

Chapter 3

Kingdom Protozoa

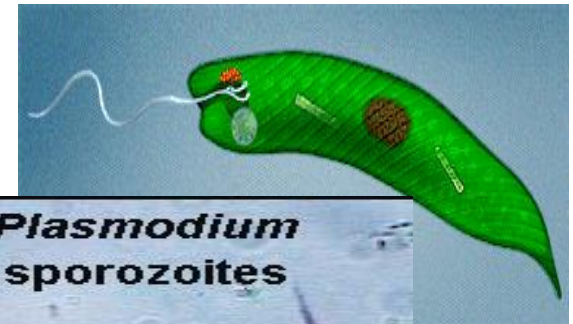
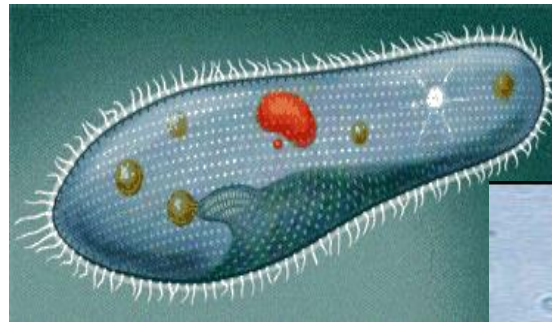
The Protozoans

(الحيوانات الأولية)

Protozoan: (Latin) = Proto: the very first
Zoa : animals

► Defining Characteristics:

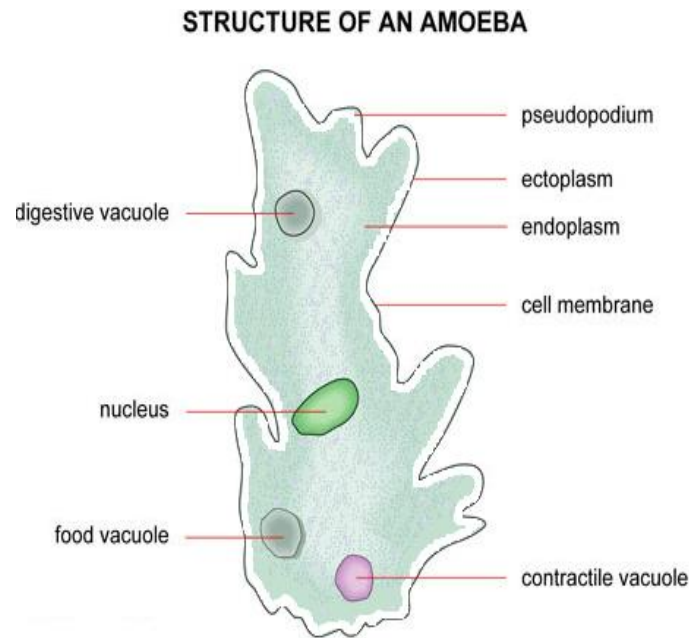
- – All are unicellular and eukaryotic lacking collagen and chitinous cell walls.
- – All are non-photosynthetic (Heterotrophic)



- ▶ Includes about **30,000 extant species** (+ 44,000 extinct)
- ▶ **Ancestors of animals** (flagellated protozoons).
- ▶ Most protozoans are **microscopic** (*5–250 μm long*).
- ▶ They are important as **primary producers, decomposes, causes of diseases, food for other invertebrates ... etc.**
- ▶ Discovered اكتشافه by **Leeuwenhoek** (16



- ▶ They occur where there is **moisture**. (تحدث حيث توجد الرطوبة).
- ▶ The body of protozoans is bound by a **cell membrane**.
- ▶ Cytoplasm is like that in higher organisms except that it has **2 regions**: ectoplasm and endoplasm.

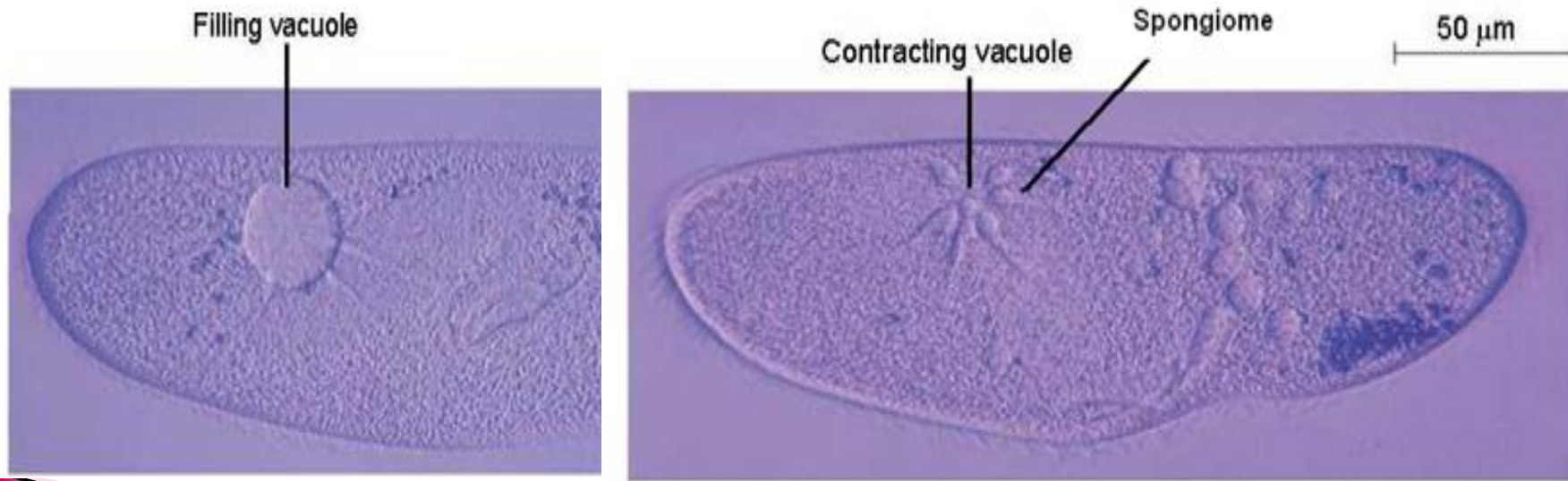


- ▶ Many protozoan are **colonial**.
- ▶ One organism divides **asexually** to form a **colony of attached, genetically identical** individuals.
- This forms the start of **multicellular life**.
- ▶ Have **all organelles** of cells of higher organisms.
- ▶ In addition, they have organelles that are not found among metazoans e.g. **contractile vacuoles, trichocysts** and **toxicysts**.



► Contractile vacuoles:

- Expel excess amounts of water from cytoplasm.
- Fluid is collected by a system of vesicles & tubules called **spongiome**.

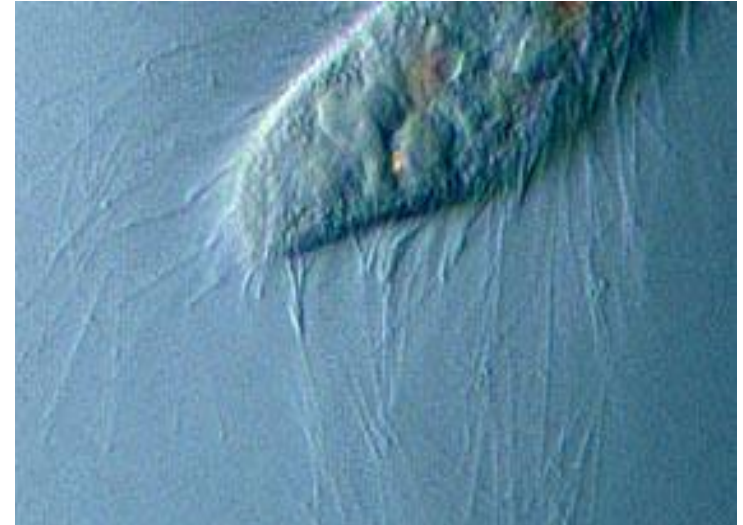


- ▶ Contractile vacuoles are common in **freshwater protozoans**.
- ▶ They function in **volume & osmotic regulation**.
- ▶ Fill & discharge **several times/ min**.
- ▶ One individual might have **several vacuoles**.



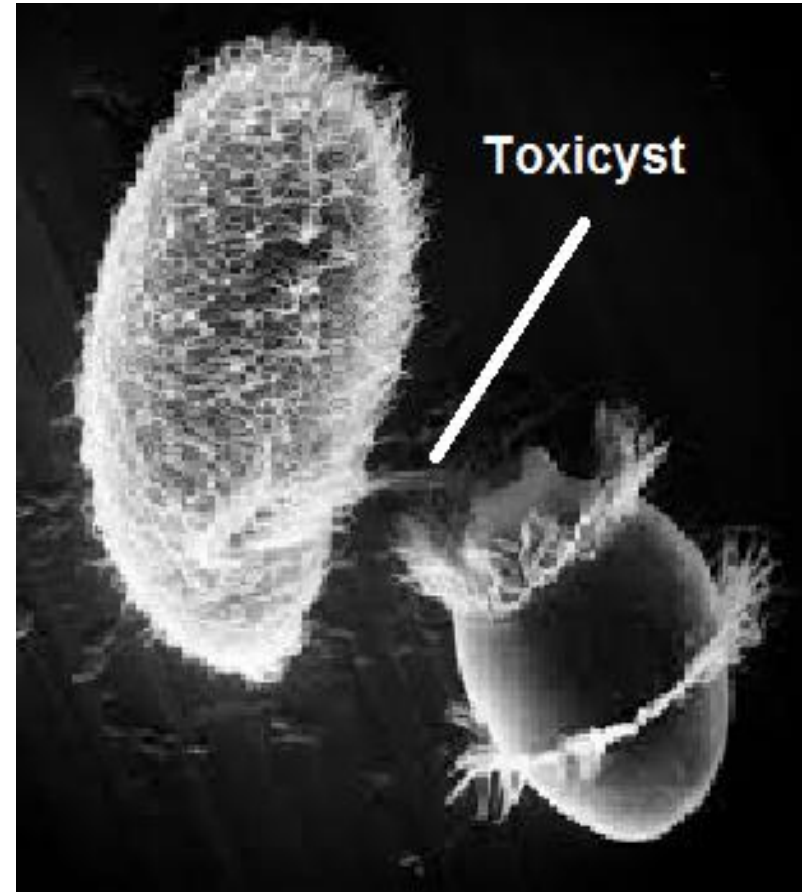
▶ Trichocysts:

- Develop within a **membrane-bound vesicle** inside the cytoplasm.
- They have **a long, thin filament** that can be **discharged very rapidly** by mechanical and/ or chemical stimuli. لديهم خيوط طويلة رفيعة يمكن تفريغها بسرعة كبيرة عن طريق المحفزات الميكانيكية و / أو الكيميائية.
- Functions: **defense & anchorage.**



► Toxicysts:

- Similar to trichocysts but they are **poisonous**.
- Involved in **predation**.
- They paralyze the prey & initiate digestion.



