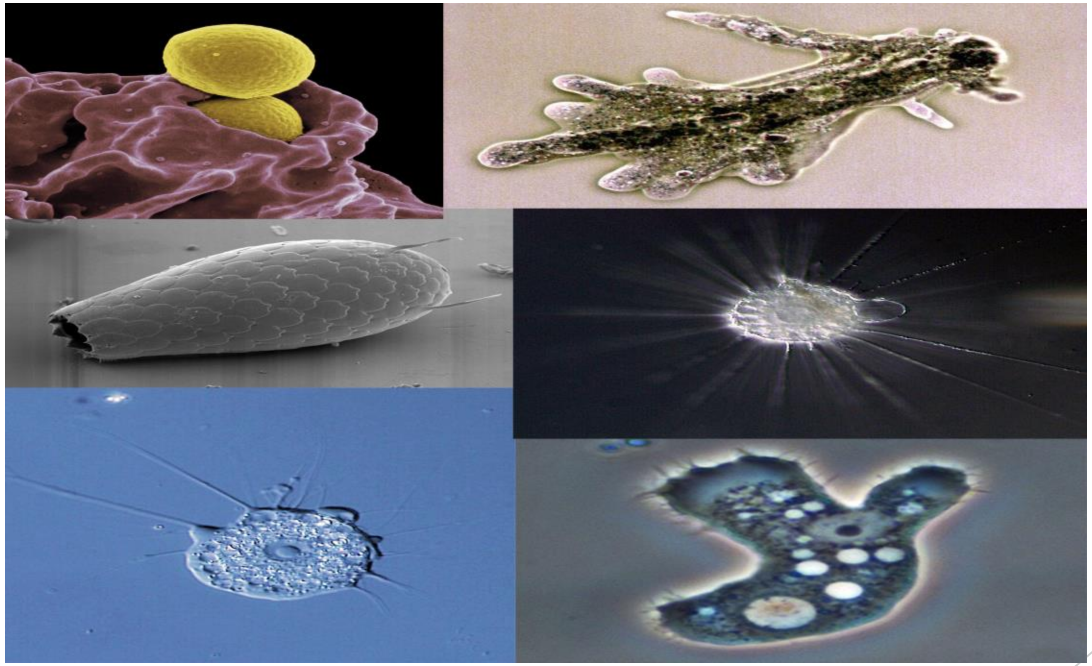
During the encysted condition the periods of unfavourable conditions are successfully passed. During encystment, binary fission may occur one or more times, resulting in 2 to 32 small daughter eu euglenae within the cyst. On the return of favourable conditions, cyst wall breaks, the animals become active and emerge from the cyst to lead a normal free swimming life.

In fact, encystment occurs only to tide over the unfavourable conditions and during this condition dispersal of Euglena occurs to a wide area.

Euglena END

AMOEBA

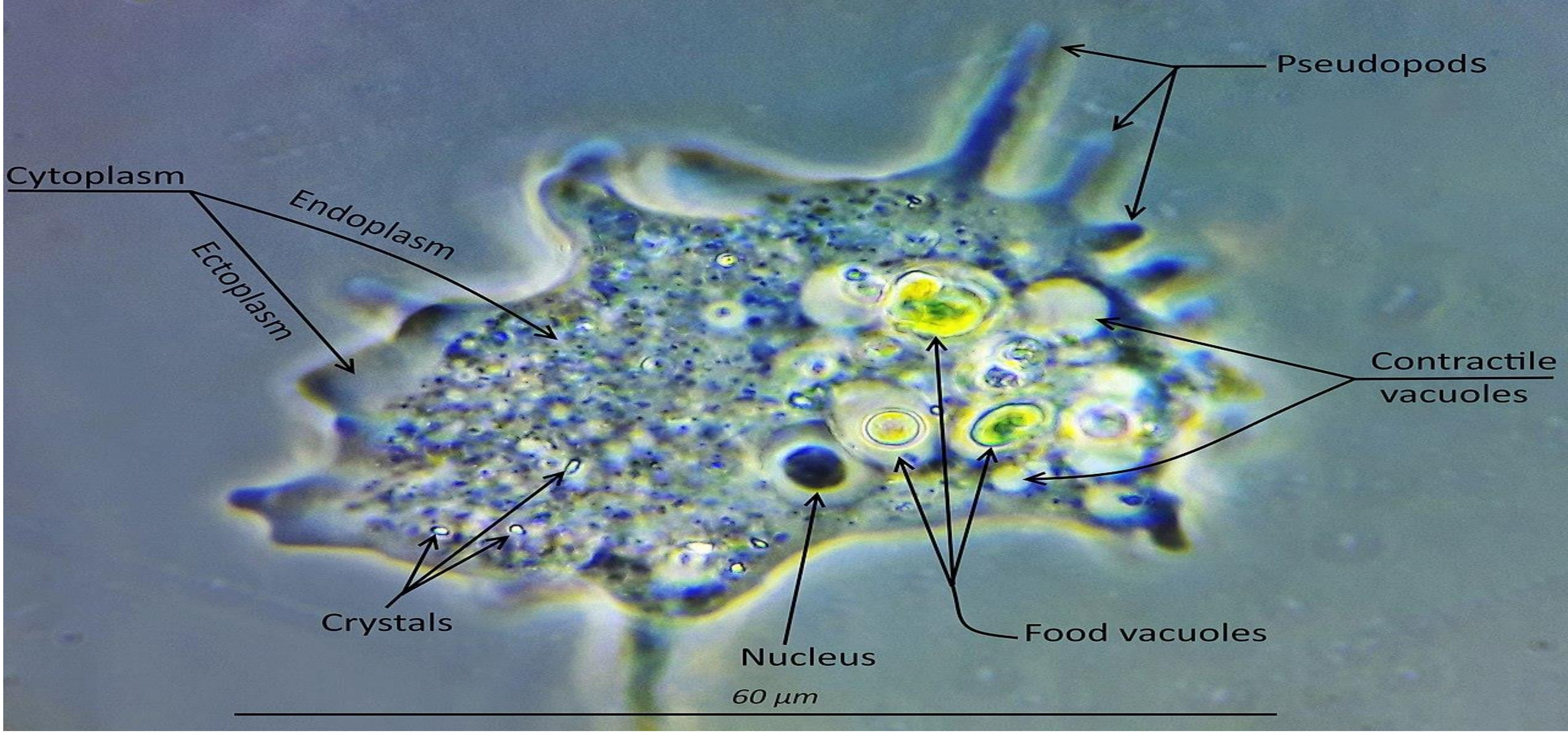
- **A single-celled animal that catches food and moves about by extending fingerlike projections of protoplasm. Amoebas are either free-living in damp environments or parasitic.**



An amoeba or ameba is a type of cell or unicellular organism which has the ability to alter its shape, primarily by extending and retracting pseudopods.Amoebae do not form a single taxonomic group; instead, they are found in every major lineage of eukaryotic organisms. Amoeboid cells occur not only among the protozoa, but also in fungi, algae, and animals

Shape, movement and nutrition

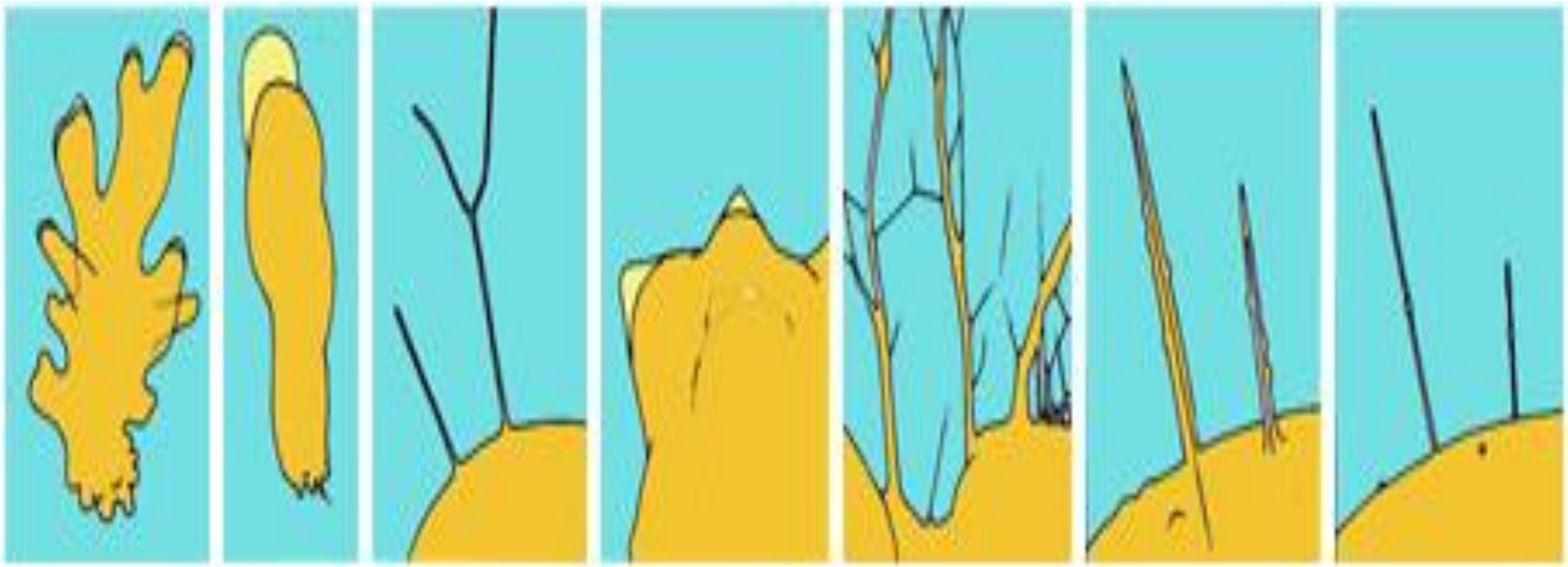
Amoebae do not have cell walls, which allows for free movement. Amoebae move and feed by using pseudopods, which are bulges of cytoplasm formed by the coordinated action of actin microfilaments pushing out the plasma membrane that surrounds the cell.



Morphology of a naked amoeba in the genus Mayorella

The appearance and internal structure of pseudopods are used to distinguish groups of amoebae from one another. Amoebozoan species, such as those in the genus Amoeba, typically have bulbous (lobose) pseudopods, rounded at the ends and roughly tubular in cross-section. Cercozoan amoeboids, such as Euglypha and Gromia, have slender, thread-like (filose) pseudopods. Foraminifera emit fine, branching pseudopods that merge with one another to form net-like (reticulose) structures. Some groups, such as the Radiolaria and Heliozoa, have stiff, needle-like, radiating axopodia (actinopoda) supported from within by bundles of microtubules

Free-living amoebae may be "testate" (enclosed within a hard shell), or "naked" (also known as gymnamoebae, lacking any hard covering). The shells of testate amoebae may be composed of various substances, including calcium, silica, chitin, or agglutinations of found materials like small grains of sand and the frustules of diatoms



The forms of pseudopodia, from left: polypodial and lobose; monopodial and lobose; filose; conical; reticulose; tapering actinopods; non-tapering actinopods

To regulate osmotic pressure, most freshwater amoebae have a contractile vacuole which expels excess water from the cell. This organelle is necessary because freshwater has a lower concentration of solutes (such as salt) than the amoeba's own internal fluids (cytosol). Because the surrounding water is hypotonic with respect to the contents of the cell, water is transferred across the amoeba's cell membrane by osmosis. Without a contractile vacuole, the cell would fill with excess water and, eventually, burst.

Marine amoebae do not usually possess a contractile vacuole because the concentration of solutes within the cell are in balance with the tonicity of the surrounding water

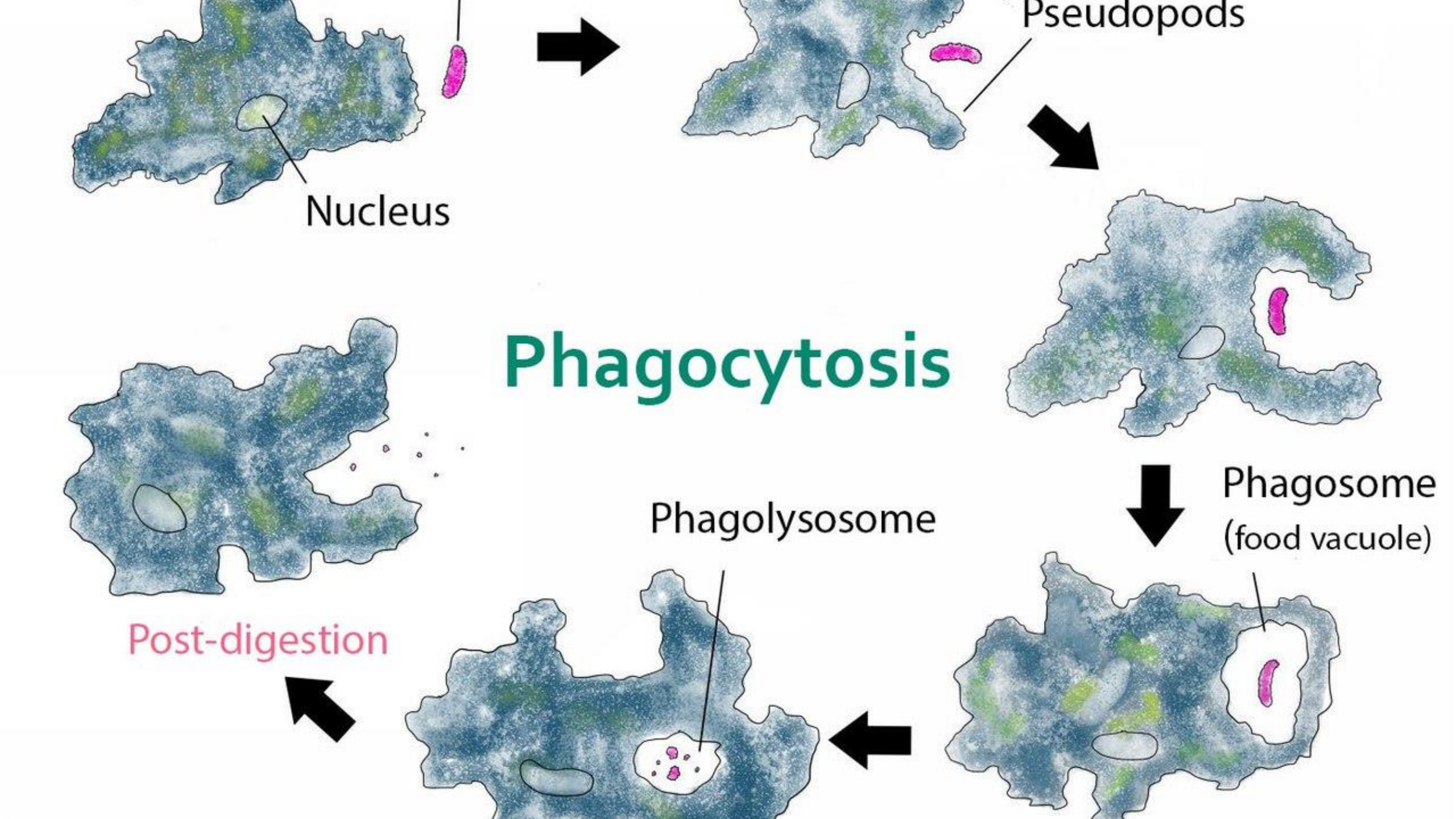
The food sources of amoebae vary. Some amoebae are predatory and live by consuming bacteria and other protists. Some are detritivores and eat dead organic material.

Amoebae typically ingest their food by phagocytosis, extending pseudopods to encircle and engulf live prey or particles of scavenged material. Amoeboid cells do not have a mouth or cytostome, and there is no fixed place on the cell at which phagocytosis normally occurs.

Some amoebae also feed by pinocytosis, imbibing dissolved nutrients through vesicles formed within the cell membrane

Size range

The size of amoeboid cells and species is extremely variable. The marine amoeboid Massisteria voersi is just 2.3 to 3 micrometres in diameter, within the size range of many bacteria. At the other extreme, the shells of deep-sea xenophyophores can attain 20 cm in diameter. Most of the free-living freshwater amoebae commonly found in pond water, ditches, and lakes are microscopic, but some species, such as the so-called "giant amoebae" Pelomyxa palustris and Chaos carolinense, can be large enough to see with the naked eye


Pseudopods
Nucleus
Phagocytosis
Phagosome
(food vacuole)
Phagolysosome
Post-digestion

Amoebae as specialized cells and life cycle stages:

Some multicellular organisms have amoeboid cells only in certain phases of life, or use amoeboid movements for specialized functions. In the immune system of humans and other animals, amoeboid white blood cells pursue invading organisms, such as bacteria and pathogenic protists, and engulf them by phagocytosis.

Amoeboid stages also occur in the multicellular fungus-like protists, the so-called slime moulds. Both the plasmodial slime moulds, currently classified in the class Myxogastria, and the cellular slime moulds of the groups Acrasida and Dictyosteliida, live as amoebae during their feeding stage. The amoeboid cells of the former combine to form a giant multinucleate organism, while the cells of the latter live separately until food runs out, at which time the amoebae aggregate to form a multicellular migrating "slug" which functions as a single organism.

Other organisms may also present amoeboid cells during certain life-cycle stages, e.g., the gametes of some green algae (Zygnematophyceae) and pennate diatoms, the spores (or dispersal phases) of some Mesomycetozoea, and the sporoplasm stage of Myxozoa and of Ascetosporea

Species or cell type	Size in micrometres
Massisteria voersi [20]	2.3–3
Naegleria fowleri [23]	8–15
Neutrophil (white blood cell)[24]	12–15
Acanthamoeba[25]	12–40
Entamoeba histolytica[26]	15–60
Arcella vulgaris[27]	30–152
Amoeba proteus[28]	220–760
Chaos carolinense[29]	700–2000
Pelomyxa palustris [30]	up to 5000
Syringammina fragilissima[31]	up to 200 000

...ergroups	Major groups and genera	Morphology
...oebozoa	• **Lobosa** : ◦ *Acanthamoeba* , *Amoeba* , *Balamuthia* , *Chaos* , *Clydonella* , *Discamoeba* , *Echinamoeba* , *Filamoeba* , *Flabellula* , *Gephyramoeba* , *Glaeseria* , *Hartmannella* , *Hollandella* , *Hydramoeba* , *Korotnevella* , *(Dactylamoeba)*, , *Leptomyxa* , *Lingulamoeba* , *Mastigina* , *Mayorella* , *Metachaos* , *Neoparamoeba* , *Paramoeba* ,*Polychaos* , *Phreatamoeba* , *Platyamoeba* , *Protoacanthamoeba* , *Rhizamoeba* , *Saccamoeba* , *Sappinia* , *Stereomyxa* , *Thecamoeba* , *Trichamoeba* , *Trichosphaerium* , *Unda* , *Vannella* , *Vexillifera* • Conosa: *Endamoeba*, *Entamoeba*, *Iodamoeba*, *Mastigamoeba*, *Mastigella*, *Pelomyxa*, *Dictyostelium*, *Physarum*	• Lobose pseudopods (Lobosa): Lobose pseudopods are blunt, and there may be one or several on a cell, which is usually divided into a layer of clear ectoplasm surrounding more granular endoplasm.
...zaria	• Cercozoa: ◦ **Filosa** : ▪ **Monadophilosa** : *Gyromitus* , *Paulinella* ▪ **Granofilosea** ▪ Chlorarachniophyceae ◦ **Endomyxa** : ▪ Proteomyxidea: orders Aconchulinida, Pseudosporida, Reticulosida ▪ Gromiidea • Foraminifera • Radiolaria	• Filose pseudopods (Filosa): Filose pseudopods are narrow and tapering. The vast majority of filose amoebae, including all those that produce shells, are placed within the Cercozoa together with various flagellates that tend to have amoeboid forms. The naked filose amoebae also includes vampyrellids. • Reticulose pseudopods (Endomyxa): Reticulose pseudopods are cytoplasmic strands that branch and merge to form a net. They are found most notably among the Foraminifera, a large group of marine protists that generally produce multi-chambered shells. There are only a few sorts of naked reticulose amoebae, notably the gymnophryids, and their relationships are not certain. • Radiolarians are a subgroup of actinopods that are now grouped with rhizarians.
...avate	• **Heterolobosea** : ◦ Vahlkampfiidae : *Monopylocystis* , *Hartmonella* , *Neovahlkampfia* , *Paratetramitus* , *Paravahlkampfia* , *Protonaegleria* , *Psalteriomonas* , *Sawyer* , *Tetramitus* , *Vahlkampfia* , *Willaert* ◦ Gruberellidae: *Gruberella*, *Stachyamoeba* • Parabasalidea : *Dientamoeba* , *Histomonas* • Other: *Rosculus* , *Acrasis* , *Heteramoeba* , *Learamoeba* , *Stygamoeba* , *Plaesiobystra* , [50] *Tulamoeba* [50]	• The Heterolobosea, includes protists that can transform between amoeboid and flagellate forms.
...erokonta	• Chrysophyceae : *Chrysamoeba* , *Rhizochrysis* • Xanthophyceae: *Rhizochloris* • Labyrinthulomycetes	• The heterokont chrysophyte and xanthophyte algae include some amoeboid members, the latter being poorly studied.[51]
...eolata	• Dinoflagellata: *Oodinium*, *Pfiesteria*	• Parasite with amoeboid life cycle stages.
...sthokonta	• Nucleariida: *Micronuclearia*, *Nuclearia*	• Nucleariids appear to be close relatives of animals and fungi.
...grouped/ ...nown	• *Adelphamoeba* , *Astramoeba* , *Dinamoeba* , *Flagellipodium* , *Flamelli* , *Gibbodiscus* , *Goceva* , *Malamoeba* , *Nolland* , *Oscillosignum* , *Paragocevia* , *Parvamoeba* , *Pernina* , *the Pope* , *Pseudomastigamoeba* , *Rugipes* , *Striamoeba* , *striolatae* , *Subulamoeba* , *Theratromyxa* , *Trienamoeba* , *Trimastigamoeba* and over 40 other genera[52]	

Pathogenic interactions with other organisms

- Trophozoites of the pathogenic Entamoeba histolytica with ingested red blood cells
- Some amoebae can infect other organisms pathogenically, causing disease:

- Entamoeba histolytica is the cause of amoebiasis, or amoebic dysentery.
- Naegleria fowleri (the "brain-eating amoeba") is a fresh-water-native species that can be fatal to humans if introduced through the nose.
- Acanthamoeba can cause amoebic keratitis and encephalitis in humans.
- Balamuthia mandrillaris is the cause of (often fatal) granulomatous amoebic meningoencephalitis.
- Amoeba have been found to harvest and grow the bacteria implicated in plague.
- Amoebae can likewise play host to microscopic organisms that are pathogenic to people and help in spreading such microbes. Bacterial pathogens (for example, Legionella) can oppose absorption of food when devoured by amoebae.
- The presently generally utilized and best-explored amoebae that host other organisms are Acanthamoeba castellanii and Dictyostelium discoideum.
- Microorganisms that can overcome one-celled critters' guards increase a shelter wherein to multiply, where they are shielded from unfriendly outside conditions by their accidental hosts

Meiosis

Recent evidence indicates that several Amoebozoa lineages undergo meiosis.