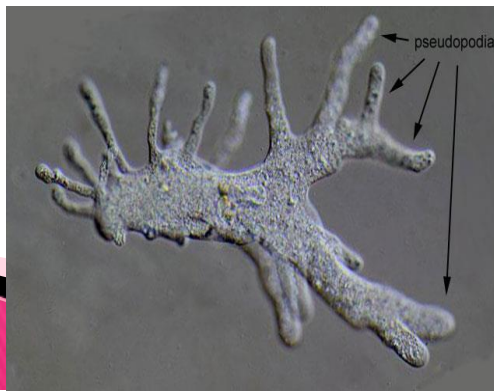
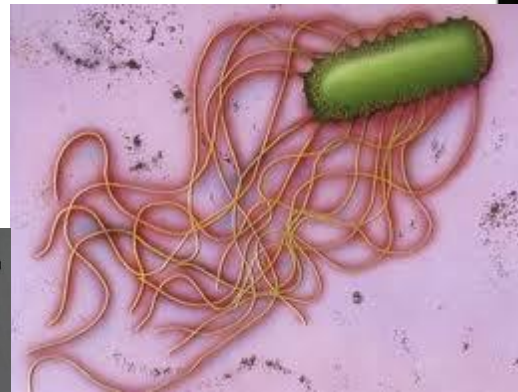
► Protozoan Locomotion:

- Most free living protozoa use one of the following locomotory organelles:

- Cilia

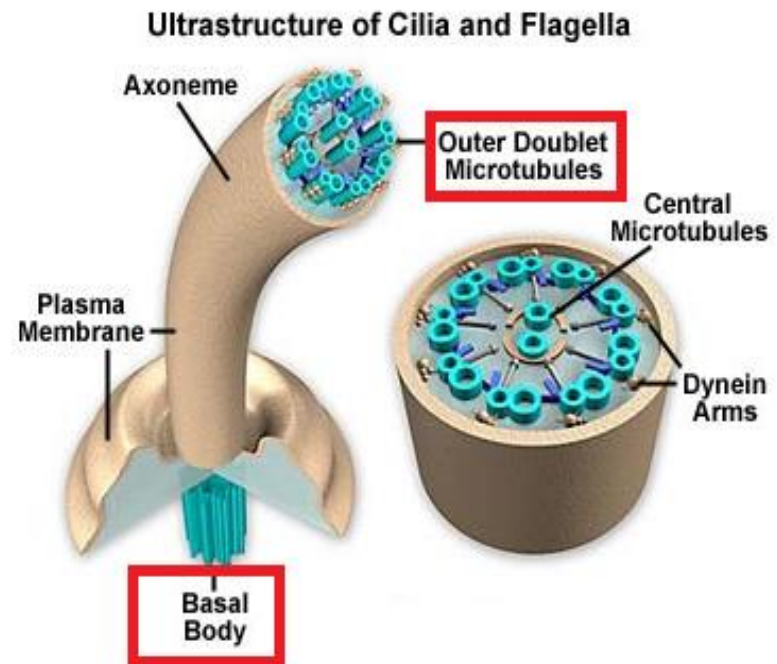
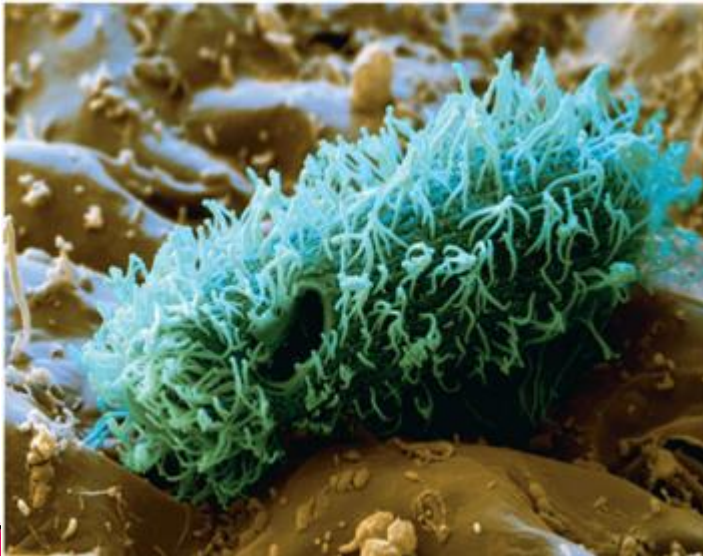
- Flagella

- Pseudopodia

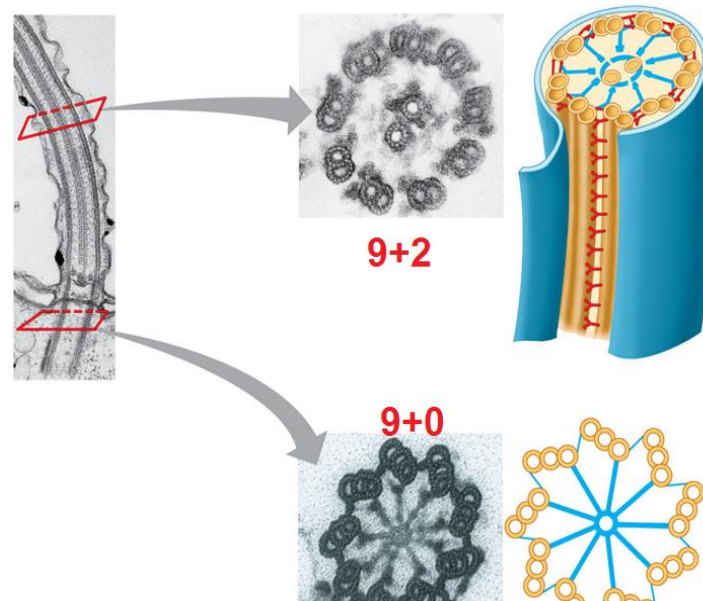


A) Cilia: structure and function

- ▶ Cilia originate from **basal bodies** (kinetosomes).
- ▶ Within cilia are **microtubule rods** composed of a protein called **tubulin** (similar to actin).



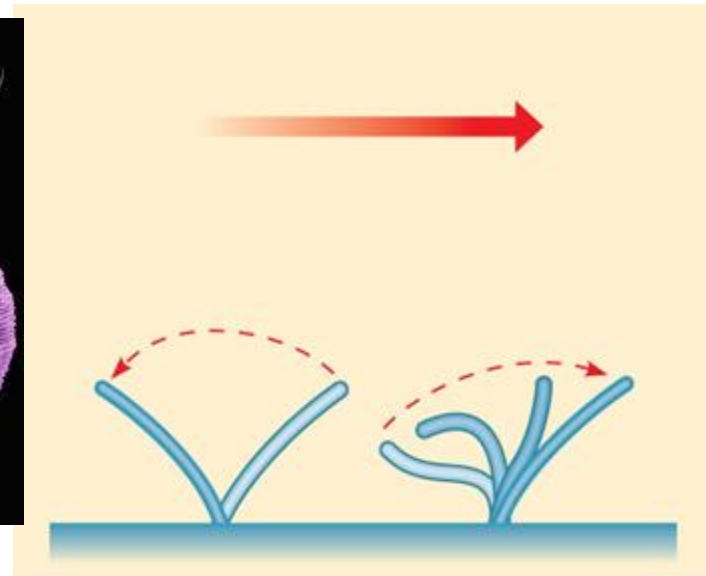
- ▶ In a **cross-section**, cilia have a **(9+2)** **arrangement** in their part **above the cell surface**, and **(9+0)** **below cell surface**.
- ▶ Arms of dynein project from microtubules these are similar to myosin.



► Cilia function in:

- **Locomotion**
- Help in **food collection**
- **Bringing oxygenated water** towards the organism.

► Ciliates are the **fastest protozoans**
(speed=2mm/sec).



B) Flagella: structure & function:

- Similar to cilia in structure and function
- Flagella and cilia are called **undulipodia**.
- Movement is **fairly rapid (200 $\mu\text{m}/\text{sec}$)**.
- This is 1 / 10 the speed of ciliates & 40 times faster than amoebas.



► Unlike cilia,

- Flagella have numerous hair-like projections called “**mastigonemes**”. These increase the surface area of the flagellum.
- Flagella are usually **longer than cilia**.
- The number of flagella is **much less than cilia**.
- Wave of movement may be initiated **at the tip** of the flagellum rather than the base.



C) Pseudopodia: Structure & function

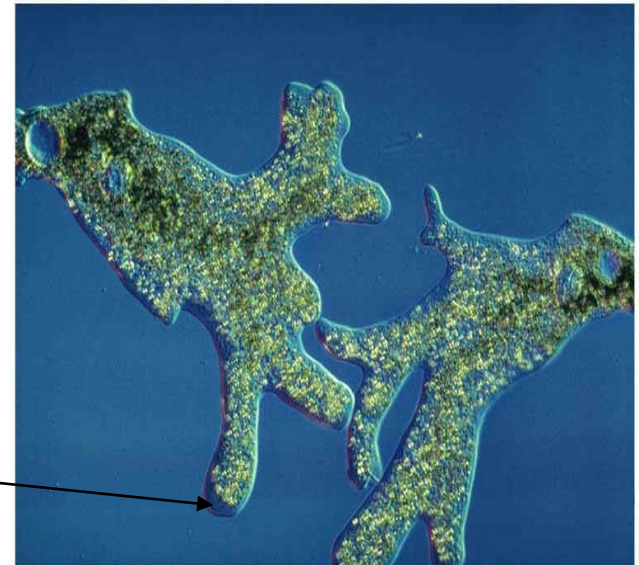
- ▶ Pseudopodia are characteristics of amoebae.
- ▶ Movement by pseudopodia is extremely slow: (300 $\mu\text{m}/\text{min}$).
- ▶ Functions of pseudopodia:
 - Locomotion
 - Food collection



Types of pseudopodia:

1) **Lobopodia**: (*Lobo*: G: lobe)

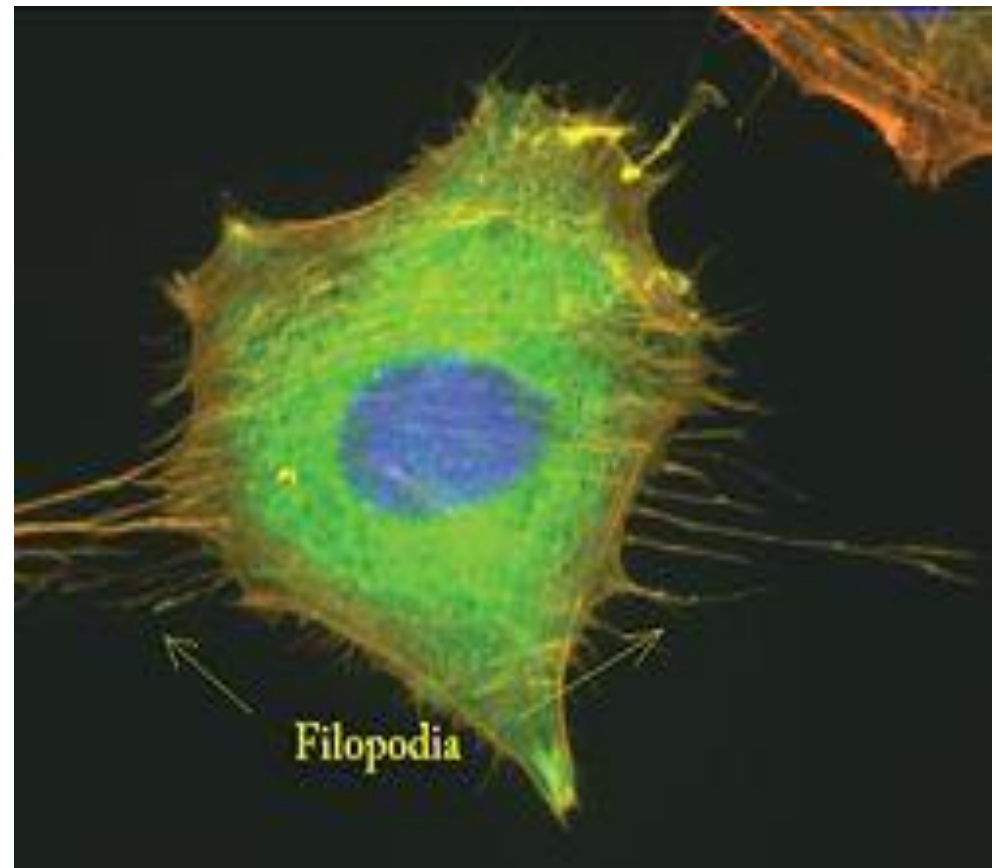
- Typical for the familiar amoeba.
- **Broad** with **rounded tips** (like fingers).
- Bear a distinct clear ectoplasmic area called the **hyaline cap** near the tip.



hyaline cap

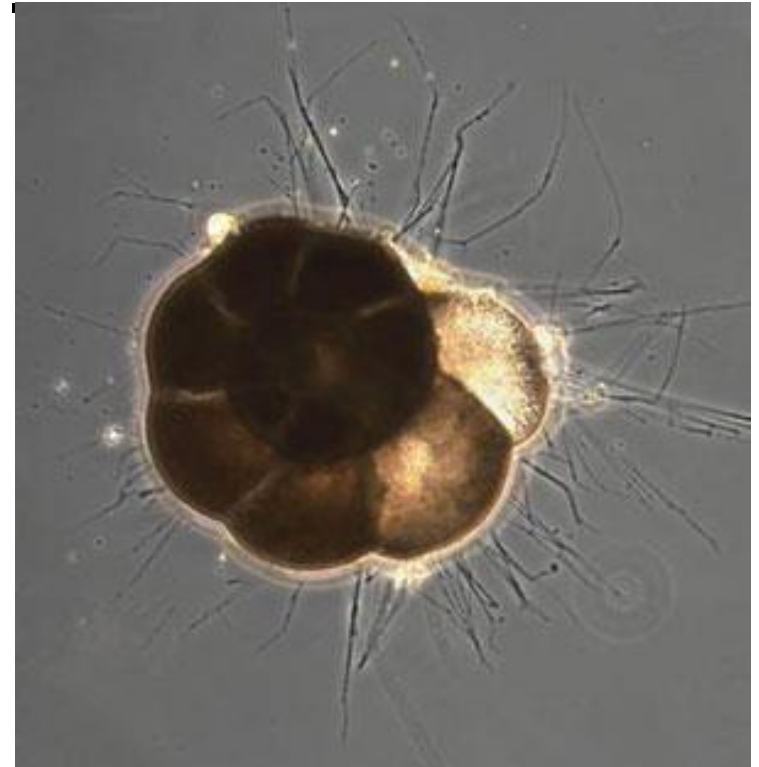
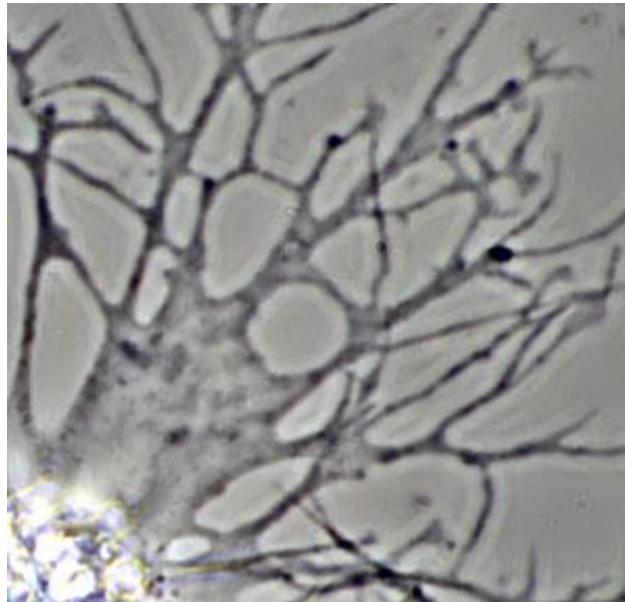
2) **Filopodia:** (*Filo*: L: Thread)

- **Very narrow** (thread-like).
- Lack a hyaline cap.
- Often branched.



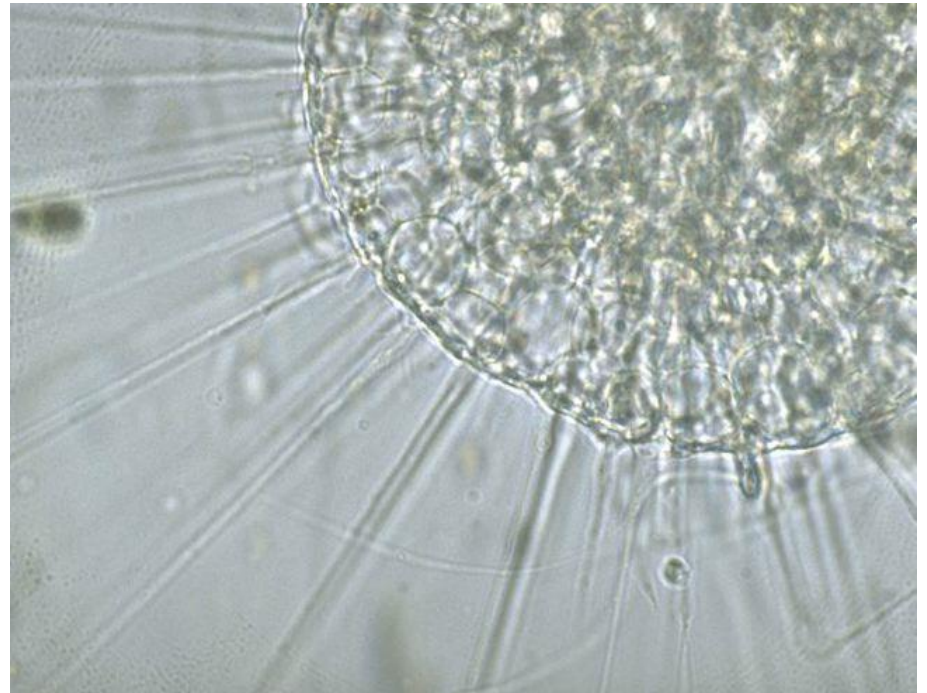
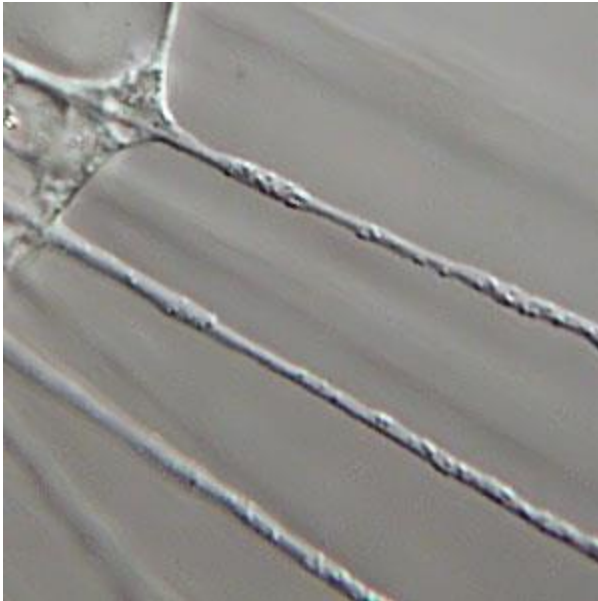
3) Reticulopodia (*reticularia*= L. a network)

- Extremely thin, branched filaments.
- Found in Foraminiferans.
- Used mainly for feeding.



4) **Axopodia** (actinopodia): (axo: G: axle)

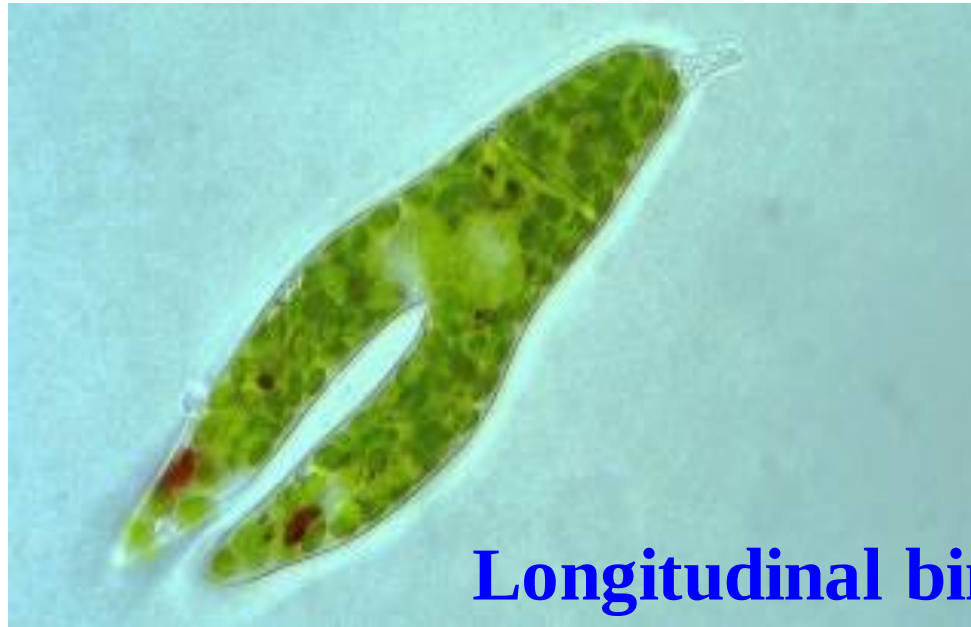
- Radiate outwards along thin spines or microtubules.
- Used for food collection



Protozoan reproduction:

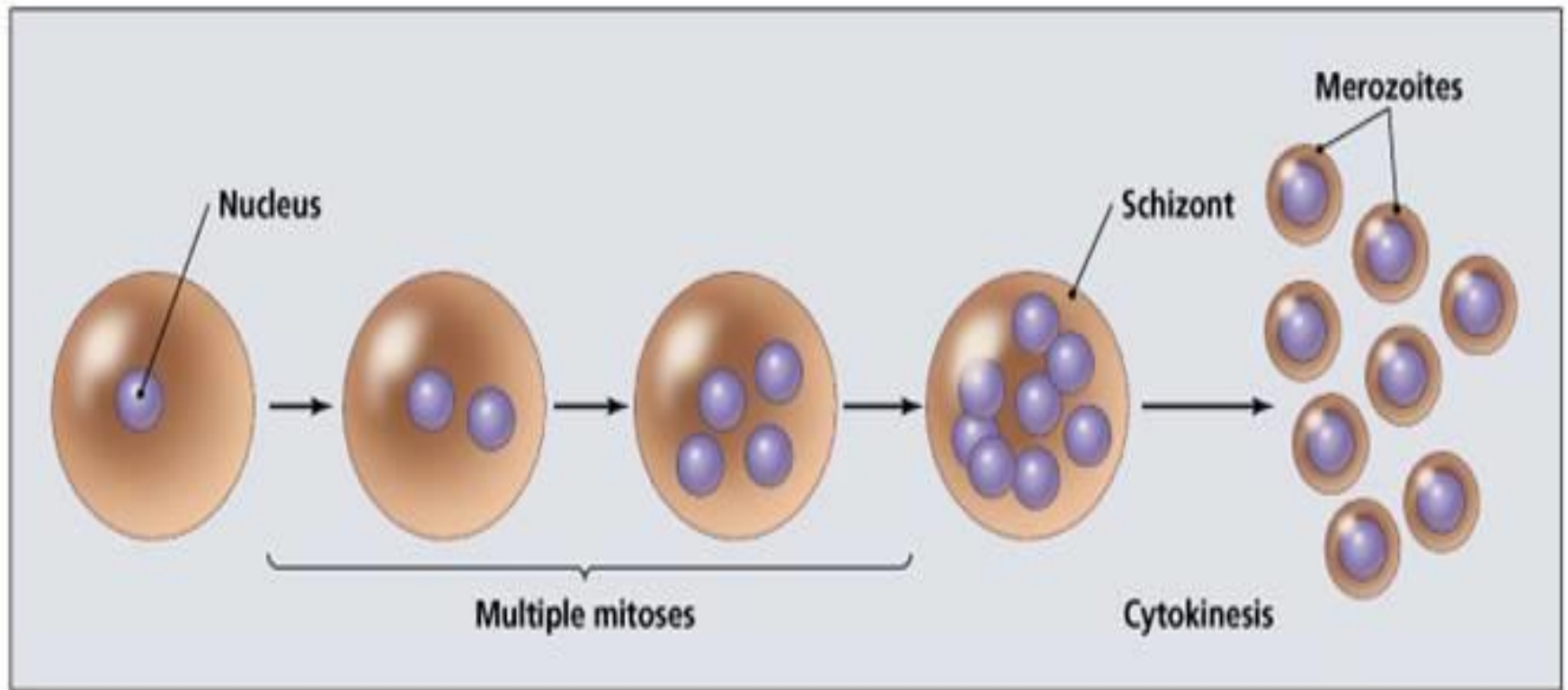
- ▶ **A sexual** reproduction is the most common type, although **sexual reproduction** occurs in almost all groups.
- **Asexual reproduction methods:**
 - 1) **Fission** (mitosis); could be:
 - a) **binary** (Longitudinal or Transverse).
 - b) **multiple**.