Orthologs of genes employed in meiosis of sexual eukaryotes have recently been identified in the Acanthamoeba genome. These genes included Spo11, Mre11, Rad50, Rad51, Rad52, Mnd1, Dmc1, Msh and Mlh This finding suggests that the "Acanthamoeba" are capable of some form of meiosis and may be able to undergo sexual reproduction.

The meiosis-specific recombinase, Dmc1, is required for efficient meiotic homologous recombination, and Dmc1 is expressed in Entamoeba histolytica. The purified Dmc1 from E. histolytica forms presynaptic filaments and catalyses ATP-dependent homologous DNA pairing and DNA strand exchange over at least several thousand base pairs. The DNA pairing and strand exchange reactions are enhanced by the eukaryotic meiosis-specific recombination accessory factor (heterodimer) Hop2-Mnd1.

These processes are central to meiotic recombination, suggesting that E. histolytica undergoes meiosis.

Studies of Entamoeba invadens found that, during the conversion from the tetraploid uninucleate trophozoite to the tetranucleate cyst, homologous recombination is enhanced. Expression of genes with functions related to the major steps of meiotic recombination also increase during encystations. These findings in E. invadens, combined with evidence from studies of E. histolytica indicate the presence of meiosis in the Entamoeba.

Dictyostelium discoideum in the supergroup Amoebozoa can undergo mating and sexual reproduction including meiosis when food is scarce.

Since the Amoebozoa diverged early from the eukaryotic family tree, these results suggest that meiosis was present early in eukaryotic evolution. Furthermore, these findings are consistent with the proposal of Lahr et al that the majority of amoeboid lineages are anciently sexual.

Paramecium is a unicellular organism with a shape resembling the sole of a shoe. It ranges from 50 to 300um in size which varies from species to species. It is mostly found in a freshwater environment. It is a single-celled eukaryote belonging to kingdom Protista and is a well-known genus of ciliate protozoa.

PARAMECIUM

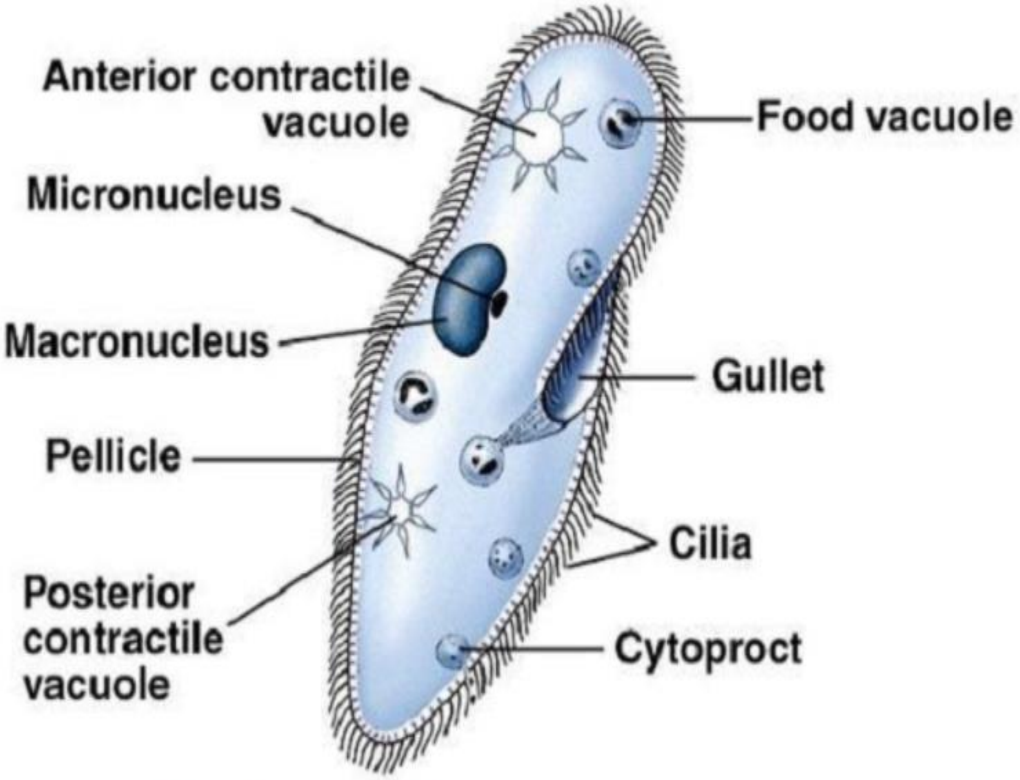


Fig. *Paramecium*

Paramecium is a unicellular organism with a shape resembling the sole of a shoe. It ranges from 50 to 300um in size which varies from species to species. It is mostly found in a freshwater environment.

It is a single-celled eukaryote belonging to kingdom Protista and is a well-known genus of ciliate protozoa.

As well, it belongs to the phylum Ciliophora. Its whole body is covered with small hair-like filaments called the cilia which helps in locomotion. There is also a deep oral groove containing not so clear oral cilia. The main function of this cilia is to help both in locomotion as well as dragging the food to its oral cavity.

Classification of Paramecium

Paramecium can be classified into the following phylum and sub-phylum based on their certain characteristics.

Phylum Protozoa

Sub-Phylum Ciliophora

Class Ciliates

Order Hymenostomatida

Genus Paramecium

Species Caudatum

Being a well-known ciliate protozoan, paramecium exhibits a high-level cellular differentiation containing several complex organelles performing a specific function to make its survival possible.

Besides a highly specialized structure, it also has a complex reproductive activity. Out of the 10 total species of Paramecium, the most common two are P.aurelia and P.caudatum.

Structure and Function

1. Shape and Size

P. cadatum is a microscopic, unicellular protozoan. Its size ranges from 170 to 290um or up to 300 to 350um. Surprisingly, paramecium is visible to the naked eye and has an elongated slipper like shape, that's the reason it's also referred to as a slipper animalcule.

The posterior end of the body is pointed, thick and cone-like while the anterior part is broad and blunt. The widest part of the body is below the middle. The body of a paramecium is asymmetrical. It has a well-defined ventral or oral surface and has a convex aboral or dorsal body surface.

2. Pellicle

Its whole body is covered with a flexible, thin and firm membrane called pellicles. These pellicles are elastic in nature which supports the cell membrane. It's made up of a gelatinous substance.

3. Cilia

Cilia refers to the multiple, small hair-like projections that cover the whole body. It is arranged in longitudinal rows with a uniform length throughout the body of the animal. This condition is called holotrichous. There are also a few longer cilia present at the posterior end of the body forming a caudal tuft of cilia, thus named caudatum.

The structure of cilia is the same as flagella, a sheath made of protoplast or plasma membrane with longitudinal nine fibrils in the form of a ring. The outer fibrils are much thicker than the inner ones with each cilium arising from a basal granule. Cilia have a diameter of 0.2um and helps in its locomotion.

4. Cytostome: It contains the following parts:

Oral groove: There is a large oblique shallow depression on the ventrio-lateral side of the body called peristome or an oral grove. This oral groove gives an asymmetrical appearance to the animal. It further extends into a depression called a vestibule through a short conical funnel. This vestibule further extends into the cytostome through an oval-shaped opening, through a long opening called a cytopharynx and then the esophagus leads to the food vacuole

Cytopyge: Lying on the ventral surface, just behind the cytostome is the cytopyge also called a cytoproct. All the undigested food gets eliminated through the cytopyge.

Cytoplasm: Cytoplasm is a jelly-like substance further differentiated into the ectoplasm. The ectoplasm is a narrow peripheral layer. It is a dense and clear layer with an inner mass of endoplasm or semifluid plasmasol that is granular in shape.

Ectoplasm: Ectoplasm forms a thin, dense and clear outer layer containing cilia, trichocysts, and fibrillar structures. This ectoplasm is further bound to pellicle externally through a covering.

Endoplasm: Endoplasm is one of the most detailed parts of the cytoplasm. It contains several different granules. It contains different inclusions and structures like vacuoles, mitochondria, nuclei, food vacuole, contractile vacuole etc.

Trichocysts: Embedded in the cytoplasm are small spindle-like bodies called trichocysts. Trichocysts are filled with a dense refractive fluid containing swelled substances. There is a conical head on the spike at the outer end. Trichocysts are perpendicular to the ectoplasm

5.Nucleus: The nucleus further consists of a macronucleus and a micronucleus.

Macro Nucleus: Macronucleus is kidney like or ellipsoidal in shape. It's densely packed within the DNA (chromatin granules). The macronucleus controls all the vegetative functions of paramecium hence called the vegetative nucleus.

Micro Nucleus: The micronucleus is found close to the macronucleus. It is a small and compact structure, spherical in shape. The fine chromatin threads and granules are uniformly distributed throughout the cell and control reproduction of the cell. The number in a cell varies from species to species. There is no nucleolus present in caudatum.

6. Vacuole: Paramecium consists of two types of vacuoles: contractile vacuole and food vacuole.

Contractile vacuole: There are two contractile vacuoles present close to the dorsal side, one on each end of the body. They are filled with fluids and are present at fixed positions between the endoplasm and ectoplasm. They disappear periodically and hence are called temporary organs. Each contractile vacuole is connected to at least five to twelve radical canals

. These radical canals consist of a long ampulla, a terminal part and an injector canal which is short in size and opens directly into the contractile vacuole. These canals pour all the liquid collected from the whole body of paramecium into the contractile vacuole which makes the vacuole increase in size. This liquid is discharged to the outside through a permanent pore. The contraction of both the contractile vacuoles is irregular. The posterior contractile vacuole is close to the cytopharynx and hence contract more quickly because of more water passing through. Some of the main functions of contractile vacuoles include osmoregulation, excretion, and respiration.

Food vacuole: Food vacuole is non-contractile and is roughly spherical in shape. In the endoplasm, the size of food vacuole varies and digest food particles, enzymes alongside a small amount of fluid and bacteria. These food vacuoles are associated with the digestive granules that aid in food digestion.

Characteristics

1. Habit and Habitat

Paramecium has a worldwide distribution and is a free-living organism. It usually lives in the stagnant water of pools, lakes, ditches, ponds, freshwater and slow flowing water that is rich in decaying organic matter.

2. Movement and Feeding

Its outer body is covered by the tiny hair-like structures called cilia. These cilia are in constant motion and help it move with a speed that is four times its body's length per second. Just as the organism moves forward, rotating around its own axis, this further helps it to push the food into the gullet. By reversing the motion of cilia, paramecium can move in the reverse direction as well.

Through a process known as phagocytosis, the food is pushed into the gullet through cilia which further goes into the food vacuoles.

The food is digested with the help of certain enzymes and hydrochloric acid. Once the digestion is completed the rest of the food content is quickly emptied into cytoproct also known as the pellicles.

The water absorbed from the surroundings through osmosis is continuously expelled from the body with the help of the contractile vacuoles present on either end of the cell. P. bursaria is one of the species which forms a symbiotic relationship with photosynthetic algae.

In this case, the paramecium provides a safe habitat for the algae to grow and live in its own cytoplasm, however, in return the paramecium might use this algae as a source of nutrition in case there is a scarcity of food in the surroundings.

Paramecium also feeds on other microorganisms like yeasts and bacteria. To gather the food it makes use of its cilia, making quick movements with cilia to draw the water along with its prey organisms inside the mouth opening through its oral groove.

The food further passes into the gullet through the mouth. Once there is enough food accumulated a vacuole is formed inside the cytoplasm, circulating through the cell with enzymes entering the vacuole through the cytoplasm to digest the food material.

Once the digestion is completed the vacuole starts to shrink and the digested nutrients enter into the cytoplasm. Once the vacuole reaches the anal pore with all of its digested nutrients it ruptures and expels all of its waste material into the environment

3.Symbiosis: Symbiosis refers to the mutual relationship between two organisms to benefit from each other. Some species of paramecium including P. bursaria and P. chlorelligerum form a symbiotic relationship with green algae from which they not only take food and nutrients when needed but also some protection from certain predators like Didinium nasutum.

There has been a lot of endosymbioses reported between the green algae and paramecium with an example being that of the bacteria named Kappa particles giving paramecium the power to kill other paramecium strains which lack this bacteria.

4. Reproduction: **Just like all the other ciliates, paramecium also consists of one or more diploid micronuclei and a polypoid macronucleus hence containing a dual nuclear apparatus. The function of the micronucleus is to maintain the genetic stability and making sure that the desirable genes are passed to the next generation. It is also called the germline or generative nucleus.**

The macronucleus plays a role in non-reproductive cell functions including the expression of genes needed for the everyday functioning of the cell.

Paramecium reproduces asexually through binary fission. The micronuclei during reproduction undergo mitosis while the macronuclei divide through amitosis. Each new cell, in the end, contains a copy of macronuclei and micronuclei after the cell undergoes a transverse division. Reproduction through binary fission may occur spontaneously.

It may also undergo autogamy (self-fertilization) under certain conditions. It may also follow a sexual reproduction process in which there is an exchange of genetic material because of mating between two paramecia who are compatible for mating through a temporary fusion.

There is a meiotic division of the micronuclei during the conjugation which results in haploid gametes and is further passed on from cell to cell. The old macronuclei are destroyed and formation of a diploid micronuclei takes place when gametes of two organisms fuse together.

Paramecium reproduces through conjugation and autogamy when conditions are not favorable and there is a scarcity of food

5.Aging: There is a gradual loss of energy as a result of clonal aging during the mitotic cell division in the asexual fission phase of growth of paramecium.

P. tetraurelia is a well-studied species and it has been known that the cell expires right after 200 fissions if the cell relies only on the asexual line of cloning instead of conjugation and autogamy.

There is an increase in the DNA damage during clonal aging specifically the DNA damage in the macronucleus hence causing aging in P. tetraurelia. As per the DNA damage theory of aging the whole process of aging in single-celled protists is the same as that of the multicellular eukaryotes.

6. Genome :Strong evidence for the three whole-genome duplications has been provided after the genome of species P. tetraurelia has been sequenced. In some of the ciliates including Stylonychia and Paramecium UAA and UAG are designated as sense codons while UGA as a stop codon.

Life cycle and pathogenicityof *Plasmodium Vivex*

Life Cycle

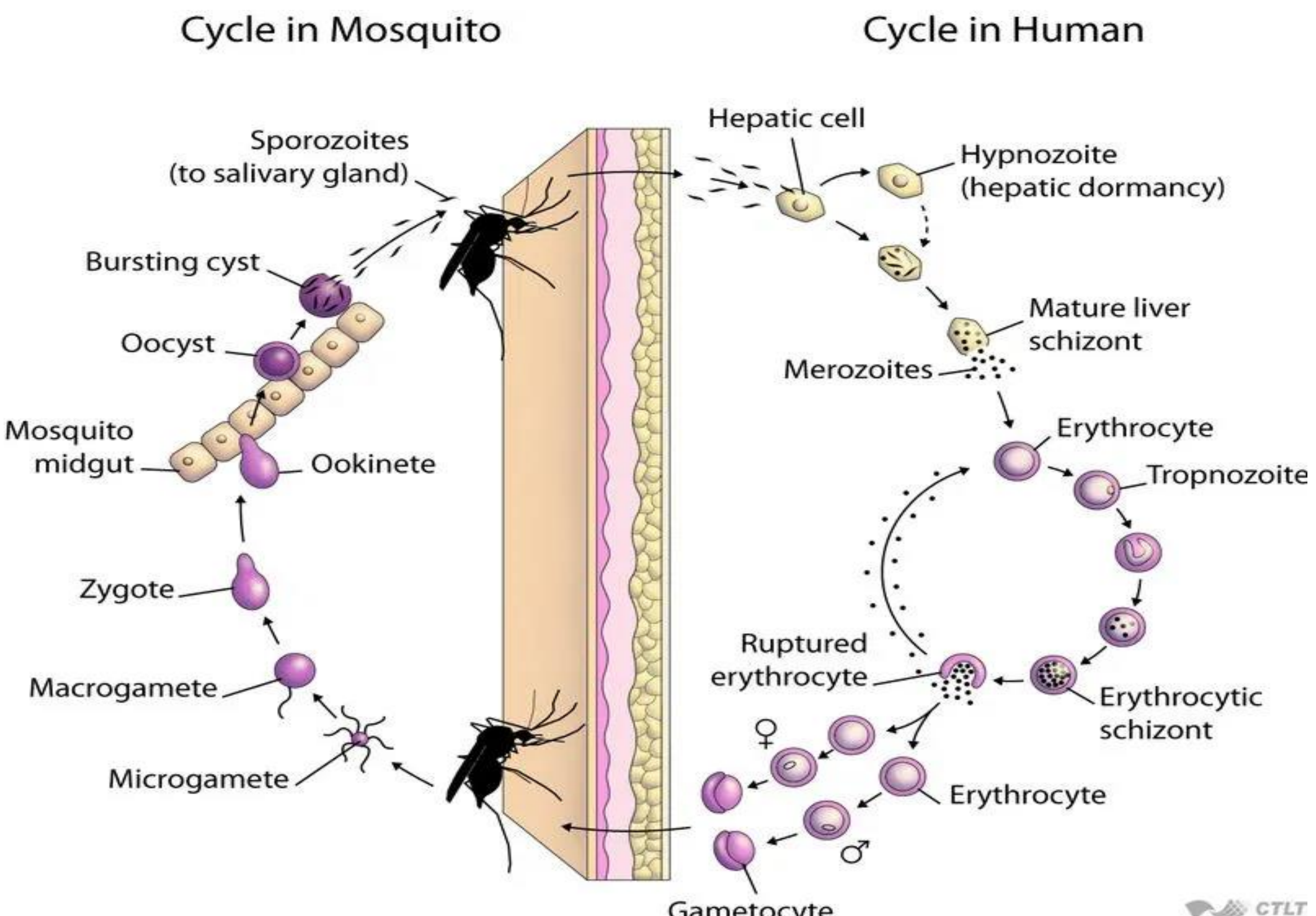
The malaria parasite has a complex, multistage life cycle occurring within two living beings, the vector mosquitoes and the vertebrate hosts. The survival and development of the parasite within the invertebrate and vertebrate hosts, in intracellular and extracellular environments, is made possible by a toolkit of more than 5,000 genes and their specialized proteins that help the parasite to invade and grow within multiple cell types and to evade host immune responses.

The parasite passes through several stages of development such as the **sporozoites (Gr. Sporos = seeds; the infectious form injected by the mosquito)**, **merozoites (Gr. Meros = piece; the stage invading the erythrocytes)**, **trophozoites (Gr. Trophes = nourishment; the form multiplying in erythrocytes)**, **and gametocytes (sexual stages)**

and all these stages have their own unique shapes and structures and protein complements. The surface proteins and metabolic pathways keep changing during these different stages, that help the parasite to evade the immune clearance, while also creating problems for the development of drugs and vaccines

Sporogony Within the Mosquitoes:

Mosquitoes are the definitive hosts for the malaria parasites, wherein the sexual phase of the parasite's life cycle occurs. The sexual phase is called sporogony and results in the development of innumerable infecting forms of the parasite within the mosquito that induce disease in the human host following their injection with the mosquito bite.



Cycle in Mosquito
Cycle in Human
Sporozoites
(to salivary gland)
Bursting cyst
Oocyst
Mosquito
midgut
Ookinete
Zygote
Macrogamete
Microgamete
Hepatic cell
Hypnozoite
(hepatic dormancy)
Mature liver
schizont
Merozoites
Erythrocyte
Tropnozoite
Ruptured
erythrocyte
Erythrocytic
schizont
♀
Erythrocyte
♂
Gametocyte
CTLT

When the female Anopheles draws a blood meal from an individual infected with malaria, the male and female gametocytes of the parasite find their way into the gut of the mosquito. The molecular and cellular changes in the gametocytes help the parasite to quickly adjust to the insect host from the warm-blooded human host and then to initiate the sporogonic cycle. The male and female gametes fuse in the mosquito gut to form zygotes, which subsequently develop into actively moving ookinetes that burrow into the mosquito midgut wall to develop into oocysts. Growth and division of each oocyst produces thousands of active haploid forms called sporozoites.

After the sporogonic phase of 8–15 days, the oocyst bursts and releases sporozoites into the body cavity of the mosquito, from where they travel to and invade the mosquito salivary glands. When the mosquito thus loaded with sporozoites takes another blood meal, the sporozoites get injected from its salivary glands into the human bloodstream, causing malaria infection in the human host. It has been found that the infected mosquito and the parasite mutually benefit each other and thereby promote transmission of the infection. The Plasmodium-infected mosquitoes have a better survival and show an increased rate of blood-feeding, particularly from an infected host.[3-5]

Schizogony in the Human Host:

Man is the intermediate host for malaria, wherein the asexual phase of the life cycle occurs. The sporozoites inoculated by the infested mosquito initiate this phase of the cycle from the liver, and the latter part continues within the red blood cells, which results in the various clinical manifestations of the disease.

Pre-erythrocytic Phase – Schizogony in the Liver:

With the mosquito bite, tens to a few hundred invasive sporozoites are introduced into the skin. Following the intradermal deposition, some sporozoites are destroyed by the local macrophages, some enter the lymphatics, and some others find a blood vessel. The sporozoites that enter a lymphatic vessel reach the draining lymph node wherein some of the sporozoites partially develop into exoerythrocytic stages and may also prime the T cells to mount a protective immune response

The sporozoites that find a blood vessel reach the liver within a few hours. It has recently been shown that the sporozoites travel by a continuous sequence of stick-and-slip motility, using the thrombospondin-related anonymous protein (TRAP) family and an actin–myosin motor.The sporozoites then negotiate through the liver sinusoids, and migrate into a few hepatocytes, and then multiply and grow within parasitophorous vacuoles. Each sporozoite develop into a schizont containing 10,000–30,000 merozoites (or more in case of P. falciparum).

The growth and development of the parasite in the liver cells is facilitated by a a favorable environment created by the The circumsporozoite protein of the parasite.The entire pre-eryhrocytic phase lasts about 5–16 days depending on the parasite species: on an average 5-6 days for P. falciparum, 8 days for P. vivax, 9 days for P. ovale, 13 days for P. malariae and 8-9 days for P. knowlesi.The pre-erythrocytic phase remains a "silent" phase, with little pathology and no symptoms, as only a few hepatocytes are affected.This phase is also a single cycle, unlike the next, erythrocytic stage, which occurs repeatedly

The merozoites that develop within the hepatocyte are contained inside host cell-derived vesicles called merosomes that exit the liver intact, thereby protecting the merozoites from phagocytosis by Kupffer cells. These merozoites are eventually released into the blood stream at the lung capillaries and initiate the blood stage of infection thereon.

In P. vivax and P. ovale malaria, some of the sporozoites may remain dormant for months within the liver. Termed as hypnozoites, these forms develop into schizonts after some latent period, usually of a few weeks to months. It has been suggested that these late developing hypnozoites are genotypically different from the sporozoites that cause acute infection soon after the inoculation by a mosquito bite, and in many patients cause relapses of the clinical infection after weeks to months.

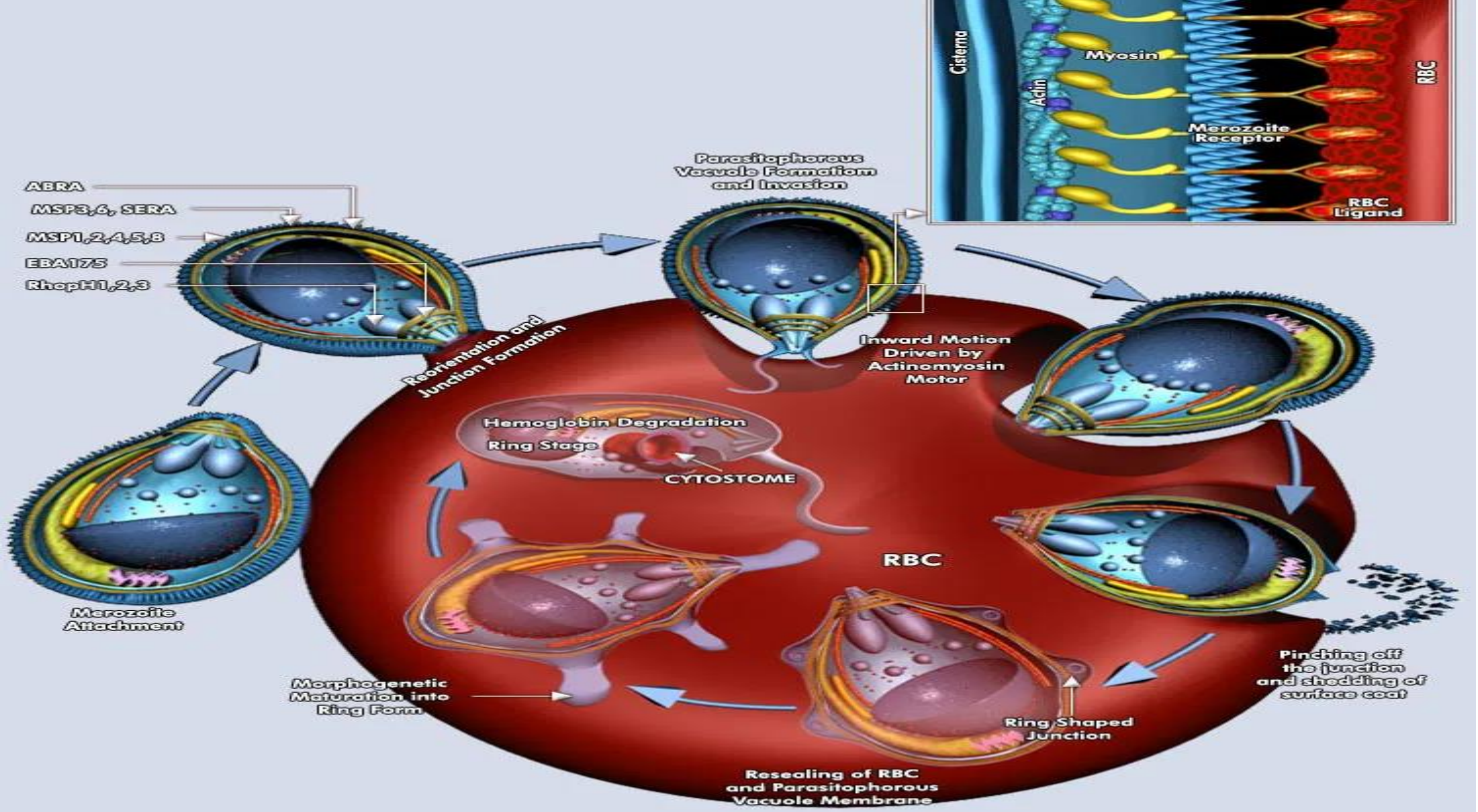
Erythrocytic Schizogony – Centre Stage in Red Cells

Red blood cells are the ‘centre stage’ for the asexual development of the malaria parasite. Within the red cells, repeated cycles of parasitic development occur with precise periodicity, and at the end of each cycle, hundreds of fresh daughter parasites are released that invade more number of red cells.

The merozoites released from the liver recognize, attach, and enter the red blood cells (RBCs) by multiple receptor–ligand interactions in as little as 60 seconds. This quick disappearance from the circulation into the red cells minimises the exposure of the antigens on the surface of the parasite, thereby protecting these parasite forms from the host immune response. The invasion of the merozoites into the red cells is facilitated by molecular interactions between distinct ligands on the merozoite and host receptors on the erythrocyte membrane. P. vivax invades only Duffy blood group-positive red cells, using the Duffy-binding protein and the reticulocyte homology protein, found mostly on the reticulocytes.

. the more virulent P. falciparum uses several different receptor families and alternate invasion pathways that are highly redundant. Varieties of Duffy binding-like (DBL) homologous proteins and the reticulocyte binding-likehomologous proteins of P. falciparum recognize different RBC receptors other than the Duffy blood group or the reticulocyte receptors. Such redundancy is helped by the fact that P. falciparum has four Duffy binding-like erythrocyte-binding protein genes, in comparison to only one gene in the DBL-EBP family as in the case of P. vivax, allowing P. falciparum to invade any red cell.

Erythrocyte Invasion by Plasmodium Merozoites



The process of attachment, invasion, and establishment of the merozoite into the red cell is made possible by the specialized apical secretory organelles of the merozoite, called the micronemes, rhoptries, and dense granules. The initial interaction between the parasite and the red cell stimulates a rapid "wave" of deformation across the red cell membrane, leading to the formation of a stable parasite–host cell junction. Following this, the parasite pushes its way through the erythrocyte bilayer with the help of the actin–myosin motor, proteins of the thrombospondin-related anonymous protein family (TRAP) and aldolase, and creates a parasitophorous vacuole to seal itself from the host-cell cytoplasm, thus creating a hospitable environment for its development within the red cell. At this stage, the parasite appears as an intracellular "ring".

Within the red cells, the parasite numbers expand rapidly with a sustained cycling of the parasite population. Even though the red cells provide some immunological advantage to the growing parasite, the lack of standard biosynthetic pathways and intracellular organelles in the red cells tend to create obstacles for the fast-growing intracellular parasites. These impediments are overcome by the growing ring stages by several mechanisms: by restriction of the nutrient to the abundant hemoglobin, by dramatic expansion of the surface area through the formation of a tubovesicular network, and by export of a range of remodeling and virulence factors into the red cell.

Hemoglobin from the red cell, the principal nutrient for the growing parasite, is ingested into a food vacuole and degraded. The amino acids thus made available are utilized for protein biosynthesis and the remaining toxic heme is detoxified by heme polymerase and sequestrated as hemozoin (malaria pigment). The parasite depends on anaerobic glycolysis for energy, utilizing enzymes such as pLDH, plasmodium aldolase etc. As the parasite grows and multiplies within the red cell, the membrane permeability and cytosolic composition of the host cell is modified.

These new permeation pathways induced by the parasite in the host cell membrane help not only in the uptake of solutes from the extracellular medium but also in the disposal of metabolic wastes, and in the origin and maintenance of electrochemical ion gradients. At the same time, the premature hemolysis of the highly permeabilized infected red cell is prevented by the excessive ingestion, digestion, and detoxification of the host cell hemoglobin and its discharge out of the infected RBCs through the new permeation pathways, thereby preserving the

TEM of P. falciparum schizont (X2810) [Credit: Dennis Kunkel Microscopy, Inc./Visuals Unlimited, Inc.]

The erythrocytic cycle occurs every 24 hours in case of P. knowlesi, 48 h in cases of P. falciparum, P. vivax and P. ovale and 72 h in case of P. malariae. During each cycle, each merozoite grows and divides within the vacuole into 8–32 (average 10) fresh merozoites, through the stages of ring, trophozoite, and schizont. At the end of the cycle, the infected red cells rupture, releasing the new merozoites that in turn infect more RBCs. With sunbridled growth, the parasite numbers can rise rapidly to levels as high as 1013 per host.

A small proportion of asexual parasites do not undergo schizogony but differentiate into the sexual stage gametocytes. These male or female gametocytes are extracellular and nonpathogenic and help in transmission of the infection to others through the female anopheline mosquitoes, wherein they continue the sexual phase of the parasite's life cycle. Gametocytes of P. vivax develop soon after the release of merozoites from the liver, whereas in case of P. falciparum, the gametocytes develop much later with peak densities of the sexual stages typically occurring 1 week after peak asexual stage densities

PATHOGENICITY OF *Plasmodium Vivex*

Definition / general

Four species of plasmodia causing human malaria are Plasmodium vivax, Plasmodium falciparum, Plasmodium malariae and Plasmodium ovale

Malaria (from the Italian 'mal' aria," meaning "bad air") is an acute and sometimes chronic infection of the bloodstream characterized clinically by fever, anemia and splenomegaly and is caused by apicomplexan parasites of the genus Plasmodium

P. vivax infections occur in both tropical and temperate zones, between 45° N and 40° S (WHO: Malaria [Accessed 10 January 2018])

Pathophysiology / etiology

Spread exclusively by female anopheline mosquitoes

Fever paroxysm occurs over 6 - 10 hours and is initiated by the synchronous rupture of erythrocytes with the release of new infectious blood stage forms known as merozoites

Transfusion induced malaria may occur when blood donors have subclinical malaria and may prove fatal for the recipient

Similarly, congenital malaria may occur in infants born to mothers from endemic areas; the infant acquires the infection at birth due to rupture of placental blood vessels with maternal fetal transfusion

Neither transfusion nor congenital malaria is expected to relapse because exoerythrocytic schizogony does not occur

Persons who lack certain Duffy blood group determinants are protected against P. vivax infection

Clinical features

In the early stages of the disease, febrile episodes occur irregularly but eventually become more synchronous, assuming the usual tertian (P. vivax, P. falciparum and P. ovale) or quartan (P. malariae) periodicity

Patients with malaria may develop anemia and may have other manifestations, including diarrhea, abdominal pain, headache and muscle aches and pains

Patients with P. vivax or P. ovale infection may have relapses after many months or years

Diagnosis

Growing trophozoites of P. vivax have irregular shapes and are termed ameboid

Identification of malarial parasites on thin blood films requires a systematic approach

Three major factors should be considered:

Appearance of infected erythrocytes

Appearance of parasites

Stages found

P. vivax and P. ovale parasites primarily infect young erythrocytes, whereas P. malariae infects older erythrocytes and P. falciparum infects erythrocytes of all ages

Appearance of RBC and size:

Enlarged

Maximum size (attained with mature trophozoites and schizonts); may be up to 2x normal erythrocyte diameter

Schüffner stippling: Maurer dots (comma shaped spots, dark blue by Giemsa staining, on RBC surface) are seen with all stages except early ring forms

Parasite cytoplasm:

Irregular

Ameboid in trophozoites

Has "spread out" appearance

Appearance of parasite pigment: golden brown, inconspicuous

Number of merozoites: 12 - 24; average is 16

Stages found in circulating blood: all stages; wide range of stages may be seen on any given film

Mixed infections

~5% of infections are mixed but diagnosis requires definite evidence of 2 separate populations of parasites

Most common mixed infections are P. falciparum and P. vivax

Finding gametocytes of P. falciparum in a person obviously infected with P. vivax is diagnostic

Case reports

27 year old woman with fever, shivering and myalgia for three months (Asian Pac J Trop Biomed 2014;4:S56)

30 year old woman with frontal lobe infarct in Plasmodium vivax infection (Neurol India 2014;62:67)

Treatment

Chloroquine remains the treatment of choice for vivax malaria, except in Indonesia's Irian Jaya (Western New Guinea) region and the geographically contiguous Papua New Guinea, where chloroquine resistance is common (up to 20% resistance) (Curr Opin Infect Dis 2009;22:430)

Chloroquine resistance is an increasing problem in other parts of the world, such as Korea and India

When chloroquine resistance is common or when chloroquine is contraindicated, then artesunate is the drug of choice, except in the U.S., where it is not approved for use

LIFE CYCLE AND PATHOGENECITY OF ENTAMOEBA HISTOLYTICA

Scientific classification
Domain: Eukaryota
Phylum: Amoebozoa
Family: Entamoebidae
Genus: Entamoeba
Species: E. histolytica

Entamoeba histolytica is an anaerobic parasitic amoebozoan, part of the genus Entamoeba

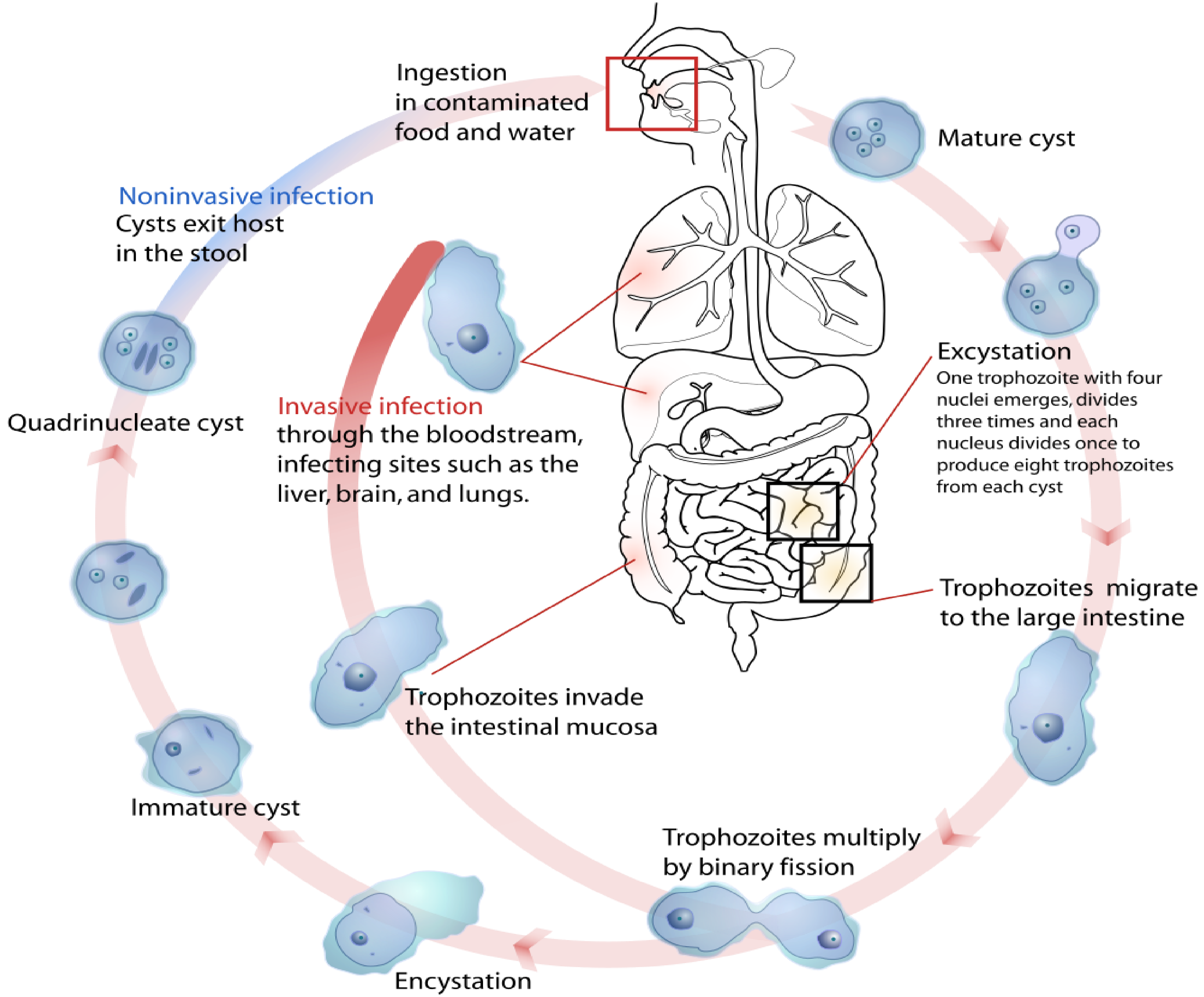
.[1] Predominantly infecting humans and other primates causing amoebiasis, E. histolytica is estimated to infect about 35-50 million people worldwide.[1] E. histolytica infection is estimated to kill more than 55,000 people each year

.[2] Previously, it was thought that 10% of the world population was infected, but these figures predate the recognition that at least 90% of these infections were due to a second species, E. dispar.