Transverse binary fission



Longitudinal binary fission

► Multiple fission:



2) Budding:

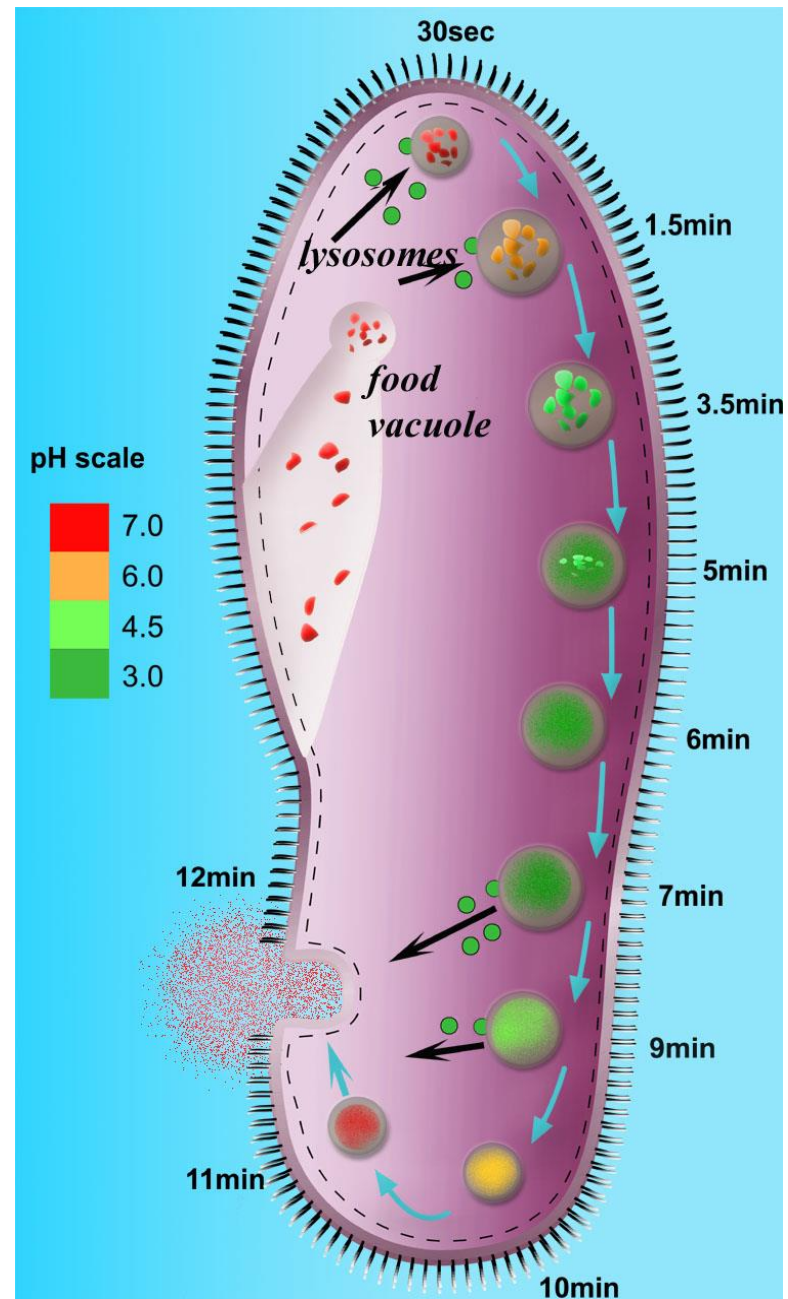
After DNA replication, parent organism divides into **two unequal parts**:



Protozoa Feeding:

- ▶ Protozoa feed by **phagocytosis**: forming **food vacuoles (Phagosomes)**.
- ▶ Vacuoles **fuse with lysosomes** & digestion starts under **different pH values**.
- ▶ Soluble material diffuse outside the vacuole into the cytoplasm.
- ▶ The undigested material is expelled by **exocytosis**.

► Endocytosis, digestion and exocytosis



Protozoan Classification

Kingdom protozoa is divided into

4 groups:

1) The Alveolata

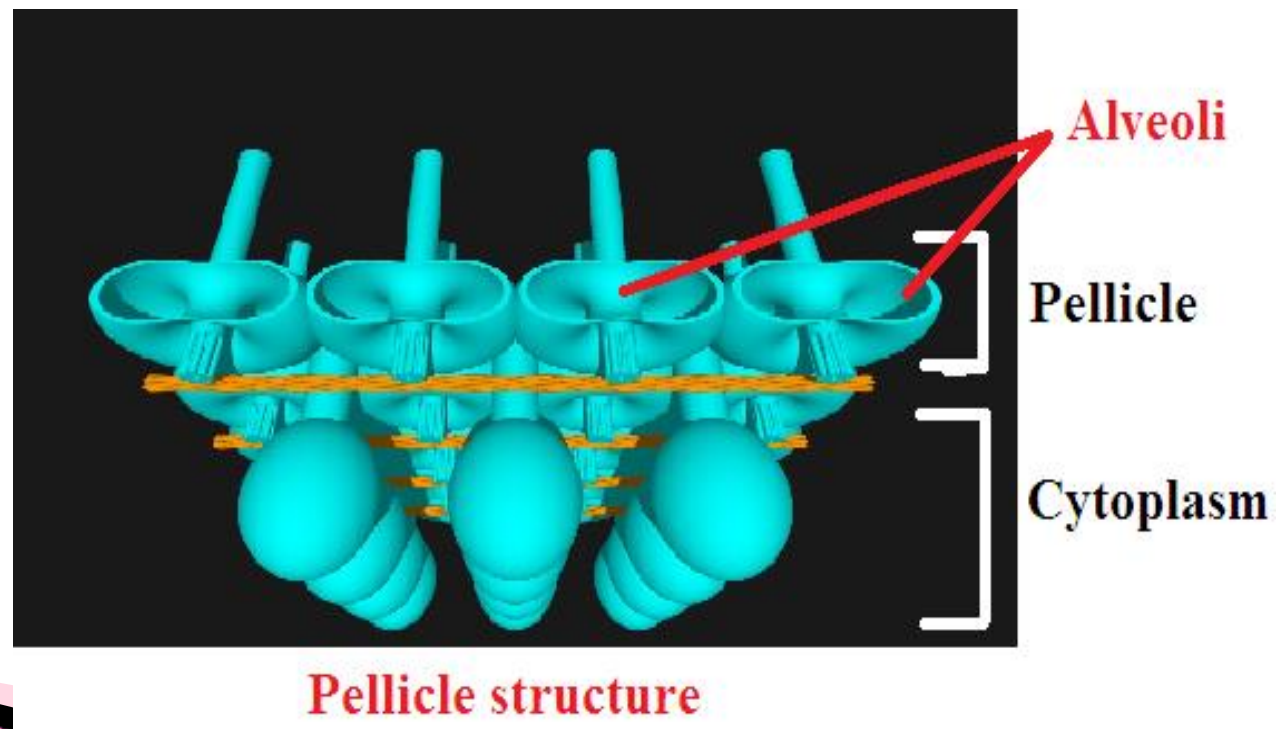
2) The Amoebozoa

3) The Rhizaria

4) The Excavata

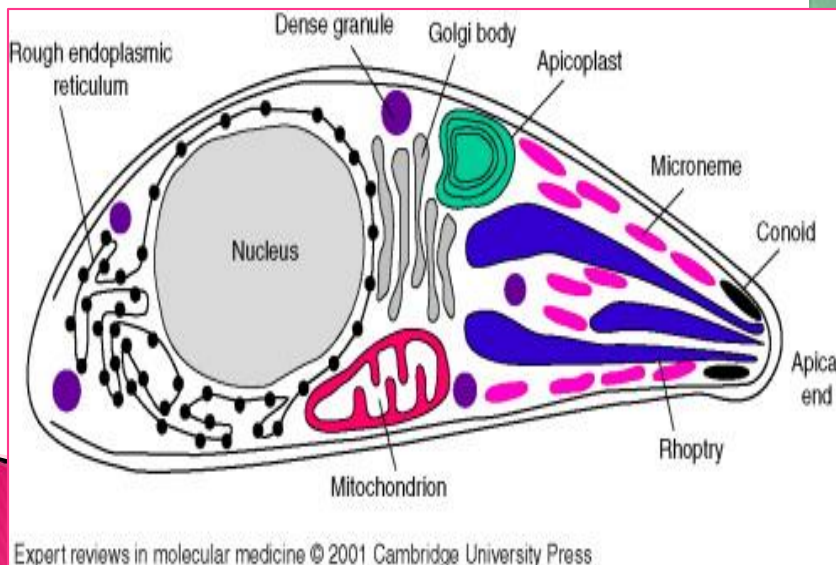
A) The Alveolate Protozoans (Alveolata)

- ▶ A **large** and **diverse** group possessing very distinctive **membrane-bound sacs (Alveoli)** just below the outer membrane (pellicle).



► Includes 3 phyla:

- **Phylum Ciliophora**
- **Phylum Dinozoa**
- **Phylum Apicomplexa**



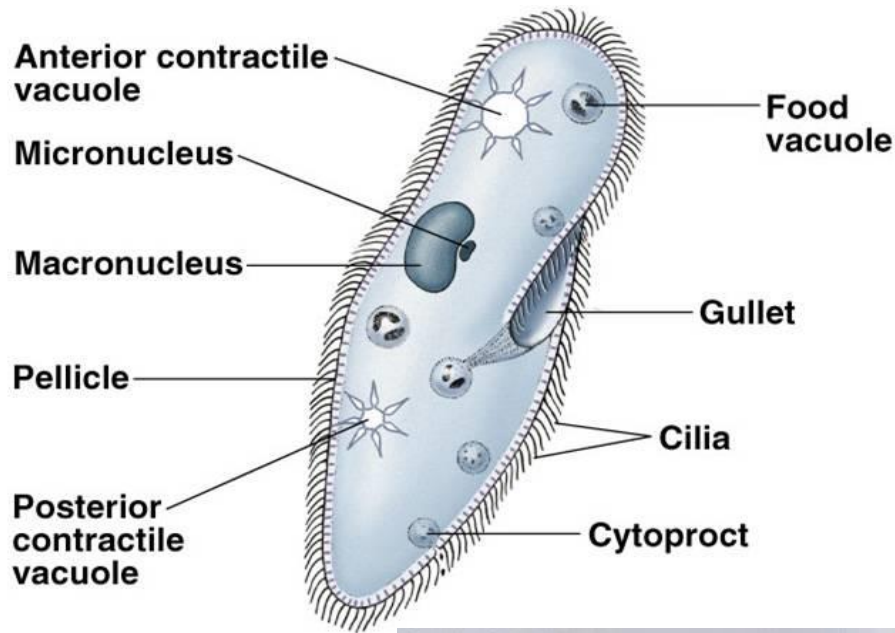
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1) Phylum Ciliophora

▶ *Ciliophora*: G. Cilia-bearing

▶ Defining Characteristics:

- About 3500 species
- Body **externally ciliated** in at least some life cycle stages.
- All individuals possess at least one **micronucleus** and at least one **macronucleus**.
- Examples: *Paramecium, Stentor, Vorticella*.



Paramecium

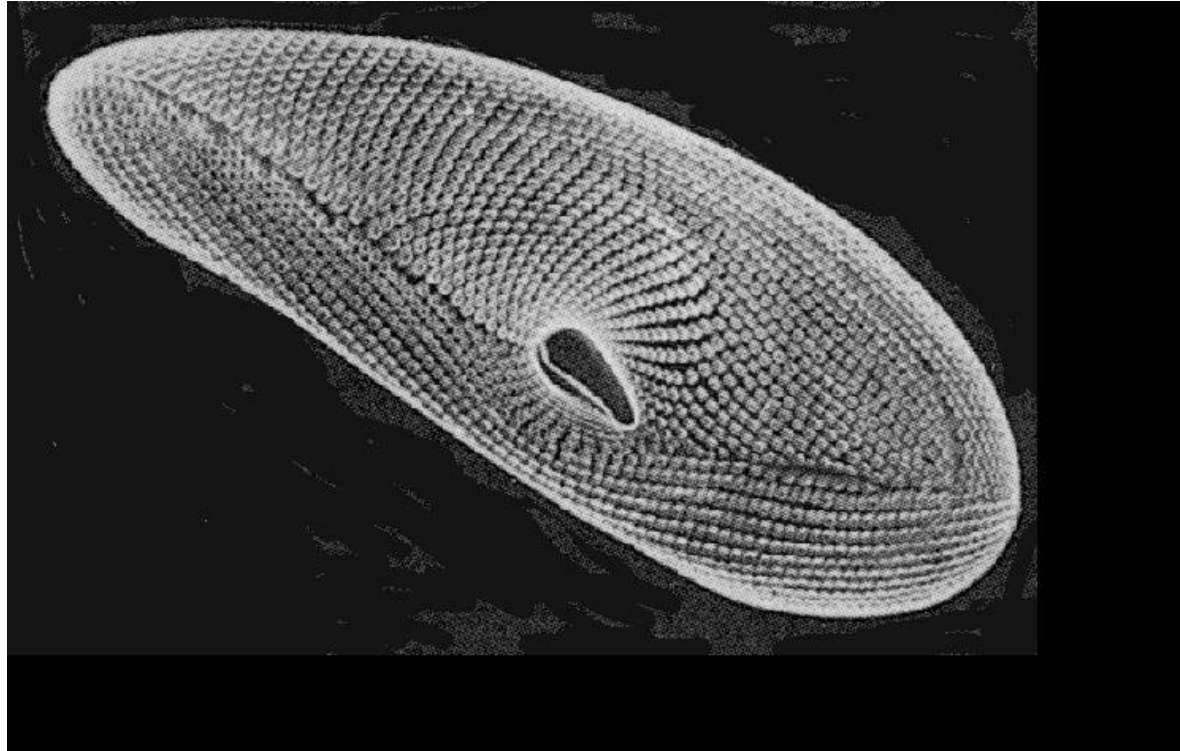
■ *Vorticella*



Stentor

- Ciliates exhibit highest degree of **sub-cellular specializations** among protozoans (advanced).
- Mostly **free-living & uniform in body plan**.
- Ciliation could be **partial** (e. g. *Vorticella*) or **complete** (e.g. *Paramecium*).
- The mouth (**cytostome**) is ciliated to help in feeding.
- Some sp. has a permanent opening to the outside **cytoproct** (procto = anus) for expelling undigested wastes.

- ▶ Ciliates have a series of membranes called **pellicle**.



▶ Reproductive characteristics:

- Each ciliate has 2 types of nuclei (dimorphic; heterokaryotic) (*all other protozoans are monomorphic; homokaryotic*).
- Each ciliate contains **one or more macronuclei** & **1 or more micronuclei** (more abundant).

▶ The macronucleus:

- Polyploid
- Contains both DNA + RNA
- Controls daily activities (non reproductive)
- Ciliates cannot live without it

▶ **The micronucleus is:**

- Essential for sexual reproduction (Diploid).
- Ciliates can live without it.

– Sexual reproduction of ciliates **does not include gamete formation.**

▶ Instead, ciliates **reproduce sexually by:**

- **Conjugation:** exchange of genetic material between 2 organisms.
- **Autogamy:** sexual activity to produce new genotypes from one individual.

لا يشمل التكاثر الجنسي للشركات العملاقة تكوين الأمشاج.

بدلاً من ذلك ، تتكاثر الشركات العملاقة جنسياً عن طريق:

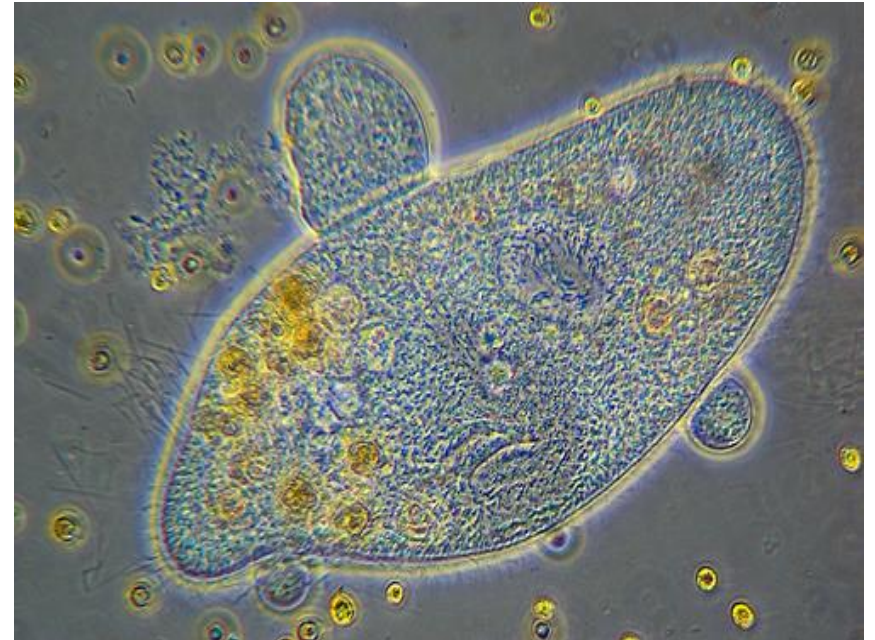
الاقتران: تبادل المواد الجينية بين كائنين.

Autogamy: النشاط الجنسي لإنتاج أنماط وراثية جديدة من واحد

فرد.

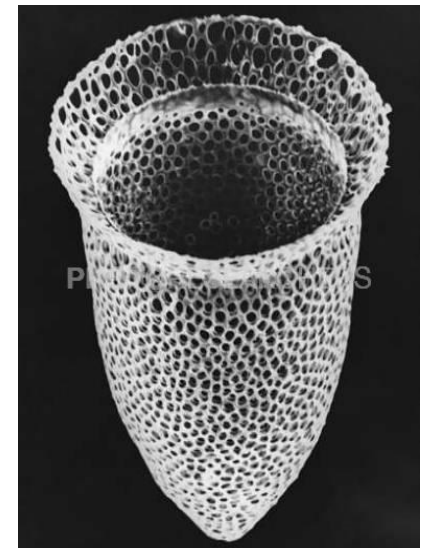
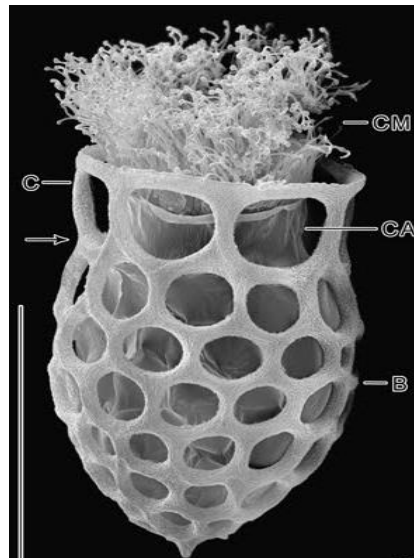


- ▶ All ciliates can reproduce **asexually** by:
 - **Transverse binary fission** (other protozoans reproduce by longitudinal).
 - **Budding**

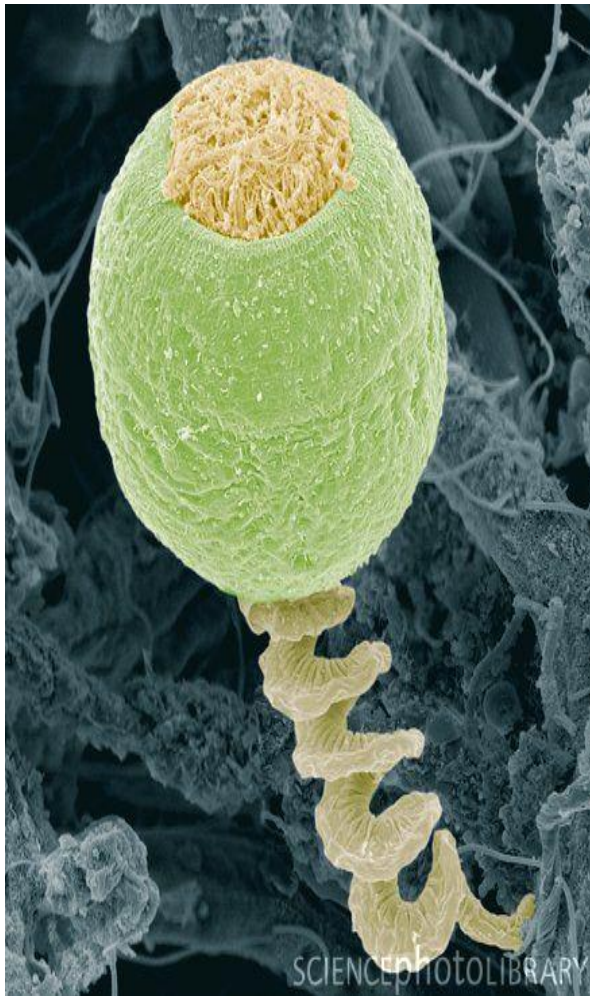


Ciliate life styles:

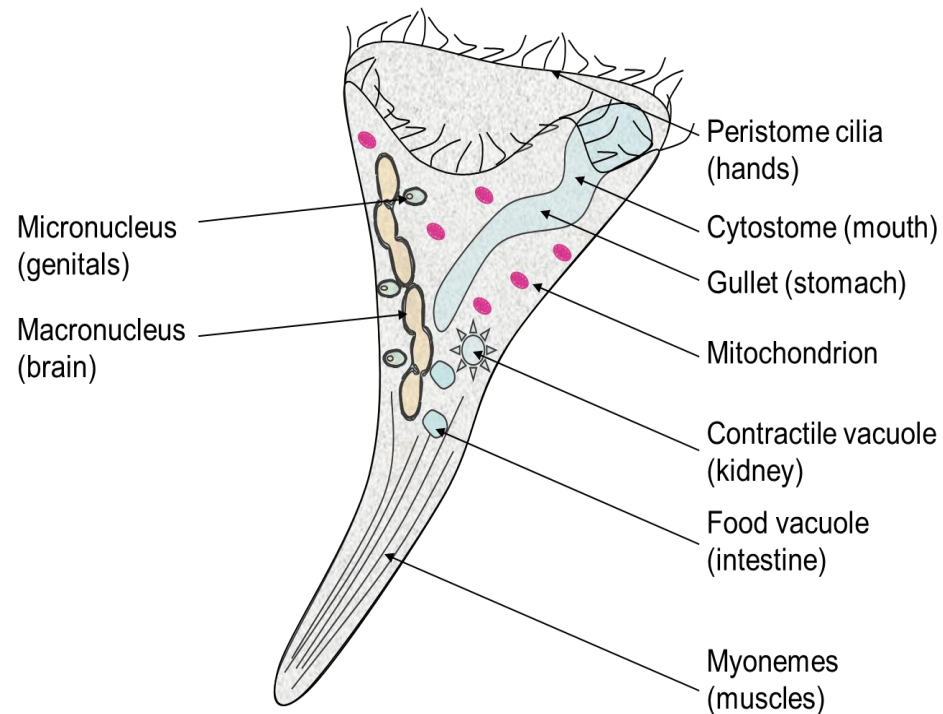
- ▶ Most ciliates are **free living** and **motile**.
- ▶ However, some are **temporarily attached** to surfaces and others are **sessile**.
- ▶ All ciliates have **pellicles**, but some have an extra protective, rigid encasement called **test or lorica** (armor).



- ▶ About 1 / 3 of ciliates are **endosymbiotic** in other invert & vertebrates.
- ▶ Most **free-living ciliates** are holozoic: they ingest particulate foods.
- ▶ Others may be raptorial: they hunt & ingest living prey.
- ▶ Some may be **passive suspension feeders** (they are usually sedentary).
- ▶ Commonly sedentary sp. have a stalk e.g. ***Vorticella***.
- ▶ The stalk may contain a spasmoneme (myoneme): *a helical, membrane-bound bundle of contractile fibers.*



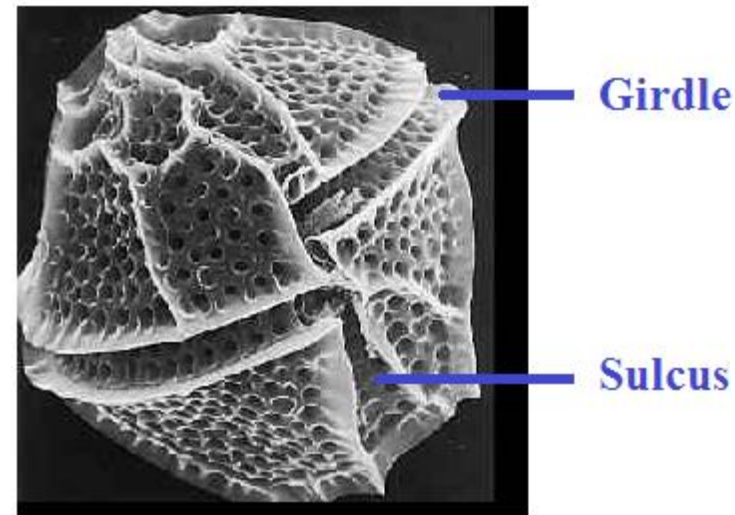
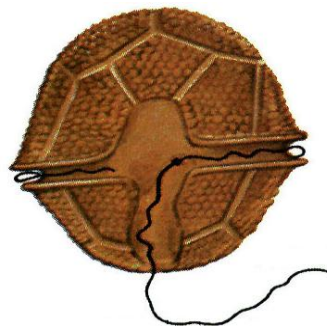
- Other sedentary sp. that **lack stalks**, e.g. *Stentor*, has contractile fibers in their body $\Rightarrow$ they permit shape changes.



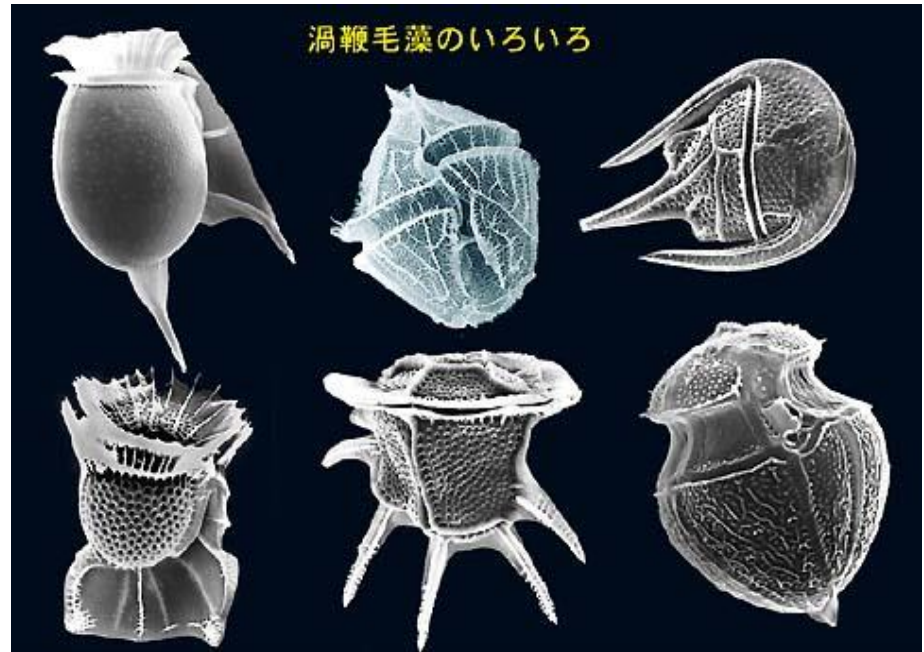
2) Phylum Dinozoa (The Dinoflagellates)

Dino=G: whirling, Zoa=G: animals

- ▶ Can be found in both **freshwater and marine habitats**.
- ▶ Each organism possesses **2 flagella**.
- ▶ One flagellum is located within a longitudinal groove called **sulcus**.
- ▶ The other is located within groove called the **girdle**.



- ▶ The entire organism is covered by **cellulose plates** that are secreted within **alveolar sacs** that are located just below the cell membrane.
- ▶ يتم تغطية الكائن الحي بأكمله بألواح السليلوز التي تفرز داخل الأكياس السنخية الموجودة أسفل غشاء الخلية مباشرة.



- ▶ Dinoflagellates commonly produce **bioluminescence**.

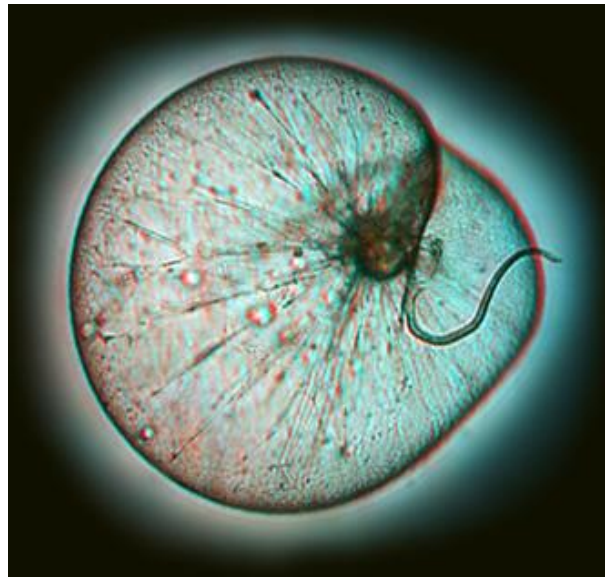


- ▶ Others are known to produce the highly toxic “**Red tides**”: where highly toxic substances are produced by certain species of Dinoflagellates. These can kill fish and human.

- ▶ ومن المعروف أن البعض الآخر ينتج "المد الأحمر" شديد السمية: حيث يتم إنتاج مواد شديدة السمية بواسطة أنواع معينة من دينوفلاجيلات. هذه يمكن أن تقتل الأسماك والبشر.



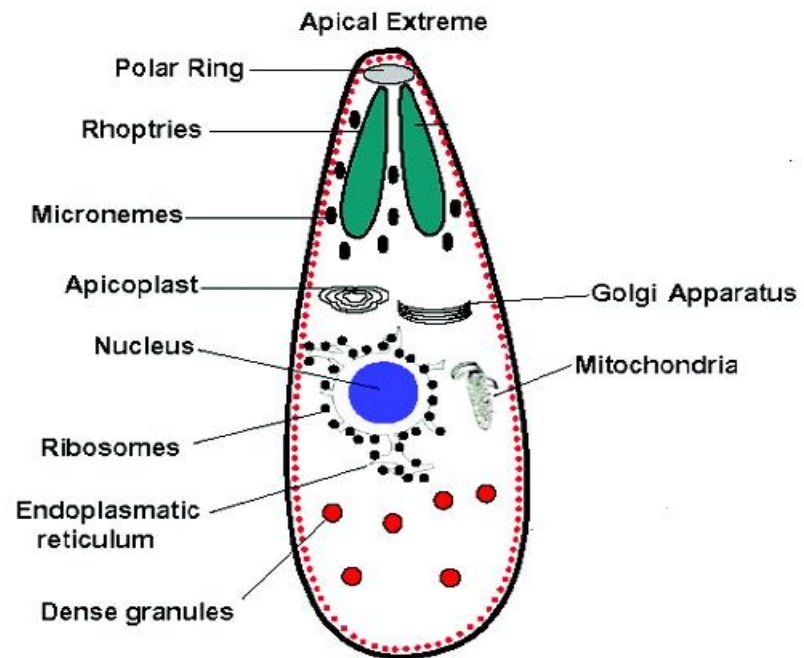
- ▶ About half of the dinoflagellates **contain chlorophyll** and photosynthesize.
- ▶ Many of these **autotrophs** live in tissues of other invertebrates (**endosymbiotic relationship**) and are called **Zooxanthellae**.
- ▶ Others are **heterotrophs** feed on particulate matter. Example: the **bioluminescent Noctiluca**.