[3] Mammals such as dogs and cats can become infected transiently, but are not thought to contribute significantly to transmission.

The word histolysis literally means disintegration and dissolution of organic tissues

LIFE CYCLE OF ENTAMOEBA HISTOLYTICA



LIFE CYCLE OF ENTAMOEBA HISTOLYTICA

Transmission

The active (trophozoite) stage exists only in the host and in fresh loose feces; cysts survive outside the host in water, in soils, and on foods, especially under moist conditions on the latter. **The infection can occur when a person puts anything into their mouth that has touched the feces of a person who is infected with E. histolytica, swallows something, such as water or food, that is contaminated with E. histolytica, or swallows E. histolytica cysts (eggs) picked up from contaminated surfaces or fingers.** The cysts are readily killed by heat and by freezing temperatures, and survive for only a few months outside of the host. When cysts are swallowed they cause infections by excysting (releasing the trophozoite stage) in the digestive tract.

Infection can be asymptomatic or can lead to amoebic dysentery or amoebic liver abscess. Symptoms can include fulminating dysentery, bloody diarrhea, weight loss, fatigue, abdominal pain, and amoeboma. The amoeba can actually 'bore' into the intestinal wall, causing lesions and intestinal symptoms, and it may reach the blood stream. From there, it can reach different vital organs of the human body, usually the liver, but sometimes the lungs, brain, spleen, etc. A common outcome of this invasion of tissues is a liver abscess, which can be fatal if untreated. Ingested red blood cells are sometimes seen in the amoeba cell cytoplasm.

Risk factors:

Poor sanitary conditions are known to increase the risk of contracting amebiasis E. histolytica. In the United States, there is a much higher rate of amebiasis-related mortality in California and Texas, which might be caused by the proximity of those states to E. histolytica-endemic areas, such as Mexico, other parts of Latin America, and Asia. E. histolytica is also recognized as anemerging sexually transmissible pathogen, especially in male homosexual relations, causing outbreaks in non-endemic regions. As such, high-risk sex behaviour is also a potential source of infection. Although it is unclear whether there is a causal link, studies indicate a higher chance of being infected with E. histolytica if one is also infected with HIV.

GENOME: These have been divided in three families called EhLINEs and EhSINEs (EhLINE1,2,3 and EhSINE1,2,3). EhLINE1 encode an endonuclease (EN) protein (in addition to reverse transcriptase and nucleotide-binding ORF1), which have similarity with bacterial restriction endonuclease. This similarity with bacterial protein indicates that transposable elements have been acquired from prokaryotes by horizontal gene transfer in this protozoan parasite.

The genome of E. histolytica has been found to have snoRNAs with opisthokont-like features. The E. histolytica U3 snoRNA (Eh_U3 snoRNA) has showed sequence and structural features similar to Homo sapiens U3 snoRNA

Pathology

Once the trophozoites are excysted in the terminal ileum region, they colonize the large bowel, remaining on the surface of the mucus layer and feeding on bacteria and food particles. Occasionally, and in response to unknown stimuli, trophozoites move through the mucus layer where they come in contact with the epithelial cell layer and start the pathological process

E. histolytica has a lectin that binds to galactose and N-acetylgalactosamine sugars on the surface of the epithelial cells, The lectin normally is used to bind bacteria for ingestion. The parasite has several enzymes such as pore forming proteins, lipases, and cysteine proteases, which are normally used to digest bacteria in food vacuoles but which can cause lysis of the epithelial cells by inducing cellular necrosis and apoptosis when the trophozoite comes in contact with them and binds via the lectin.

Enzymes released allow penetration into intestinal wall and blood vessels, sometimes on to liver and other organs. The trophozoites will then ingest these dead cells.

This damage to the epithelial cell layer attracts human immune cells and these in turn can be lysed by the trophozoite, which releases the immune cell's own lytic enzymes into the surrounding tissue, creating a type of chain reaction and leading to tissue destruction. This destruction manifests itself in the form of an 'ulcer' in the tissue, typically described as flask-shaped because of its appearance in transverse section. This tissue destruction can also involve blood vessels leading to bloody diarrhea, amebic dysentery. Occasionally, trophozoites enter the bloodstream where they are transported typically to the liver via the portal system. In the liver a similar pathological sequence ensues, leading to amebic liver abscesses. The trophozoites can also end up in other organs, sometimes via the bloodstream, sometimes via liver abscess rupture or fistulas. In all locations, similar pathology can occur.

Transcriptomic study of E. histolytica for promoter analysis of variable expression class of all the genes reveals that the highly transcribed genes of E. histolytica belongs to virulence factor genes. The study also have reported about the presence of novel downstream regulatory motifs in E. histolytica

Pathogenesis

E. histolytica causes tissue destruction which leads to clinical disease. E. histolytica–induced tissue damage by three main events: direct host cell death, inflammation, and parasite invasion

Diagnosis

Diagnosis is confirmed by microscopic examination for trophozoites or cysts in fresh or suitably preserved faecal specimens, smears of aspirates or scrapings obtained by proctoscopy, and aspirates of abscesses or other tissue specimen. A blood test is also available but is only recommended when a healthcare provider believes the infection may have spread beyond the intestine (gut) to some other organ of the body, such as the liver. However, this blood test may not be helpful in diagnosing current illness because the test can be positive if the patient has had amebiasis in the past, even if they are not infected at present. Stool antigen detection and PCR are available for diagnosis, and are more sensitive and specific than microscopy.

Treatment

There are a number of effective medications. Generally several antibiotics are available to treat Entamoeba histolytica. The infected individual will be treated with only one antibiotic if the E. histolytica infection has not made the person sick and most likely be prescribed with two antibiotics if the person has been feeling sick. Otherwise, below are other options for treatments.

Intestinal infection: Usually nitroimidazole derivatives (such as metronidazole) are used because they are highly effective against the trophozoite form of the amoeba. Since they have little effect on amoeba cysts, usually this treatment is followed by an agent (such as paromomycin or diloxanide furoate) that acts on the organism in the lumen.

Liver abscess: In addition to targeting organisms in solid tissue, primarily with drugs like metronidazole and chloroquine, treatment of liver abscess must include agents that act in the lumen of the intestine (as in the preceding paragraph) to avoid re-invasion. Surgical drainage is usually not necessary except when rupture is imminent.

People without symptoms: For people without symptoms (otherwise known as carriers, with no symptoms), non endemic areas should be treated by paromomycin, and other treatments include diloxanide furoate and iodoquinol.[citation needed] There have been problems with the use of iodoquinol and iodochlorhydroxyquin, so their use is not recommended. Diloxanide furoate can also be used by mildly symptomatic persons who are just passing cysts.

Genus and species	*Entamoeba histolytica*
Etiologic agent of:	Amoebiasis; amoebic dysentery; extraintestinal amoebiasis, usually amoebic liver abscess; "anchovy sauce"); amoeba cutis; amoebic lung abscess ("liver-colored sputum")
Infective stage	Tetranucleated cyst (having 2-4 nuclei)
Definitive host	Human
Portal of entry	Mouth
Mode of transmission	Ingestion of mature cyst through contaminated food or water
Habitat	Colon and cecum
Pathogenic stage	Trophozoite
Locomotive apparatus	Pseudopodia ("false foot"")
Motility	Active, progressive and directional
Nucleus	'Ring and dot' appearance: peripheral chromatin and central karyosome
Mode of reproduction	Binary fission
Pathogenesis	Lytic necrosis (it looks like "flask-shaped" holes in Gastrointestinal tract sections (GIT)
Type of encystment	Protective and Reproductive
Lab diagnosis	Most common is direct fecal smear (DFS) and staining (but does not allow identification to species level); enzyme immunoassay (EIA); indirect hemagglutination (IHA); Antigen detection – monoclonal antibody; PCR for species identification. Sometimes only the use of a fixative (formalin) is effective in detecting cysts. Culture: From faecal samples - Robinson's medium, Jones' medium

	Jones' medium
Treatment	Metronidazole for the invasive trophozoites PLUS a lumenal amoebicide for those still in the intestine. Paromomycin (Humatin) is the luminal drug of choice, since Diloxanide furoate (Furamide) is not commercially available in the United States or Canada (being available only from the Centers for Disease Control and Prevention). A direct comparison of efficacy showed that Paromomycin had a higher cure rate.[29] Paromomycin (Humatin) should be used with caution in patients with colitis, as it is both nephrotoxic and ototoxic. Absorption through the damaged wall of the intestinal tract can result in permanent hearing loss and kidney damage. Recommended dosage: metronidazole 750 mg three times a day orally, for 5 to 10 days followed by paromomycin 30 mg/kg/day orally in 3 equal doses for 5 to 10 days or Diloxanide furoate 500 mg 3 times a day orally for 10 days, to eradicate lumenal amoebae and prevent relapse.[30][31]
Trophozoite stage	
Pathognomonic/diagnostic feature	Ingested RBC; distinctive nucleus
Cyst Stage	
Chromatoidal body	'Cigar' shaped bodies (made up of crystalline ribosomes)
Number of nuclei	1 in early stages, 4 when mature
Pathognomonic/diagnostic feature	'Ring and dot' nucleus and chromatoid bodies

LOCOMOTION IN PROTISTA

Modes of Locomotion in Protists:

5 Modes

The following points highlight the five modes of locomotion in Protists. The modes are:

1. Pseudopodial Locomotion
2. Flagellar Locomotion
3. Ciliary Locomotion
4. Wriggling Locomotion
5. Locomotion by Mucilage Propulsion.

Mode # 1. Pseudopodial Locomotion:

It is slow creeping type of locomotion which is performed with the help of protoplasmic outgrowths called pseudopodia.

Pseudopodial locomotion occurs in sarcodines and slime moulds.

Pseudopodia are of four types:

(i) Wolf-podia:

These pseudopodia are lobe- like with broad and blunt ends. These are present in Amoeba,

(ii) Philosophy:

These pseudopodia are fine, thread-like, tapering, and are composed of ecto-plasm. These are found in Euglypha.

(iii) Axo-could:

These are long and stiff, with hard axial filament. These pseudopodia are present in Actinophrys.

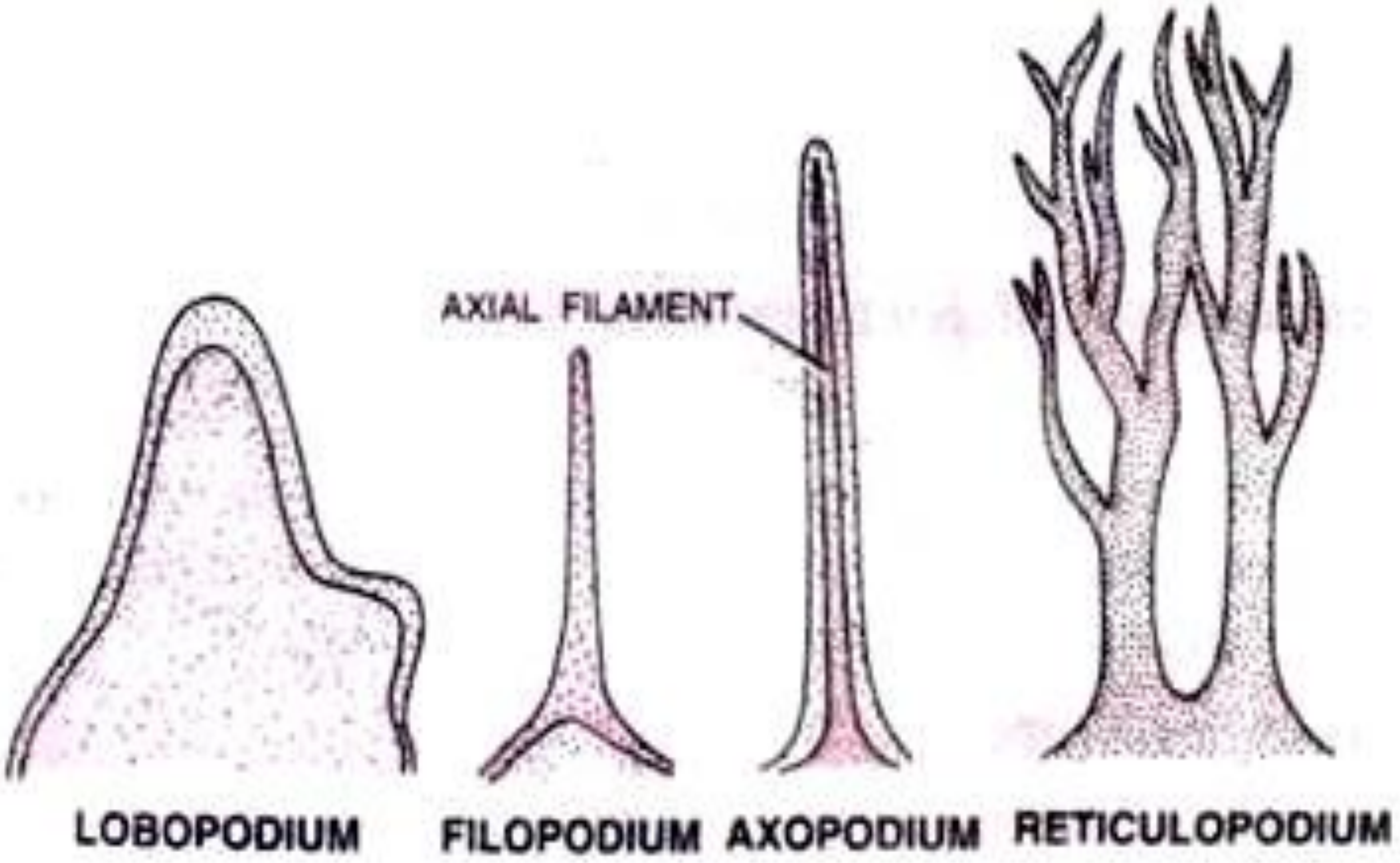


Fig. 2.22. Types of pseudopodia.

Mode # 2. Flagellar Locomotion:

Flagella show whip-like movement. They usually beat independently. This type of locomotion occurs in dinoflagellates (e.g., Gonyaulax), euglenoids (e.g., Euglena) and zoo-flagellates (e.g., Leishmania). Vickerman and Cox (1967) have suggested that the flagellum makes direct contribution to locomotion. However, several theories have been put forth to explain the mechanism of flagellar movement. Butschli observed that the flagellum undergoes a series of lateral movements and in doing so, a pressure is exerted on the water at ripressure is exerted on the water at right angles to its surface.

This pressure creates two forces one directed parallel, and the other at right angles, to the main axis of the body. The parallel force will drive the animal forward and the force acting at right angles would rotate the animal on its own axis

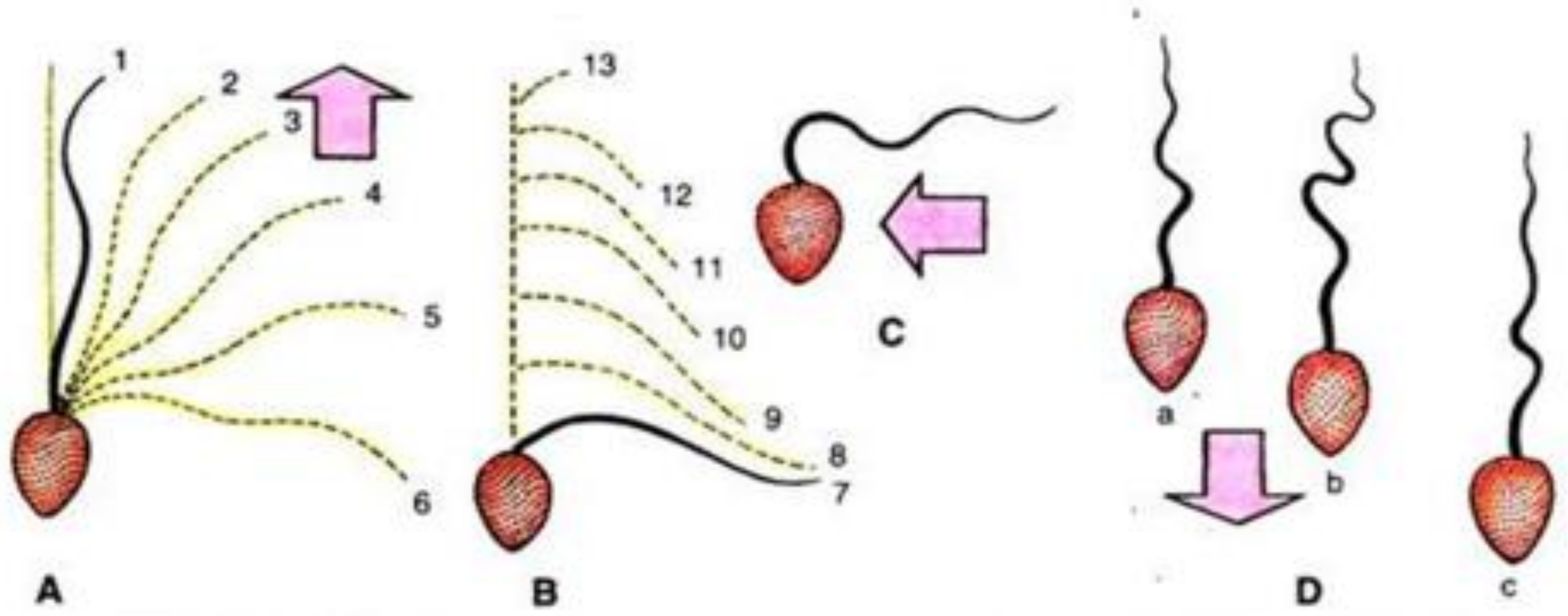


Fig. 12.5. Action of flagellum. A—Recovery stroke, successive stages from 1 to 7; B—Effective stroke, successive stages 8 to 13.

Gray (1928) suggested that a series of waves pass from one end of the flagellum to the other. These waves create two types of forces, one in the direction of the movement and the other in the circular direction with the main axis of the body. The former will drive the animal forward and the latter would rotate the animal.

Mode # 3. Ciliary Locomotion:

Cilia show oar-like movement. All the cilia of a cell show coordinated movements which are of two types, isochronic and metachronic rhythms. In isochronic or synchronous rhythm, all the cilia of a cell beat simultaneously. They do so in rapid succession one after the other in case of metachronic rhythm. It occurs in ciliates (e.g., Paramecium).

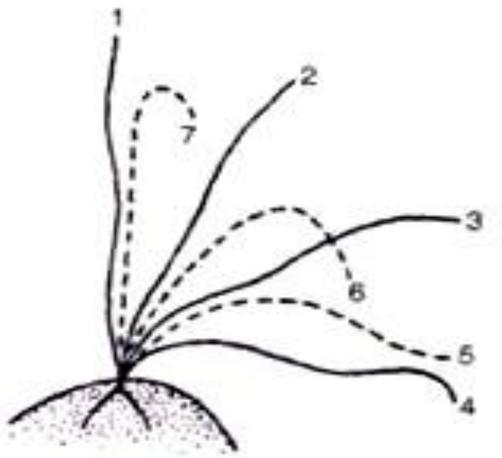


Fig. 2.23. Beating of a flagellum.

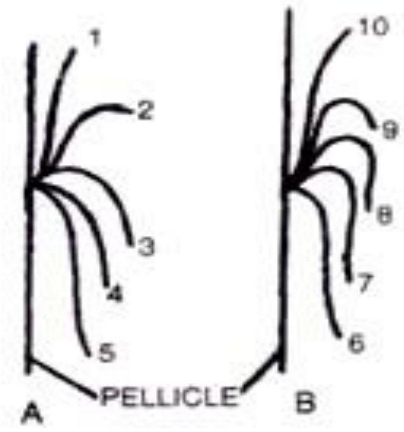


Fig. 2.24. Movement of a cilium. A, Effective stroke; B, Recovery stroke.

Mode # 4. Wriggling Locomotion: OR EUGLENOID

It is slow worm-like movement which is performed with the help of a wave of contraction and expansion in the body, e.g., sporozoans, no flagellates, euglenoids. Euglena sometimes shows a very peculiar slow wriggling movements. A peristaltic wave of contraction and expansion passes over the entire body from the anterior to the posterior end and the animal moves forward. The body becomes shorter and wider first at the anterior end, then in the middle and later at the posterior end.

This type of movement is called euglenoid movement by which slow and limited movement occurs. Euglenoid movements are g

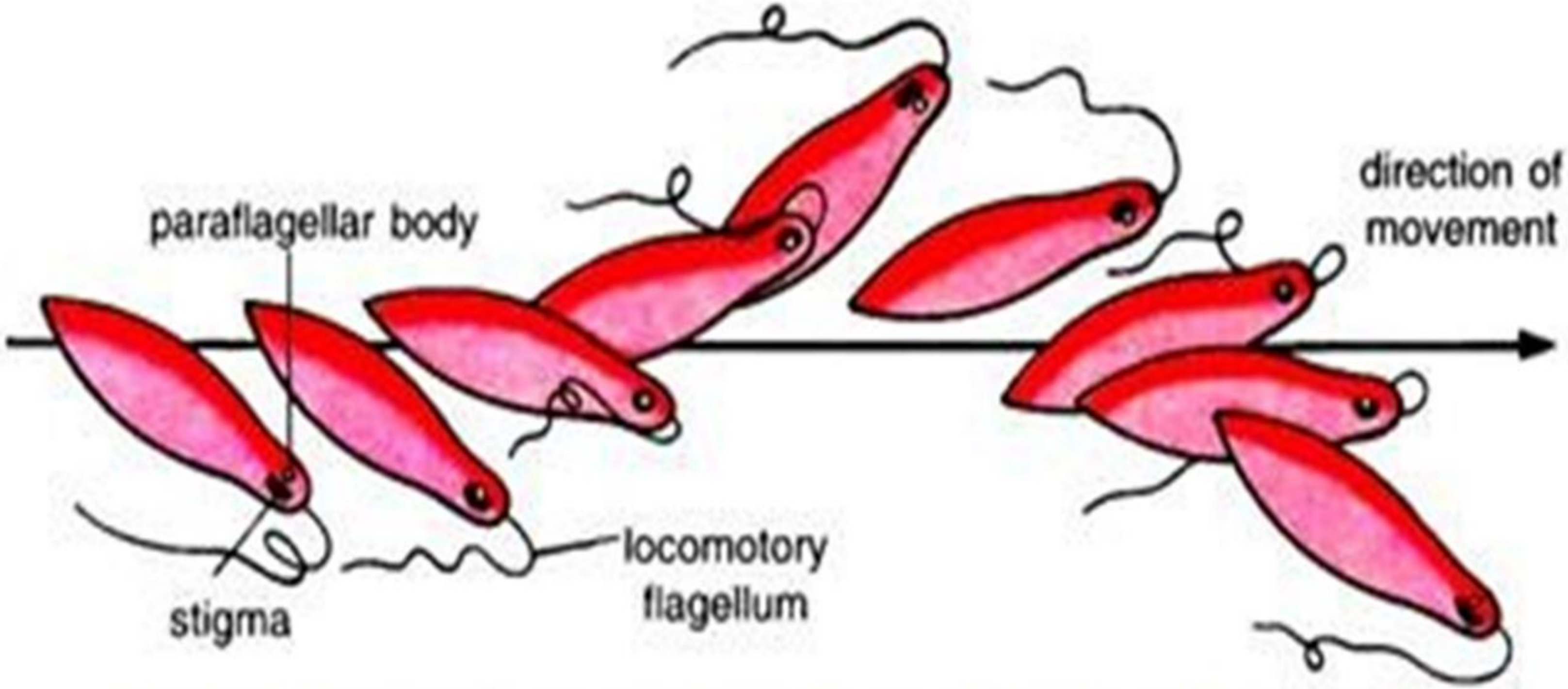


Fig. 12.6. *Euglena*. Successive stages in flagellar movement.

Mode # 5. Locomotion by Mucilage Propulsion:

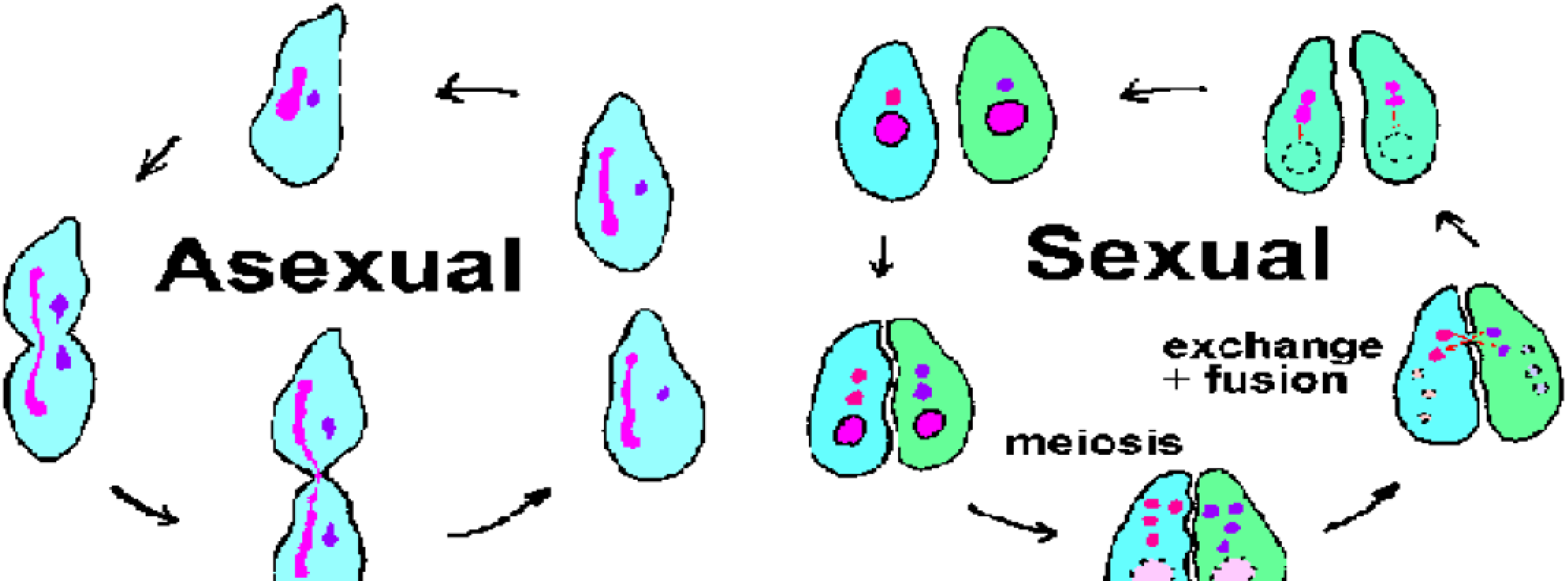
Some protists like diatoms do not have any organelles of locomotion. They can, however, move from one place to another through secretion of mucilage. This type of locomotion occurs in the direction opposite to that of mucilage secretion.

REPRODUCTION OF PROTISTA

- Protists are simple eukaryotes.
- They have short generation time and rapid rate of reproduction.
- A major aspect of Protist success is their great and variable range of reproductive strategies.
- Most Protists have been able to capitalize on the advantages of both asexual and sexual reproduction although some reproduce only asexually.

TYPES OF REPRODUCTION

- Mode of reproduction variable in different groups :
- I ASEXUAL REPRODUCTION
-



ASEXUAL REPROUCTION

- It involves the mitotic division of the parent body into two or more individuals that develop into the mature or adult form.
- Since these are unicellular it can simply be called a type of cell division.
- It involves a single parent.
- By definition it does not generate a new genotype.
- It does not involve meiosis or fertilization.

TYPES OF ASEXUAL REPRODUCTION

- It is of the following types:

1 Binary fission

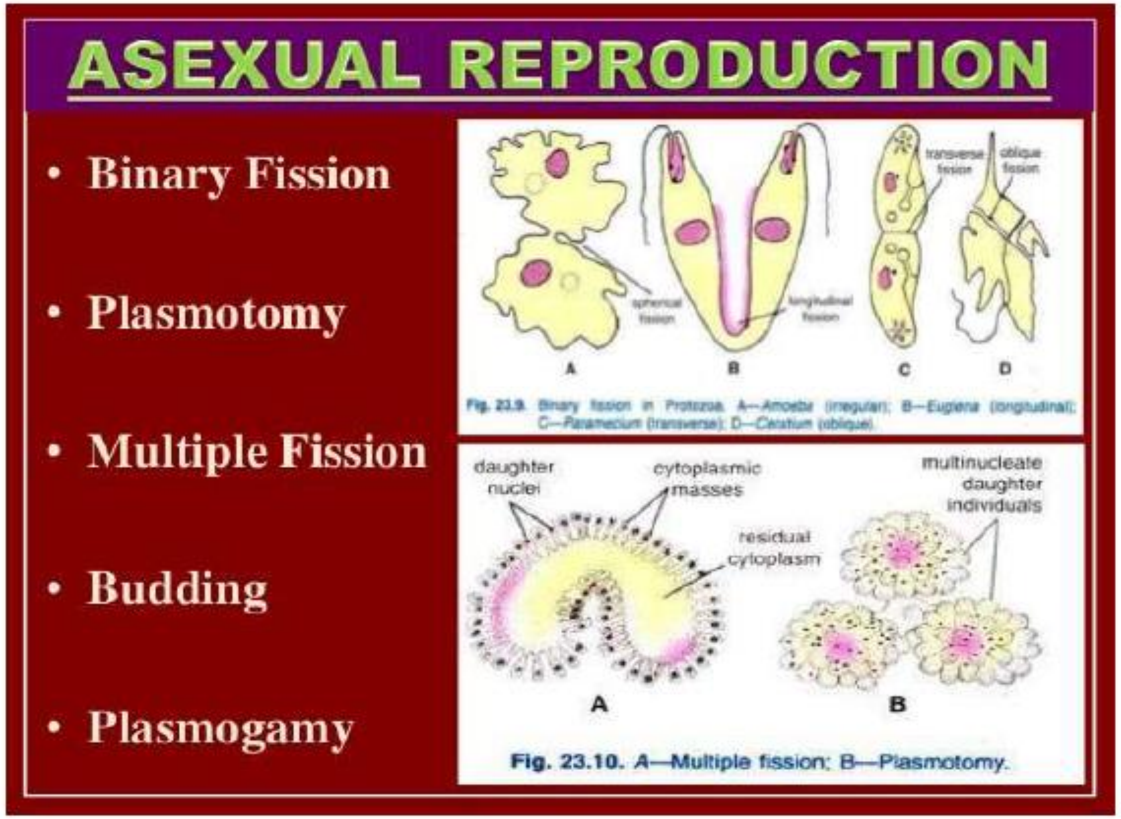
2 Multiple fission

3 Budding

4 Plasmotomy

5 Endopolyogeny

6 Regenration



BINARY FISSION

- It involves a single mitotic division resulting into two progenies.
- It results into two similar or equal progeny.
- It may be of the following types:

  i Simple binary fission

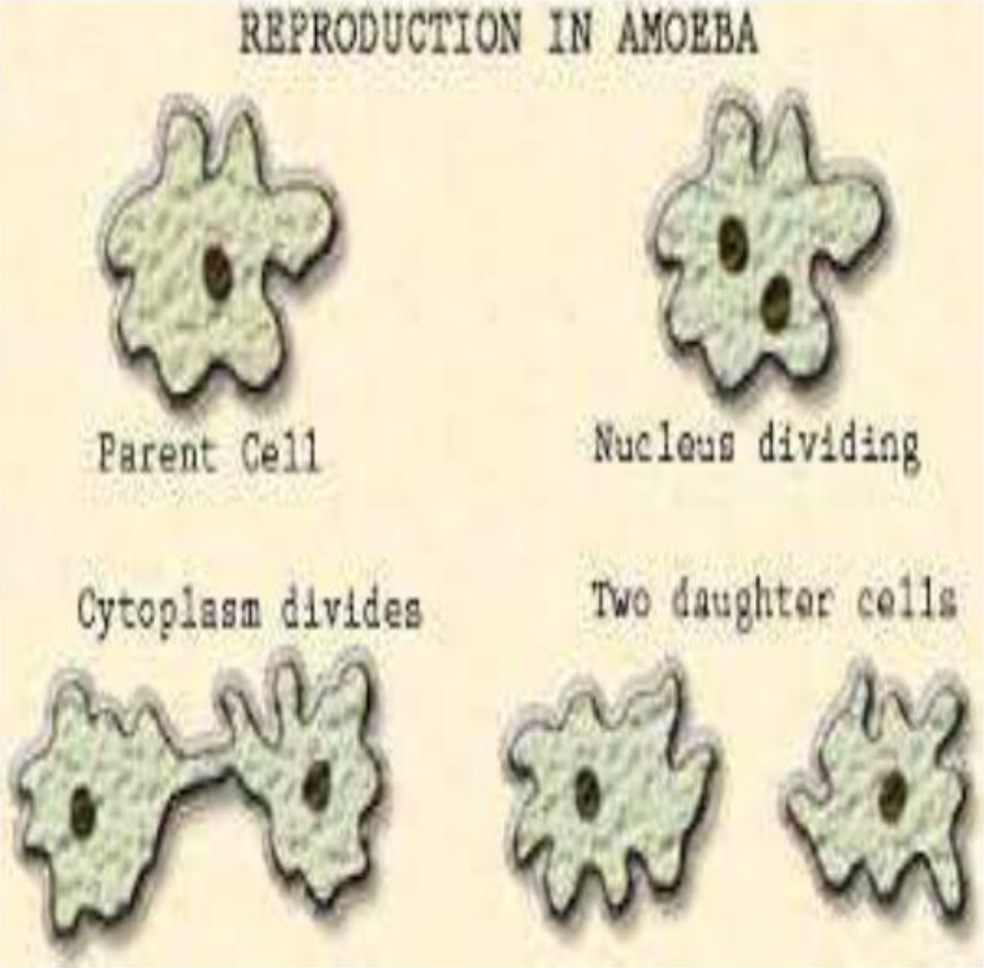
  ii Longitudinal binary fission

  iii Transverse binary fission

  iv Oblique binary fission

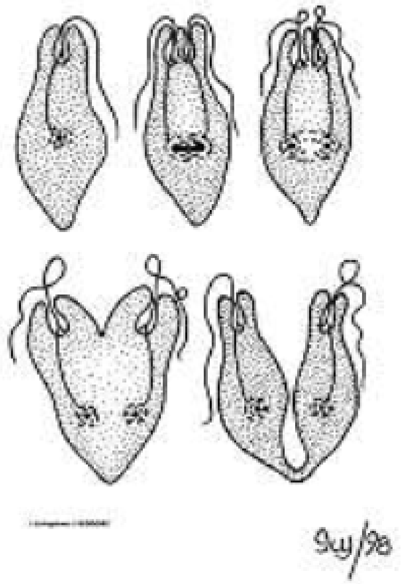
SIMPLE BINARY FISSION

- In this type of binary fission the plane of division can not be recognized *eg Amoeba*.
- Nuclear division is followed by cytokinesis.
- Nucleus divides by mitosis which is closed i.e. nuclear membrane remains intact throughout mitosis.



LONGITUDINAL BINARY FISSION

- In this the plane of axis of division is along the longitudinal axis of the body.
- It cuts between the rows of basal bodies.
- The progenies look similar to the parent except in size.
- *Eg- Euglena,Trypanosoma*



TRANSVERSE BINARY FISSION

- In this the plane of division is transverse i.e. cuts at the middle of the antero-posterior axis.
- In *Paramecium* only the micronucleus divides by mitosis.Macronucleus divides amitotically.

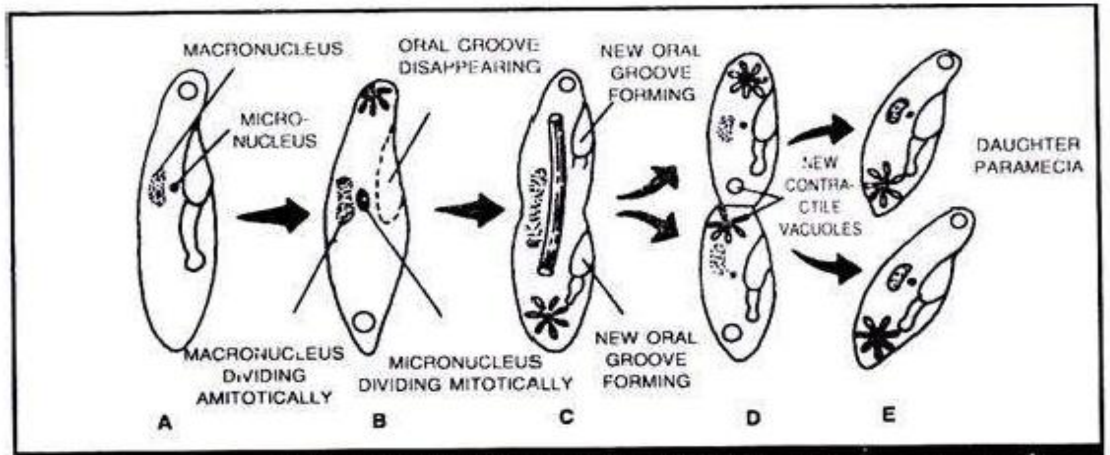
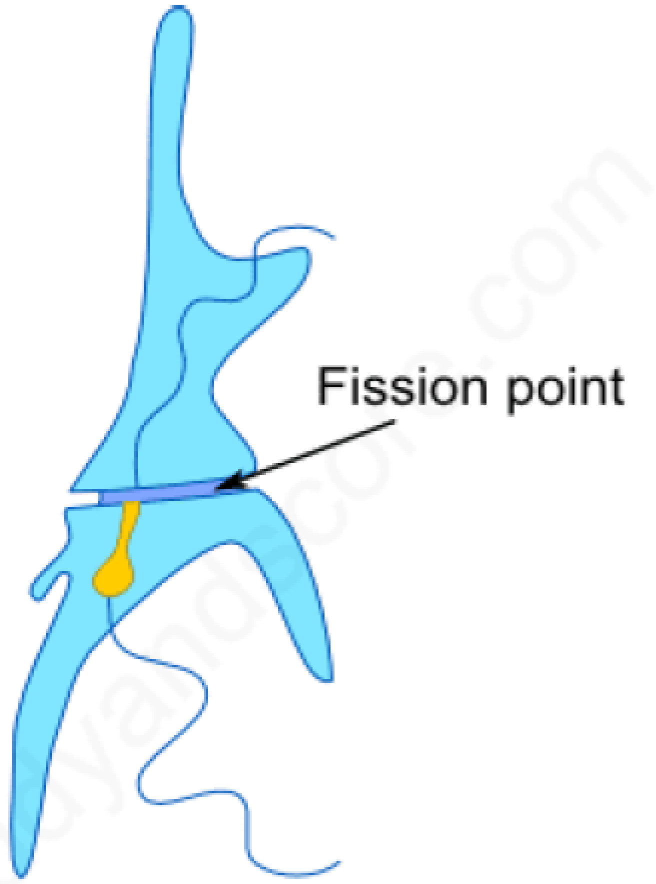


Fig. 3(A).2 *Paramecium*. Transverse binary fission

OBLIQUE BINARY FISSION

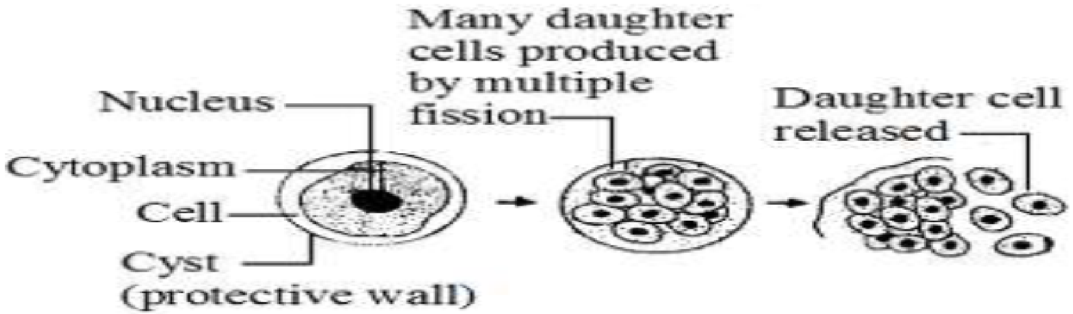
- In this the plane of division is oblique.
- Each one develops the missing part.
- Eg-*Ceratium*



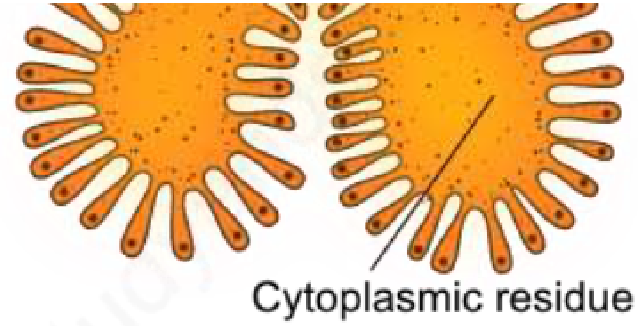
OBLIQUE BINARY FISSION
Eg: *Ceratium*

MULTIPLE FISSION

- In multiple fission,many nuclear divisions precede the rapid differentiation of the cytoplasm into many distinct uninucleate individuals.
- A mass of residual protoplasm may remain which is degenerated and lost.
- It may occur at certain phase in the life-cycle of a protist.
- It is common in *Plasmodium* (schizogony,sporogony), *Monocystis*(gamogony,sporogony),*E ntamoeba* (metacyst),*Aggregata* etc.



Multiple Fission in Plasmodium



MULTIPLE FISSION
Eg: *Aggregata*

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BUDDING

- It is a form of unequal fission.
- It involves a preparatory phase before division.s
- In this a portion of the parent breaks off and differentiates to form a new individual.
- It may be of two types:

  a.exogenous budding-occurs at the surface of the body;eg *Ephelota,Noctiluca* etc.

  b.endogenous budding-occurs within an internal chamber or pouch; eg- *Suctoria*

In budding a small outgrowth develops from the parent body which separates and develops into a new individual. Example: Arcella (a sarcodine)

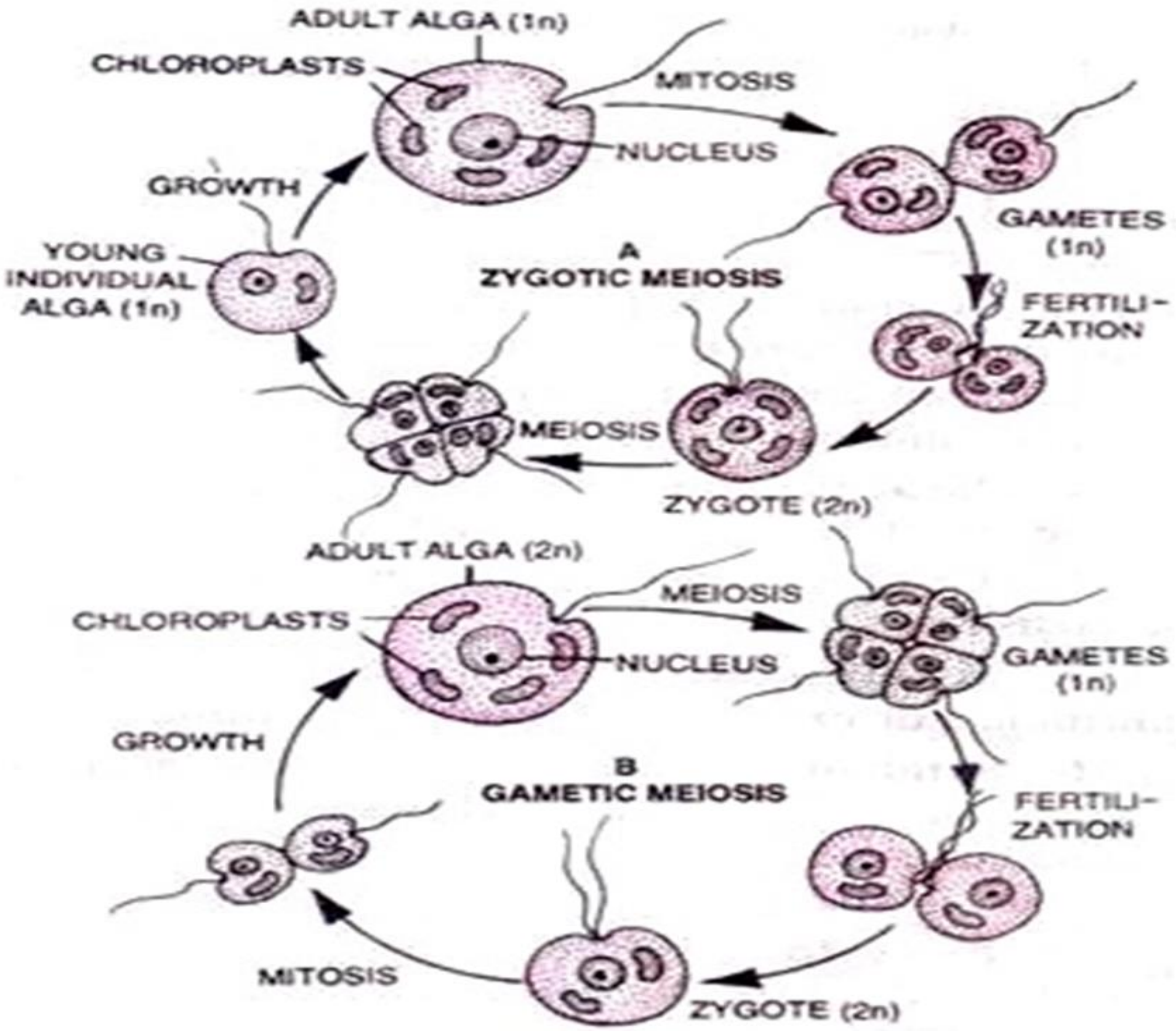
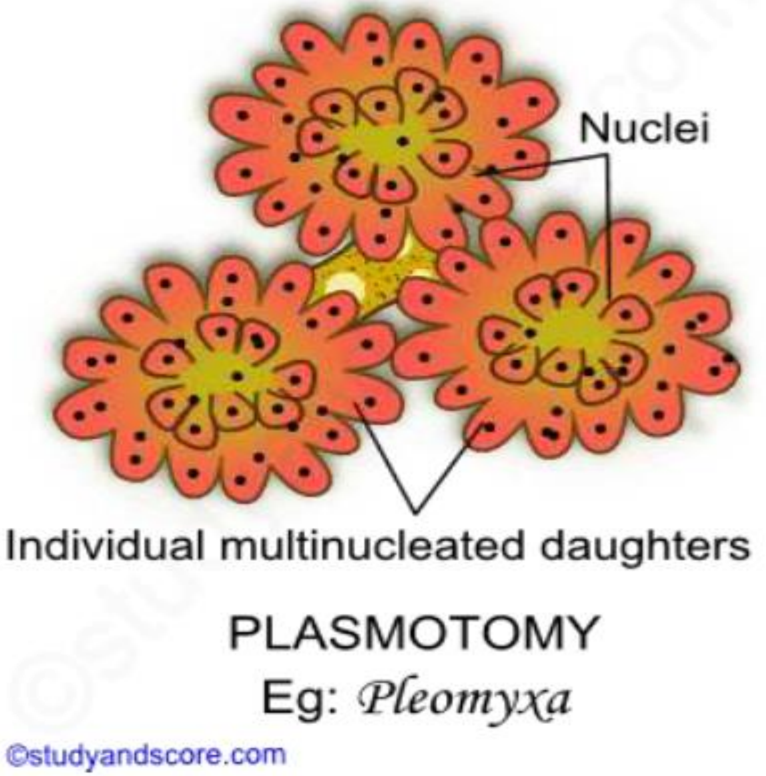


Fig. 2.25. A, Life cycle showing zygotic meiosis; B, Life cycle showing gametic meiosis.

PLASMOTOMY

- It is considered to be a form of budding.
- In the multinucleate Protists the parent simply divides into two multinucleate daughter individuals, in the absence of any mitotic division.
- The original nuclei are distributed between the two progeny.
- *Eg-Opalina ,Pleomyxa etc*



ENDOPOLYOGENY

- It is also considered to be a form of internal budding.
- In this more than two offsprings are formed within the parent organism.
- In this two or possibly more nuclear divisions occur before merozoite formation begins.
- Eg –*Toxoplasma gondii*

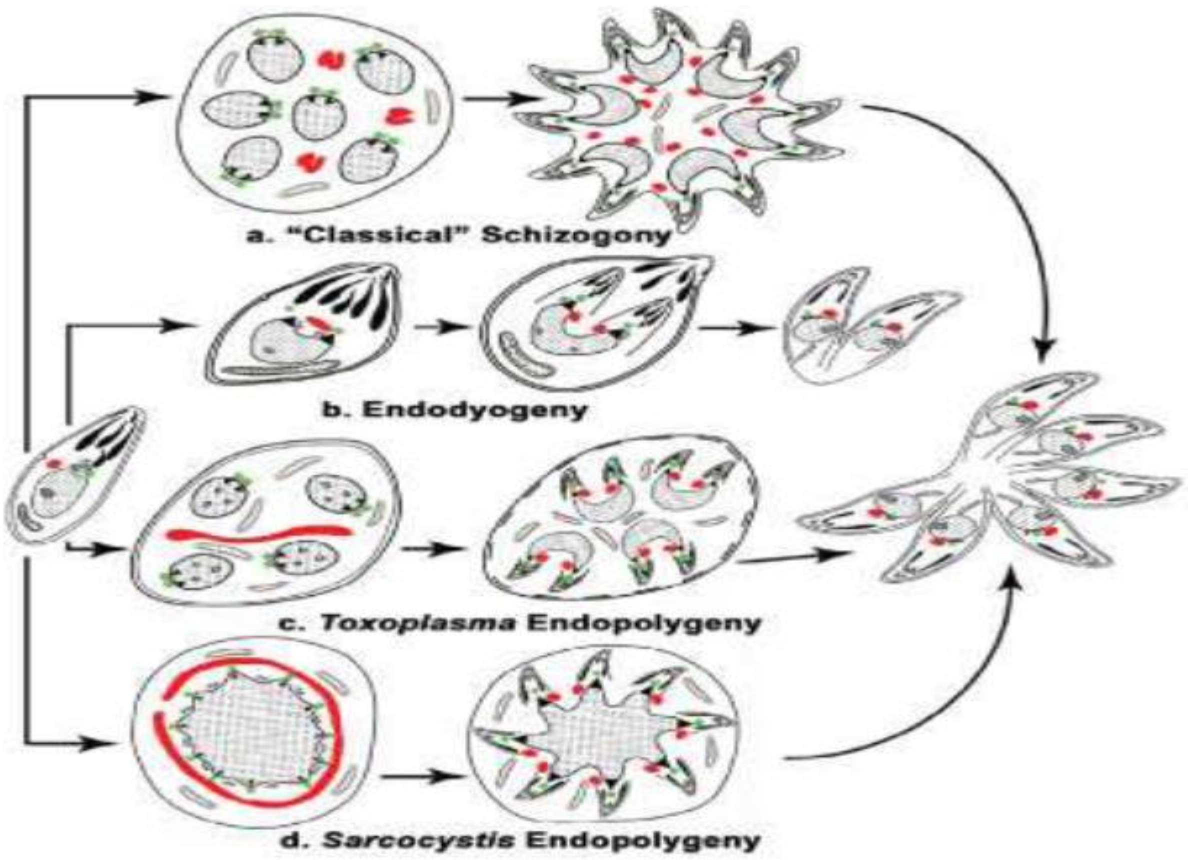
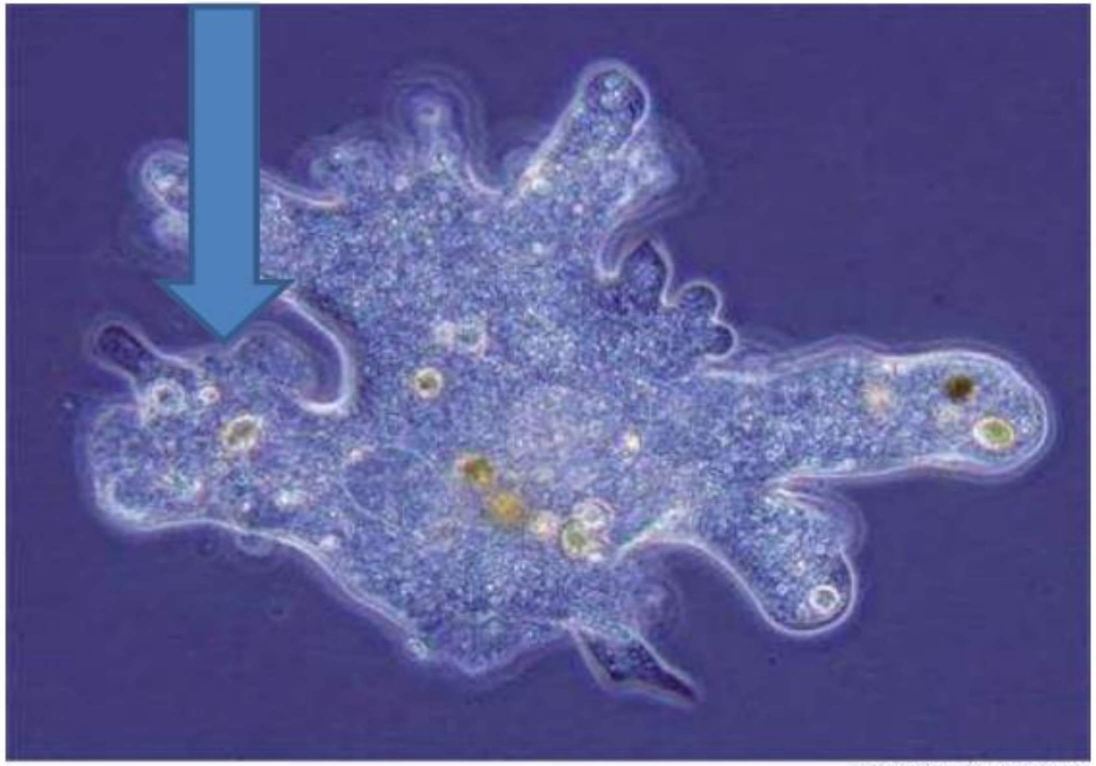


Fig. 6: diagram summarising the differences in timing of nuclear division and the location of daughter formation in the four forms of asexual proliferation undergone by apicomplexan parasites. The coccidian stages of *Toxoplasma gondii* employ *Toxoplasma* endopolygeny, while the tachyzoites and bradyzoites undergo endodyogeny (Ferguson et al. 2007, with permission).

REGENERATION

- It is the replacement of the lost parts of the body.
- It is also a specialized type of asexual reproduction.
- A specific part of the protoplasm and nucleus can regenerate the entire organism.
- Widespread among free living Protists such as *Amoeba.*
- Not so common in parasitic Protists.



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SEXUAL REPRODUCTION

- It is the production and fusion of male and female gametes to form a zygote which develops into the adult.
- But mostly it is a specialized case of nuclear exchange or reorganization in a unicellular eukaryote like protists.
- It involves **meiosis.**
- It may take place in between asexual reproduction

TYPES OF SEXUAL REPRODUCTION

In the Protists it is of the following type:

1.Syngamy
2.Conjugation
3.Autogamy
4.Endomixis
5.Hemixis
6.Cytogamy
7.Parthenogenesis

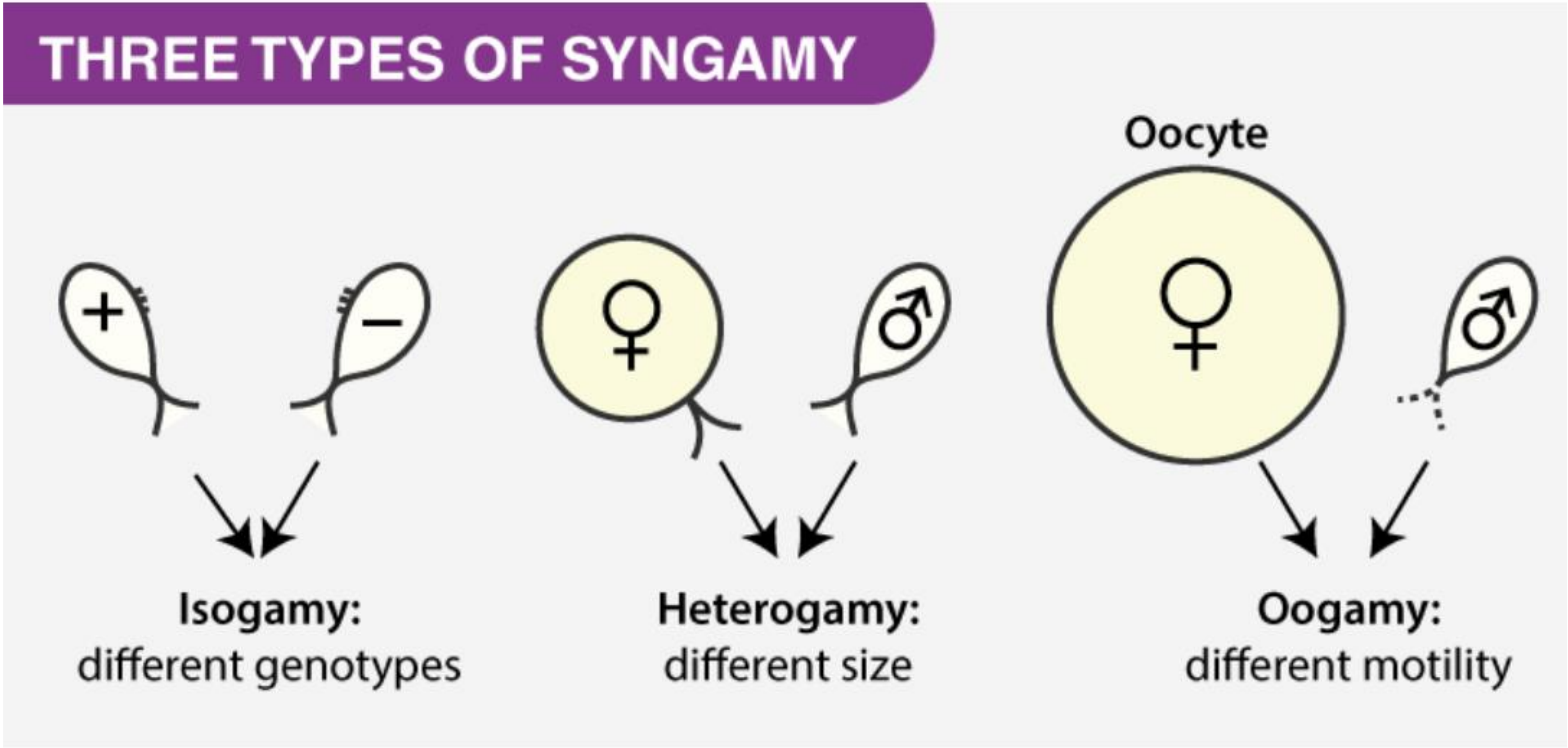
SYNGAMY

- It is the complete fusion of the whole individual which act as gamonts or gametes.
- Fused diploid nucleus is known as synkaryon.
- It may be of the following type:

HOLOGAMY-it is the fusion of two mature individuals which do not produce gametes.Seen in some rhizopods and flagellates;eg

PAEDOGAMY-it is the fusion of two young individuals which are not mature; eg

Sometimes ,fusion of similar gametes is called **isogamy** and fusion of dissimilar gametes is called **anisogamy.**



THREE TYPES OF SYNGAMY
Oocyte
+
−
♀
♂
♀
♂
Isogamy:
different genotypes
Heterogamy:
different size
Oogamy:
different motility

CONJUGATION

- It special type of sexual reproduction seen in *Paramecium caudatum which has one macronucleus and one micronucleus.*
- It involves two individuals of the same species but of two different mating strains.
- There is temporary union of the two individuals for about 24 to 48 hours and they are called conjugants.
- They unite ventrally and the pellicle fuses at the place of contact to form a cytoplasmic bridge
- Macronucleus degenerates and micronucleus undergoes changes in series.
- Micronucleus divides by meiosis to form four haploid daughter nuclei.
- Only one in each remain viable which divides by mitosis into two.
- One becomes large, stationary female pronucleus and the other becomes small, migratory male pronucleus.
- There is reciprocal exchange of micronuclei and its fusion with the macronucleus toss form the diploid zygote by this AMPHIMIXIS process.
- Each conjugant then separate.They are now called as exconjugants.

CONJUGATION contd.....

- In each exconjugant the zygotic nucleus divides by three quick mitotic divisions.
- Eight daughter nuclei are formed in each.
- Four in each grows big to form the macronuclei.
- Four remain small of which three degenerates in each.
- One micronucleus in each divide by mitosis followed by cytokinesis.
- Each daughter receives two macronuclei and one micronucleus.
- Micronucleus divides by mitosis followed by cytokinesis
- Thus four+four=eight small daughter *Paramecia* formed from the two exconjugants
- These grow to retain the adult form.

CONJUGATION: PROCESS

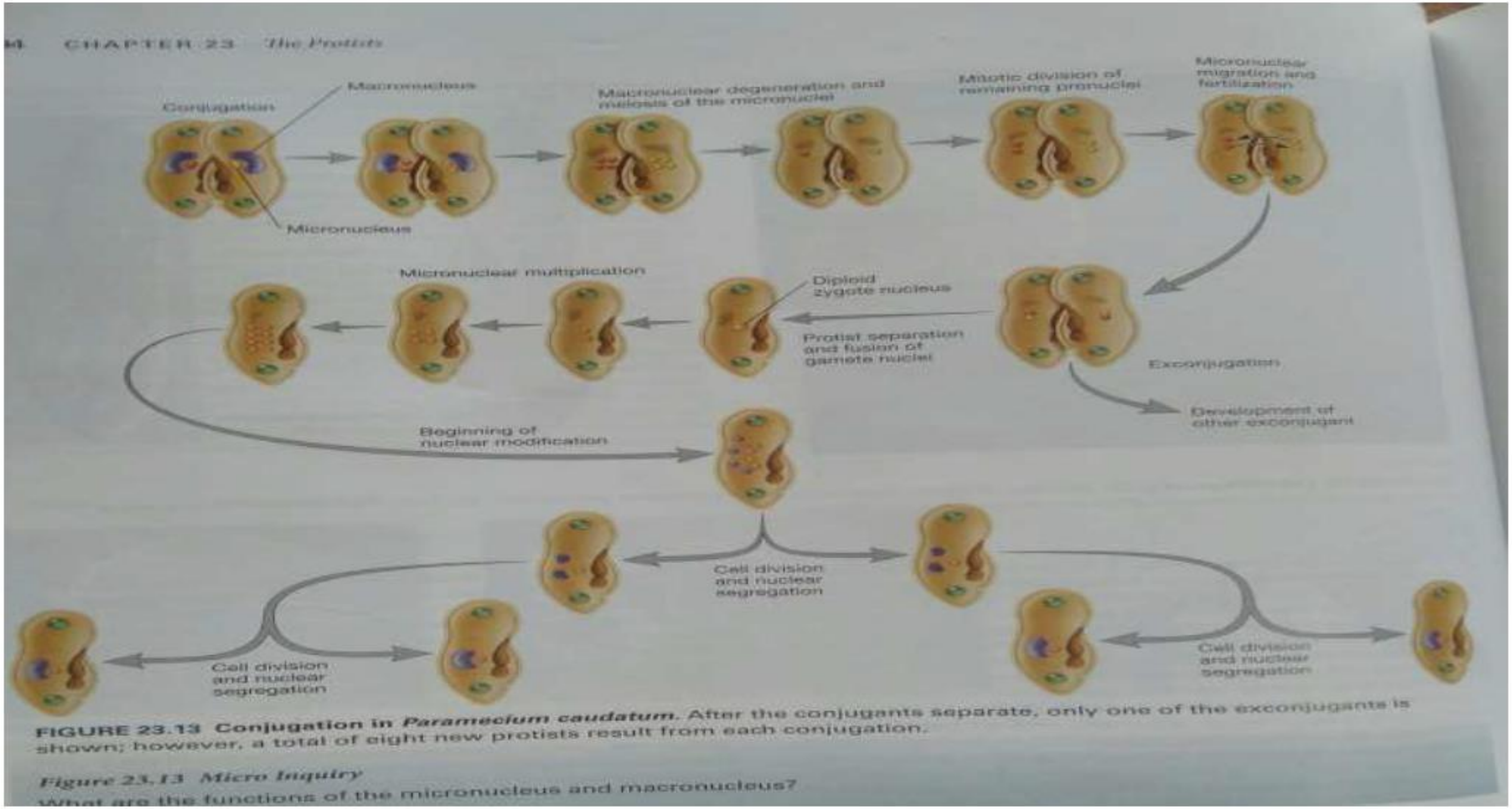


FIGURE 23.13 Conjugation in *Paramecium caudatum*. After the conjugants separate, only one of the exconjugants is shown; however, a total of eight new protists result from each conjugation.

Figure 23.13 Micro Inquiry
What are the functions of the micronucleus and macronucleus?

AUTOGAMY

- Described by Dilller in 1936.
- He called it as self fertilization.
- It takes place in ***Paramecium aurelia*** which has one macronucleus and **two** micronuclei.
- It involves only one individual.
- It always leads to homozygosity.
- It is a special type of nuclear reorganization.
- It takes place as follows:

 The macronucleus disintegrates.

 A temporary protoplasmic cone forms near the cytostome.

AUTOGAMY contd .....

both the micronuclei divide by **MEIOSIS** to produce eight daughter nuclei.

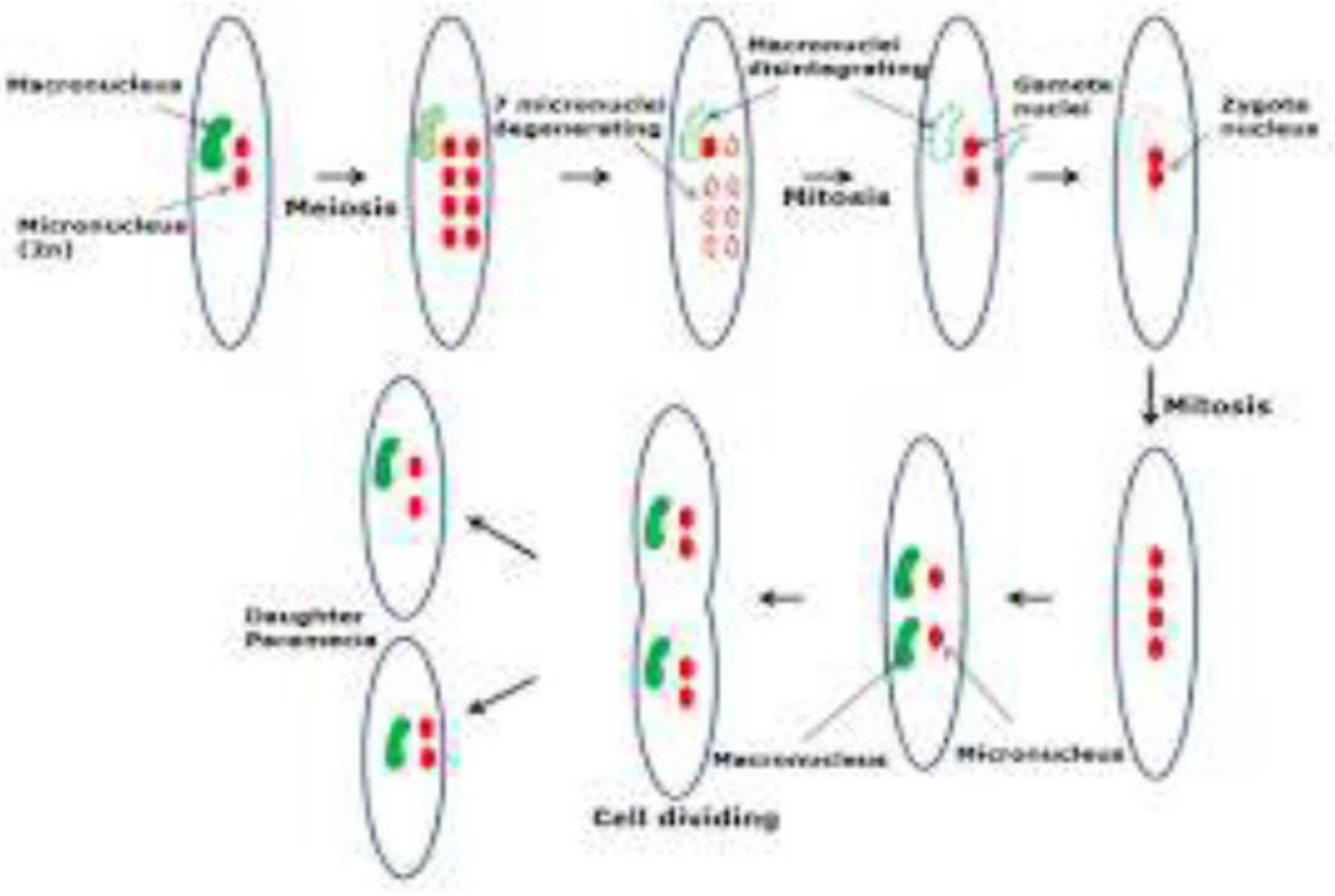
seven of these degenerate and only ONE remains which divide by **mitosis** to produce two gamete nuclei.

these two enter the protoplasmic cone and fuse to form the diploid zygote nucleus.

it divides by **TWO** quick **mitosi**s to produce FOUR daughter nuclei of which two become large (macronuclei) and two remain small(micronuclei).

The micronuclei divide by **mitosis** followed by cytokinesis to produce two *Paramecia* each with a macronucleus and two micronuclei.

PROCESS OF AUTOGAMY



ENDOMIXIS

- Described by Woodruff and Erdmann in 1914.
- Special method of nuclear reorganisation in Paramecium aurelia.
- It involves a single individual and is similar to autogamy or hemixis.
- Four daughter Paramecia are formed,each having one maconucleus and one micronucleus

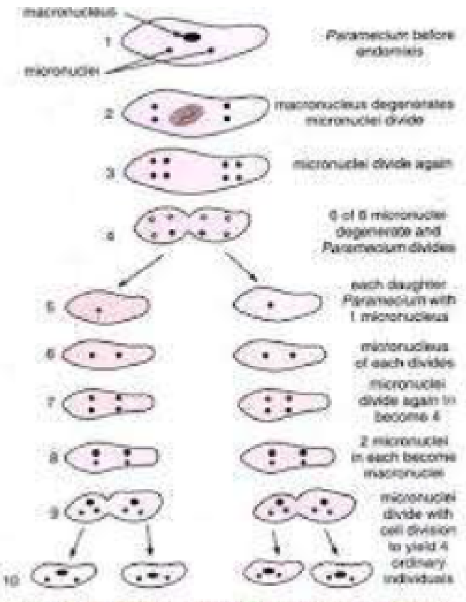


Fig. 20.22. *Paramecium aurelia*. Diagram showing nuclear changes during endomixis.

HEMIXIS

- Described by Diller in ***Paramecium aurelia***.
- Special type of nuclear reorganisation in **a single** individual.
- In this the macronucleus is rejuvenated.
- Macronucleus gives off chromatin balls which are supposed to consist of redundant or waste materials.
- Micronuclei divide normally.

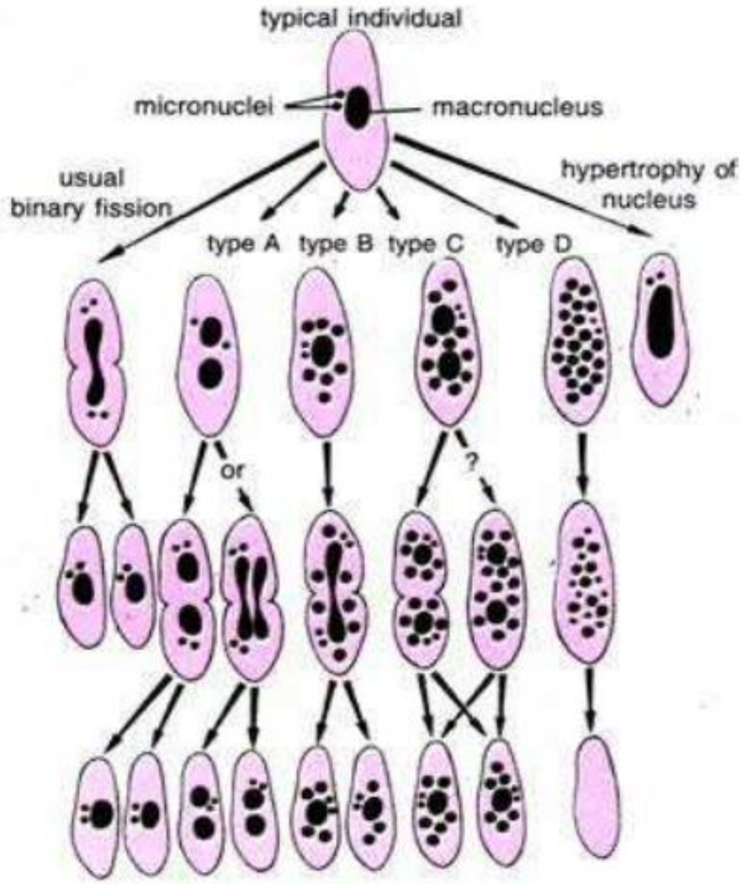


Fig. 20.24. *Paramecium aurelia*. Diagrams of the macronuclear behaviour during hemixis.

CYTOGAMY

- It was reported by Wichterman(1940) in the small strains of *Paramecium caudatum.*
- It involves **two** *Paramecia*
- The process is similar to conjugation but there is no exchange of gametes between the two.
- Instead , in each the two haploid gamete nuclei fuse to form a diploid synkaryon or zygote nucleus.

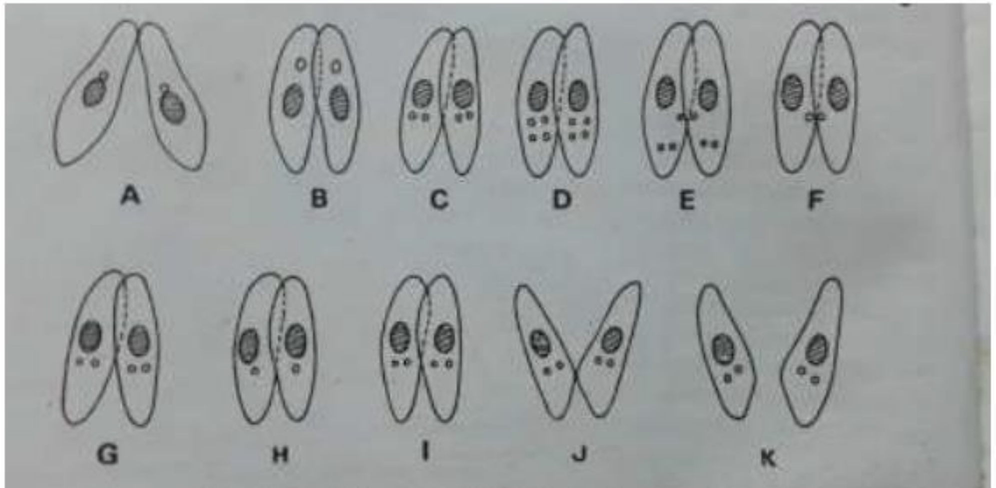
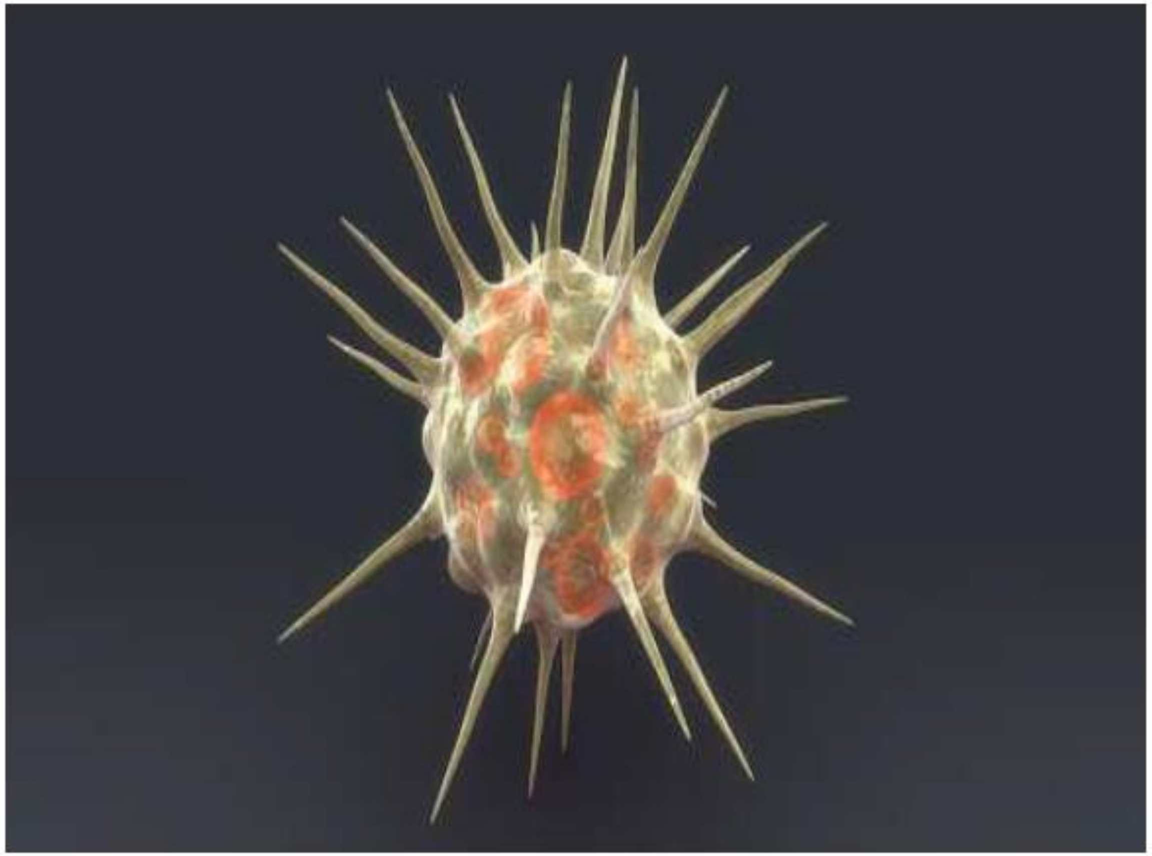


Fig. 8. *Paramecium caudatum*, stages in cytogamy.

PARTHENOGENESIS

- It takes place in certain Protists in which the gametes fail to fertilize.
- It is a special type of asexual reproduction.
- It is the production of offsprings from unfertilized eggs.
- Eg- *Actinophrys*



Symmetry is the arrangement of body parts in a balanced, geometrical design, divisible into equal halves by planes of division

EVOLUTION OF SYMMETRY AND SEGMENTATION OF METAZOA

The ability for locomotion has influenced the shape of the metazoan animals which in turn has conferred specific types of symmetries to metazoan groups.

Most of the metazoans show differentiation of the anterior end or head (cephalization); associated with cephalization, there is the centralization of the nervous system in the head region.

Although all metazoans share some characteristic features, their body plans differ in symmetry, internal organization, developmental patterns and modes of formation of, body cavity. These differences provide us a means of grouping them or organising them into different phyla.

SYMMETRY Arrangement of parts or organs on either side of an imaginary dividing line or around a common axis or radially around a point so that opposite parts are mirror images of one another is called symmetry. There are two broad divisions of symmetry, (i) primary, or embryonic (ii) secondary, or adult. .The latter may or may not be the same as the primary one. For example, the larva of starfish is bilaterally symmetry but the adult starfish is radially symmetrical. The primary symmetry is bilateral and secondary symmetry is radial. With regard to symmetry animals can be basically of fivetypes (i) asymmetrical (ii) spherical (iii) bilateral (iv) radial and (v) biradial

1.Asymmetrical

Some creatures are asymmetrical : no matter which way we try to divide them through the middle, no two halves would appear alike . In simpler words : these are animals which cannot be cut into two identical halves through any plane or axis (longitudinal, sagittal or transverse), Amoeba and most of the poriferens are examples.

2.Spherical

At the other extreme, is spherical symmetry. The animals with spherical symmetry can be divided into identical halves along a number of planes which pass through the centre or in other words every plane through the centre will yield two halves which arc mirror images of each other. This type of symmetry is found chiefly in some protozoa and is rare in other groups of animals. Actinophrys and colonial Volvox are typical .

3. Radial

Radial symmetry is the symmetry in which the parts are so arranged akound a central axis or shaft, like the spokes of a wheel, that any verticaI cut through the axis would divide the whole animal into two identical halves

The common jelly fish and hydra

(cnidaria) - exhibit radial symmetry . The starfish and their relatives have a modified form of radial symmetry. They cah be divided along 5 planes, each giving two distinct halves. This is known as pentermerous symmetry. One side of the body has the mouth and is known as the oral surface; the opposite side is aboral. Cuts

made along the oral-aboral axis will result in identical halves.

4.Biradial symmetry is a variant of this and it is found in sea anemones and ctenophores.

Though the animal appears to be radially symmetrical, it can be divided only into two equal halves along two per-radial positions - along the tenticular plane and along the sagittal plane at right angles to it.

Radial and biradial animals are usually sessile, floating freely or weak swimmers. These animals are called the Radiata.

5.Bilateral

Bilaterally symmetrical animals have the major axis running from head (anterior) to tail(posterior). They have a ventral (lower) and dorsal (upper) surface that are different from each other. They have only two sides that look alike, the right and left. The animal can be divided into just two identical halves through a plane which passes from anterior to posterior end.

Almost all animals including human beings except for sponges, ctenophores and cnidarians show bilateral symmetry. Adult echinoderms, though radially symmetrical (pentamerous) have larvae that are bilateral. This is because they have evolved from bilaterally symmetrical ancestors. In general,bilateral animals that adopt a sessile existence commonly exhibit a shift towards radial symmetry. The shift may be slight as in acorn barnacles where only protective circular wall plates are arranged radially or the shift may be profol~nd as in the case of sea stars or starfishes.Bilateral animals are called Bilateria.

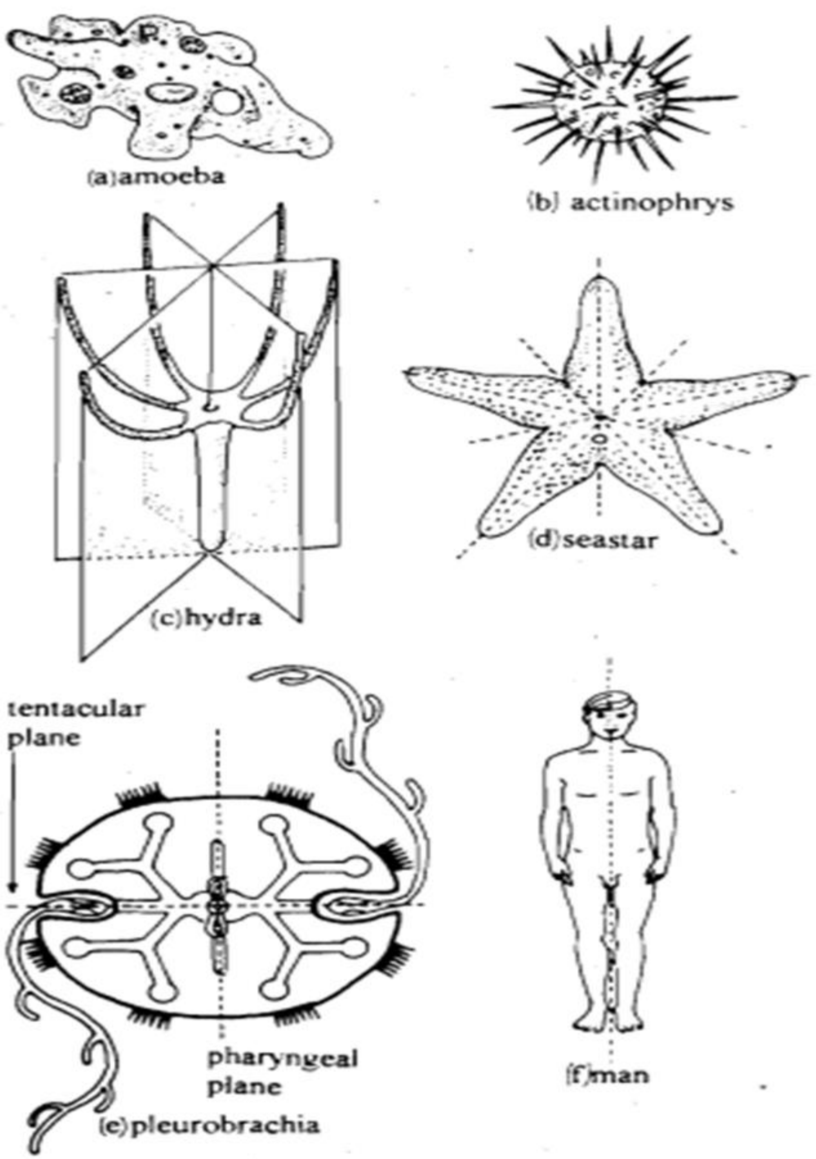


Fig. 3.7: Different types of body symmetries a) asymmetrical b) spherically symmetrical, (c-d) radially symmetrical. (e) biradially symmetrical (f) bilaterally symmetrical.

Origin of Metazoa; Metamerism & Symmetry

colonial hypothesis of metazoan origin.

The colonial theory or flagellate theory is the classic & still most widely acceptable theory of the origin of metazoans.

This theory was 1st put forward by Haeckel (1874), later modified by Metschnikoff (1886) & revived by Hyman (1940).

Proposition:-

Colonial theory holds that multicellular animals came about through association of many unicellular flagellates, forming a colony.

With increase in the no. of individual cells, they became more & more specialized in structure & functions.

Soon, individuality in the cells was lost & the whole colony itself became a single multicellular individual or a metazoan.

Criticism:-

According to Colonial theory, the metazoan ancestors were Volvox like phytoflagellates. But these are plant like organisms have cell walls, chlorophyll etc. The theory doesn't explain how these plant characters were lost in metazoan ancestors during the course of evolution.

The flagellate protozoan colonies are of several types such as linear, spherical, tree like, plate like & solid as well as hollow. Of these, which type gave rise to the ancestral Metazoa, has been a subject of great speculation.

cyclomerism theory of the origin of metamerism.

The cyclomerism theory was originally proposed by Sedgwick (1884) & greatly supported by Remane (1950, 1963).
This theory assumes that coelom originated in some ancestral radiate actinozoan coelenterate, through the separation of 4 gastric or enterocoelic pouches from the central digestive cavity or gut.
Division of 2 pouches resulted into 3 pairs of coelomic cavities- protocoel, mesocoel & metacoel in the protocoelomate or ancestral coelomate.
Loss of protocoel & mesocoel led to the unsegmented coelomates such as molluscs.
Later subdivision of metacoel produced primary segments leading to the segmented annelids.
The phylogenetic implication of this theory is that all bilateral metazoans were originally segmented & coelomate & the acoelomate groups (flatworms, nemerteans) have lost these characters secondarily.

How does the segmentation of an annelid worm differ from the repeating units of the body of a tapeworm?

The segmentation of annelids is called true segmentation or metamerism whereas the repeating body units of a tape worm represents pseudometamerism.

In annelids the no. of segments is generally constant for each species while the no. of body segments in a tapeworm is not fixed as new segments are continuously added throughout life.

In an annelid growth occurs due to simple elongation of pre existing segments whereas in a tapeworm growth occurs due to addition of new segments from a region of proliferation, just behind the scolex.

All segments are of the same age & at the same stage of development in an annelid while the proglottids of a tapeworm differ from one another in age & in the stage of development.

In an annelid the body segments are functionally interdependent & integrated whereas segments or proglottids of a tapeworm are independent & self contained units each having a full set of sex organs & a portion of excretory & nervous systems.

Open in

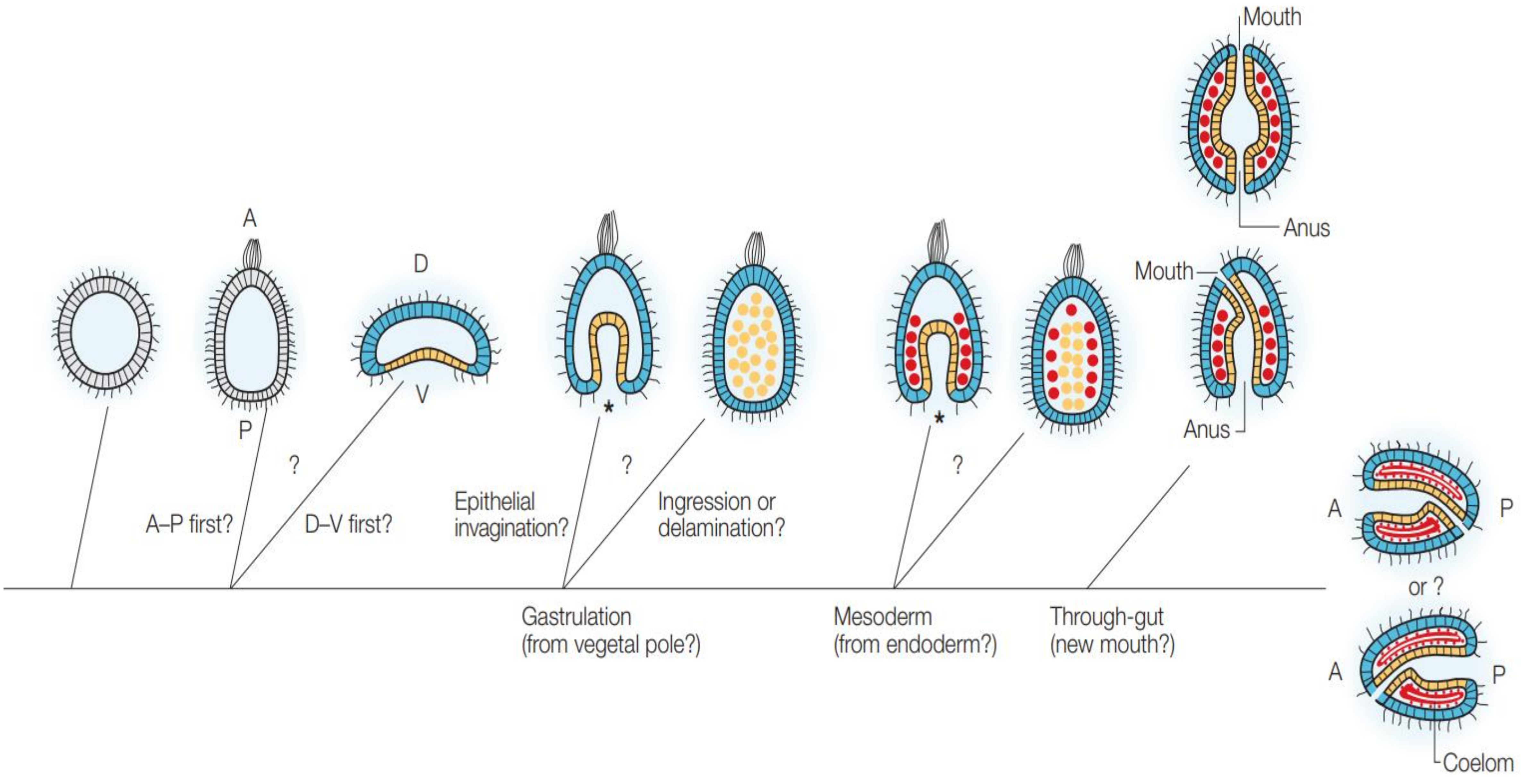

Mouth
Anus
A
D
Mouth
P
V
Anus
?
?
?
A–P first?
D–V first?
Epithelial
invagination?
Ingression or
delamination?
A
P
or ?
A
P
Gastrulation
(from vegetal pole?)
Mesoderm
(from endoderm?)
Through-gut
(new mouth?)
Coelom

**Figure 1 | How did the metazoan body plan evolve? The figure shows one of several evolutionary scenarios9
for how the body plan evolved in the plankton46. Like most theories on this topic, this one proposes that the increase in body-plan complexity that occurred over evolutionary time is loosely based on the developmental stages of metazoan embryogenesis.
A simple, hollow, ciliated ball of cells (left) is transformed by gastrulation into a multilayered embryo that consists of an outer ectodermal layer of cells (blue) that surrounds an internal endodermal layer (the gut, yellow). Gastrulation might occur by epithelial invagination or by individual cells INGRESSING OR DELAMINATING by a process of epithelial–mesenchymal transitions.
Note that these models have implications for the origins of axial properties — that is, the transition from radial symmetry to
bilateral symmetry, and the development of anterior–posterior (A–P) and dorso–ventral (D–V) axes — and for the relationship of
landmarks, such as the site of gastrulation (*), to the mouth or anus of modern-day animals. For example**

in this hypothetical model, the site of gastrulation corresponds to the posterior end of modern bilaterian animals and a new mouth opens on the ventral side, anteriorly.

(Recent work in anthozaon cnidarians (a basal metazoan; see main text) contests this proposal40, and
argues that the site of gastrulation corresponds to the oral pole of bilaterians.)

A suite of 'gastrulation-specific' genes would respond to the axial asymmetries that are set up during early embryogenesis, and generate new germ layers (in this case mesoderm, red) and their novel cell types.

It is assumed that muscle (red circles) was the first form of mesoderm to appear and was followed by coelomic mesoderm.

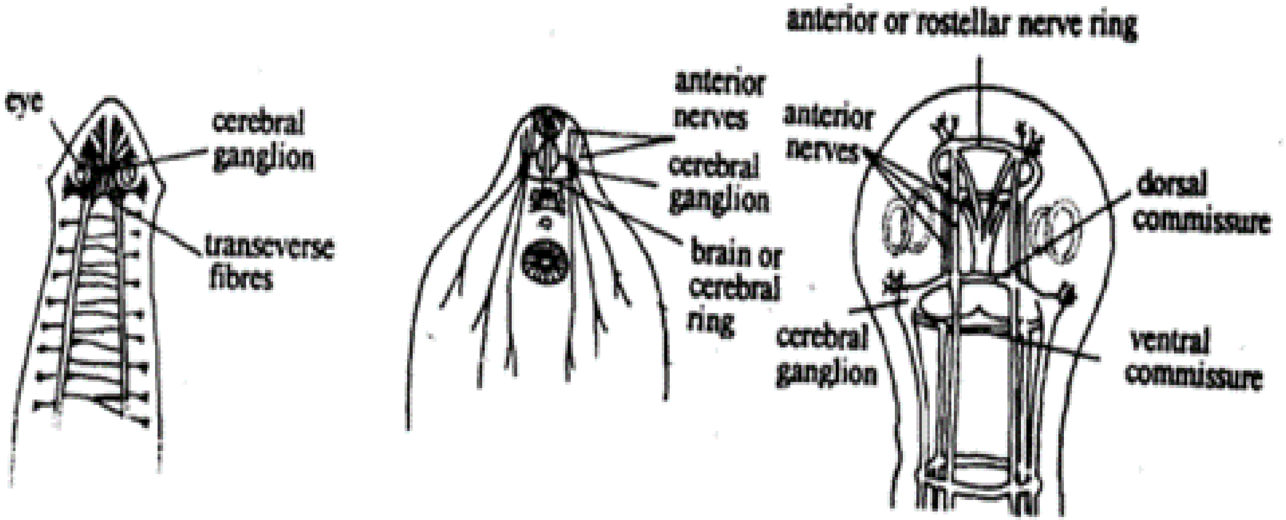
CEPHALISATION AND SEGMENTATION

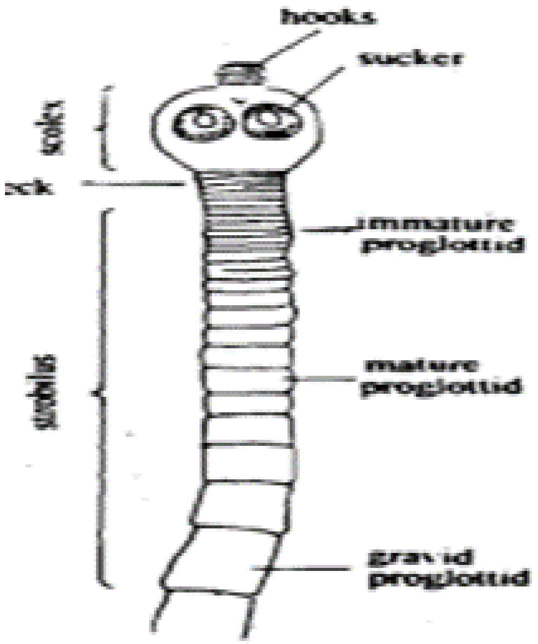
Bilateral animals when creeping or swimming, have a tendency to keep the same end of the body forward and the same surface down towards the substratum. In such a case the sensory organs and nervous system would also have a tendency to be concentrated at the anterior end. This differentiation of a 'head end' is known as cephalisation'(literal l y head development). Cephalisation has evolved to various degrees in bilateral animals.

The mouth is usually located at the leading end with which become associated the organs for food capture, as the sensory organs on the head can detect food. Neurons become organised into brain in this region for rapid coordination; longitudinal nerve cords'are developed for rapid transmission of information throughout the length of

Segmentation or metamerism is the division of the body into smaller transverse compartments along the anterior-posterior axis. Segmentation is widespread among animals, with true segmentation occurring in annelids, arthropods and most chordates though some other groups show supeificiill segmentation of ectodcrmal body wall.

body. Cephalisation in its most primitive form can be seen in Platyhelminthes (Fig. 3.14).





g. 3.15: Superficial segmentation seem in tape-worms.

SUMMARY

The term Metazoa does not have currently any formal biological status, but is still used to refer to the organisms included in kingdom Animalia of the Five - Kingdom Classification. Increasing complexity of organisms is an evident feature in animal phylogeny. Thus we see that protoplasmic level of body organisation foundin protozoans is simplest. Cellular level is found in sponges (Porifera). The cnidarians and ctenophores have attained tissue level of organisation and some of them even have organs, while the rest of the animals i.e., from platyhelminthes to mammals have the highest evolved organ syslkn level of body organisation. Metazoans are characterised by a complex multicellular structural organisation. They are heterotrophic sexually reproducing diploid organisms. Many of them reproduce asexually too. Their embryos undergo progressive stages ~f growth anddevelopment.

Animals have a basic body plan which is described in terms of symmetry based on which they can be identified as asymmetrical, spherically symmetrical, radially, biradially and bilaterally symmetrical. The distinction is based on, along how many planes the animal can be divided into to get equal halves: none (asymmetrical), many (spherical and radial), one (bilateral), and two (biradial). In Platyhelminthes, the space between the body wall and the gut is filled with mesodermal parenchymal cells; it has no body cavity. Animals above the level of Platyhelminthes have body cavity.

The body cavity can be of two types: pseudocoel and true coelom. Pseudocoel is a remanant of the blastocoel, and is not lined with coelomic epithelium. It is found in nematodes.

Two quite different patterns of cleavage are recognised among'animals that show a fundamental division in their evolution. Protostome embryos typically show spiral cleavage with what is called mosaic development and deuterostome embryos show radial cleavage with regulative embryonic development. The animals are basically either diploblastic i.e.. made up of two germ layers viz.ecto and endoderm (e.g., poriferans and cnidarians) or are triploblastic i.e., made up of three germ layers viz., ecto, endo and mesoderm (e.g., Platyhelminthes to

mammals). The various structures of the whole body are derived from thebe three fundamental germ layers which can only be seen in embryonic conditions.

Cephalisation with concentration of sense organs and nervous tissues at the head region is characteristic of bilateral animals. It distinguishes an anterio-posterior axis in the animal's body. Segmentation or metamerism in bilateral animals provides a framework for specialization of body regions for different functions. True segmentation is found in annelids, arthropods and chordates. Multicellular metazoans have arisen from unicellular organisms. Three theories havebeen suggested to explain their evolution; a) syncytial theory; b) colonial theory;

c) polyphyletic theory.

It is generally accepted by most zoologists that metazoans have originated from colonial choanoflagellates. The hypothelical ancestral metazoan was probably a planula like organism. Which gave rise to the sponges as a separate branch. The cnidarians and ctenopleores are probably the most primative metazoans. These form the Radiata while the Platyhelminthes and all other higher groups that have evolvedfrom the flatworms form the Bilateria.

THANK YOU