3) Phylum Apicomplexa

Defining Characteristic:

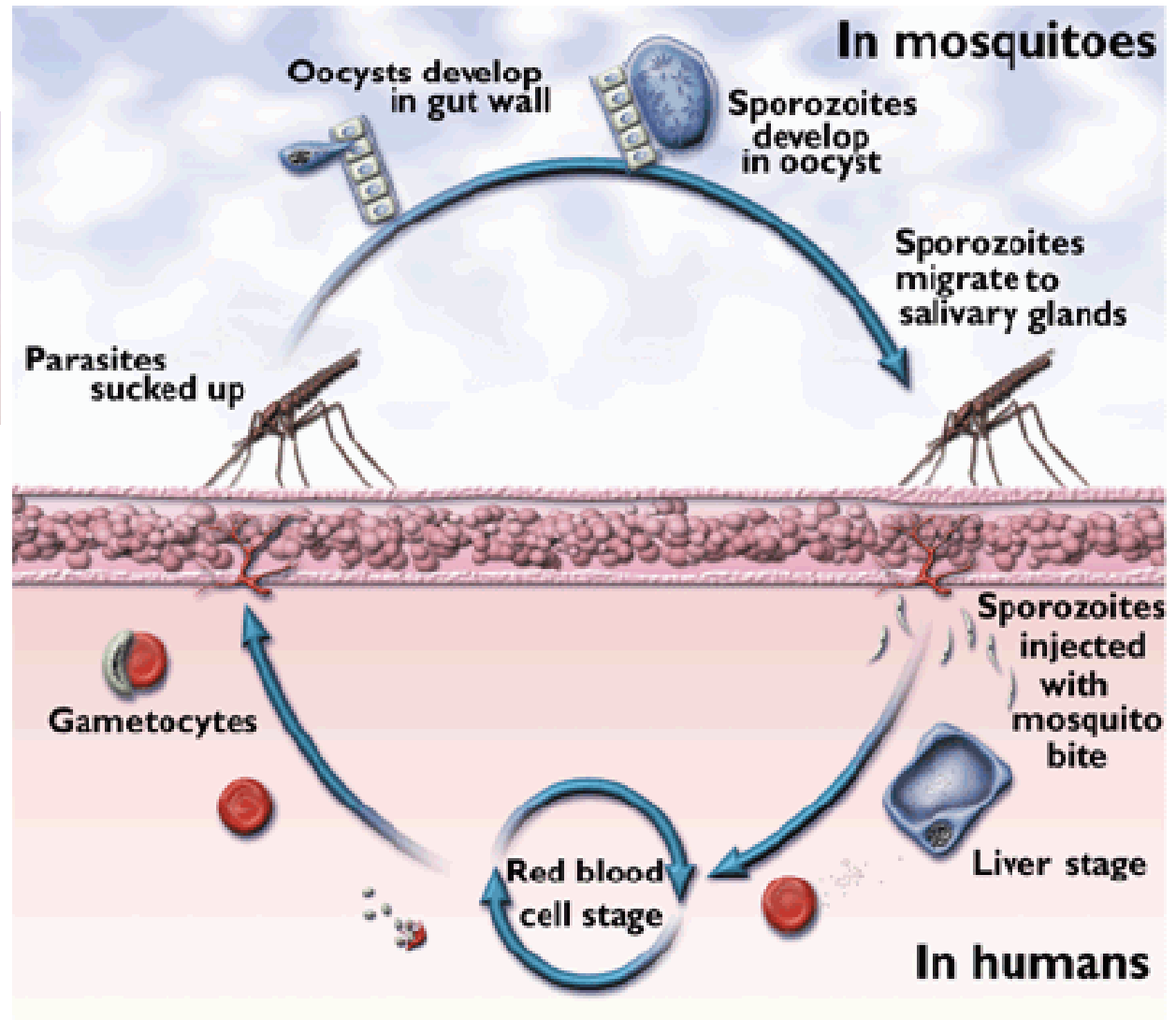
- ▶ Infective stages possess a **distinctive cluster of microtubules and organelles** (The **Apical Complex**) at one end of the cell in certain stages of the life cycle.



- ▶ Contains **more than 6000 sp.**
- ▶ All members are **endoparasites** of animals.
- ▶ Adults **lack locomotory organelles**, however, many sp. produce flagellated gametes.
- ▶ Includes **2 important groups**:
 - The gregarines: parasitize insects and other Invertebrates.
 - The coccidians: includes many blood cell parasites of humans. Example: the genus *Plasmodium*; the malaria parasite.

- ▶ **Malaria:**
- ▶ Caused by 4 species of *Plasmodium* that transmit human malaria, the most deadly of which is *P. falciparum*.
- ▶ *Malaria is the most important disease in the world today.*
- ▶ Worldwide, it infects about 500 Millions/year.
- ▶ 2–3 Millions die/yr most of them are children. (this means 1 person dies every 10–12 seconds).
- ▶ Life cycle includes: *sexual reproduction (by gametes)*, *asexual reproduction (fission)*, and *resistant or infective spores*.

- ▶ Malaria is transmitted by a mosquito called *Anopheles*.



► Notes about the life cycle:

- Only **gametocytes**, living within the human RBCs **infect the mosquito**.
- Only the **haploid sporozoites**, found in the mosquito salivary gland cells, **can infect humans**.
- **Pathological effects** in humans are caused by the **RBCs merozoites**.
- The parasite is **haploid for most of its life cycle**, the **diploid stage occurs in the mosquito**.

► Malaria Control:

- In the past:

- A pesticide called **DDT** was used to control the mosquito population.
- In addition a drug called **chloroquine** was used as a drug against the parasite.
- With time, both mosquito and parasite **became resistant** to DDT and chloroquine.

- Now:

- other control strategies are being investigated.

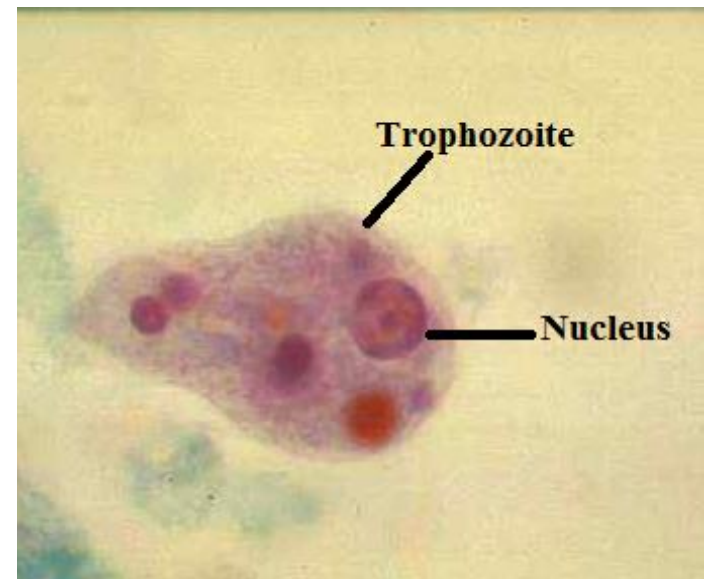
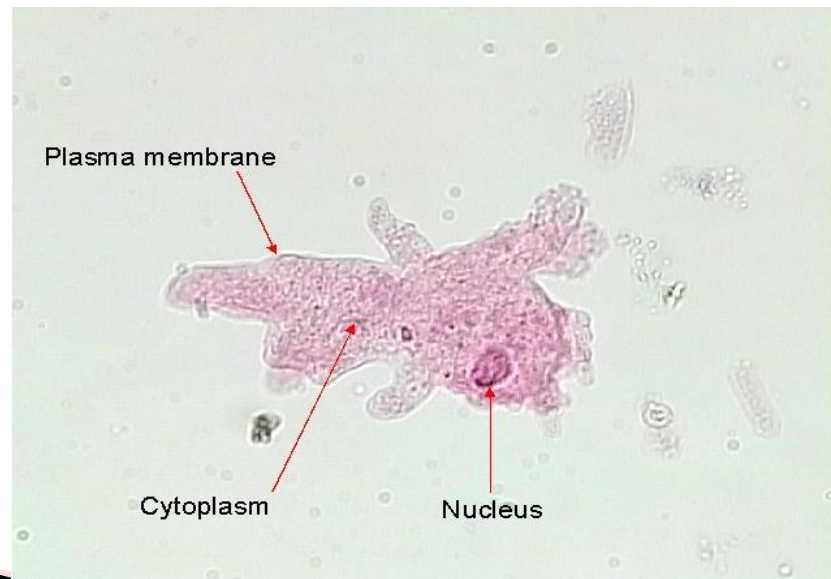
B) The Amoebozoans

- ▶ Many thousands that **exhibit amoeboid movement**.
- ▶ **Mostly free living** with few human parasitic species like the *Entamoeba histolytica*.
- ▶ **Divided into 4 groups:**

1) The naked amoebae (the Gymnamoeba):

- **Defining Characteristics:** shapeless “ameoboid body”, **move by pseudopodia** (*Lobopodia or filopodia*).
- Lack any covering outside their cell membranes “**naked**”.

- About **200 species** of mostly free living organisms.
- **Feed** on bacteria, other protozoa and algae by means of **phagocytosis** and **pinocytosis**.
- Example: *Amoeba*, *Entamoeba*



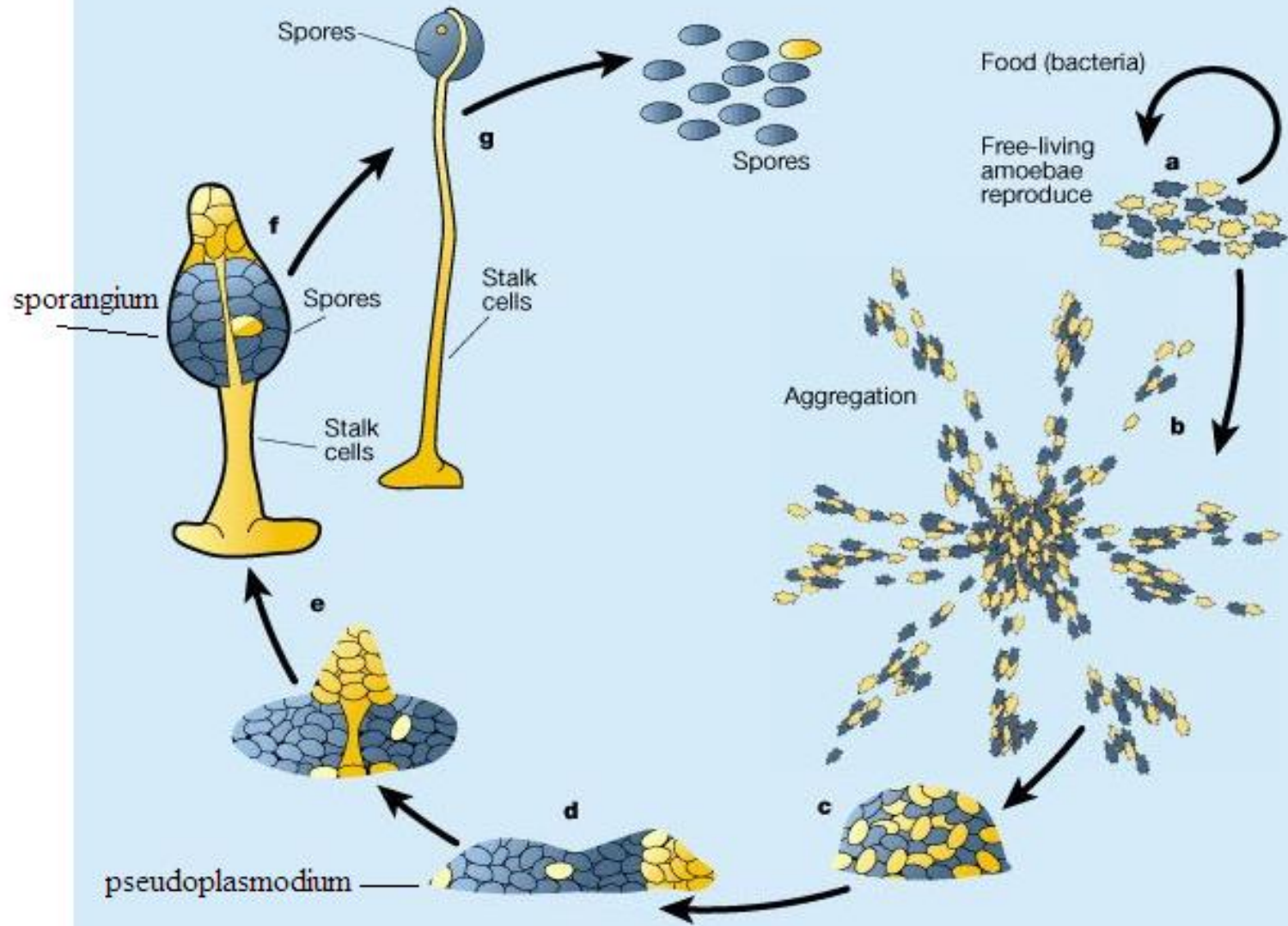
2) The Arcellinids and related test-bearing amoebae:

- Secrete a single-chambered **proteinaceous** or **siliceous** covering called **the Test: L: Shell**.
- Others have an **agglutination of sand or detritus** (this gives the body a shape).
- Found in soil, lakes and rivers.
- All have **Lobopodia**
- Example: ***Arcella***



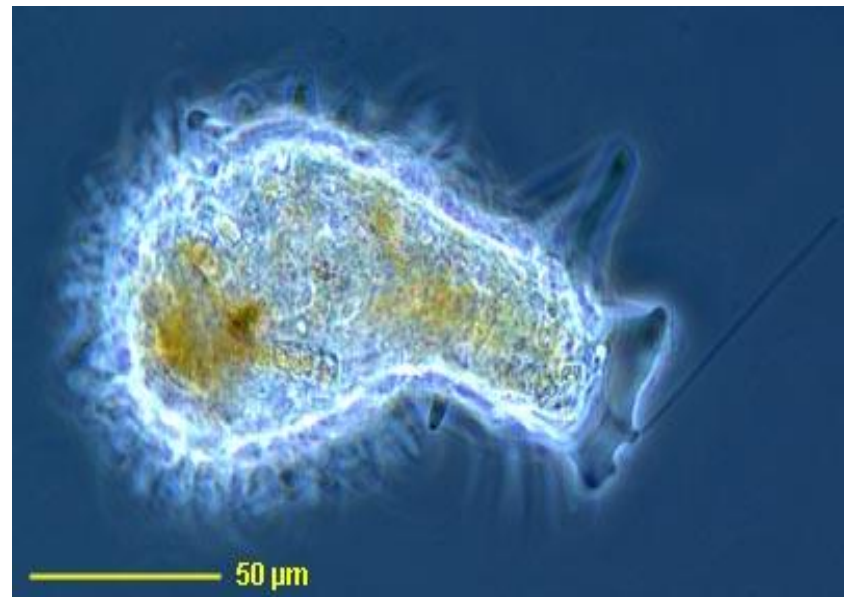
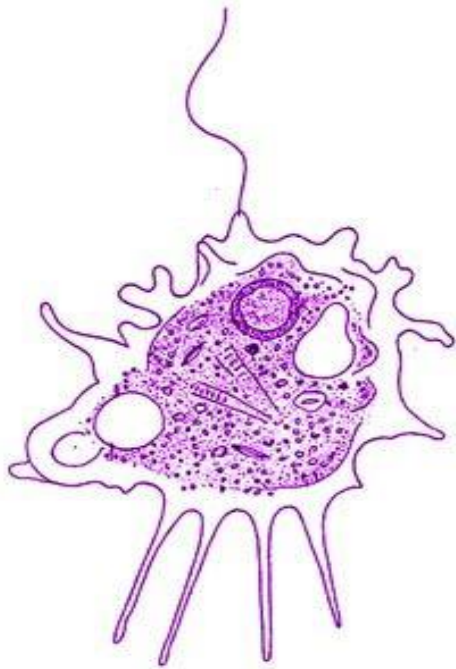
3) The Slime Molds:

- Includes the **cellular** and **acellular** slime molds, members of the **Eumycetozoa** (**Fungus animals**).
- They have often been **classified as fungi or plants**.
- Nevertheless:
 - For most of their life, slime molds exist as individual **amoeboid cells**.
 - Move and feed by **pseudopodia** (**Lobopodia**).
- Most species are free-living. Example: *Prostelium*



4) The Mastigamoebae

- Members possess both **pseudopodia and flagella** either **simultaneously or in sequence**.
- Live in stagnant water (fresh & marine).
- Close relatives to Eumycetozoa.
- Example: *Mastigella*



C) The Rhizaria

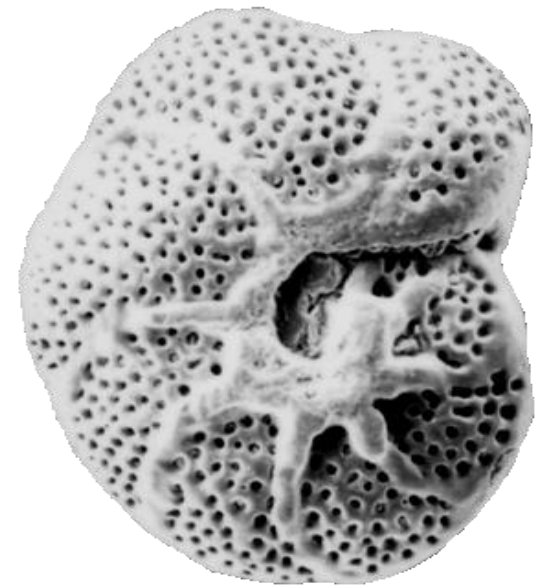
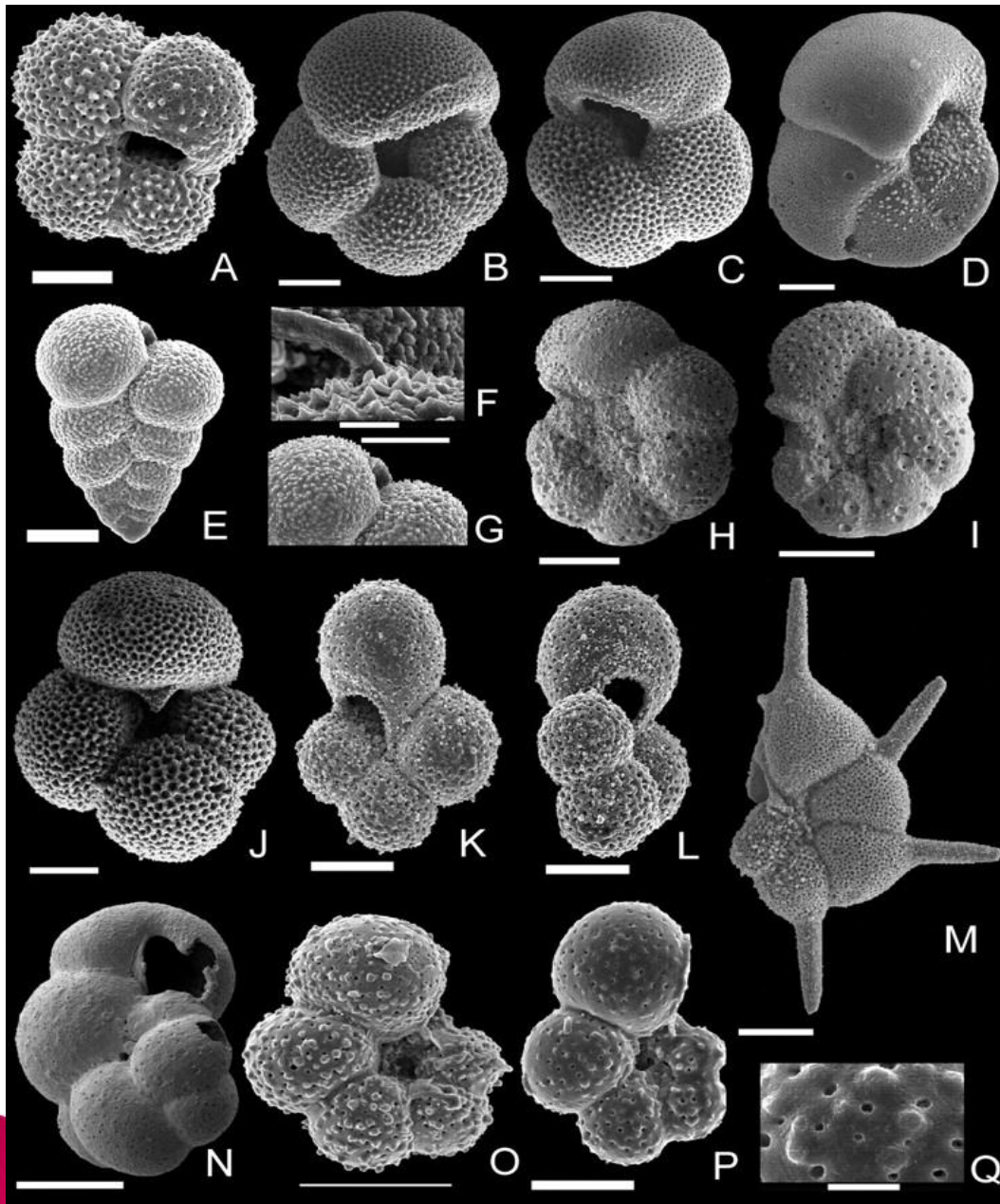
- ▶ Rhiza=G: root
- ▶ Have **filopodia or reticulopodia**
- ▶ Members are **not united** by any morphological or biochemical features.



▶ It includes 3 Phyla:

1) Phylum Foraminifera:

- ▶ Foramini . fera: L. bearing . Openings.
- ▶ Defining Characteristics:
 - All **secrete multi-chambered tests**, generally of **CaCO₃**.
 - Pseudopodia (**reticulopodia**) emerge through pores in the test & branch extensively to form dense networks.
- ▶ Referred to as the “**forams**”



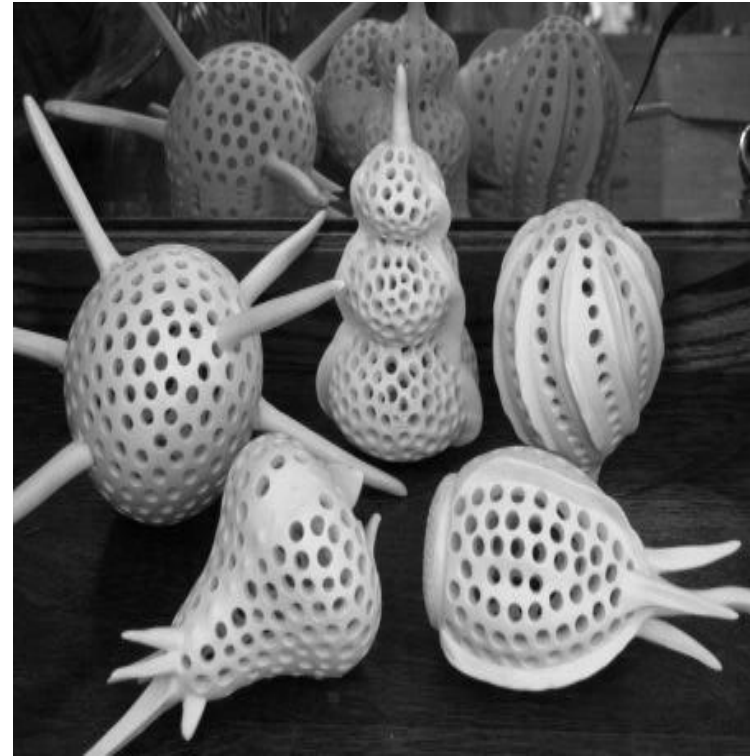
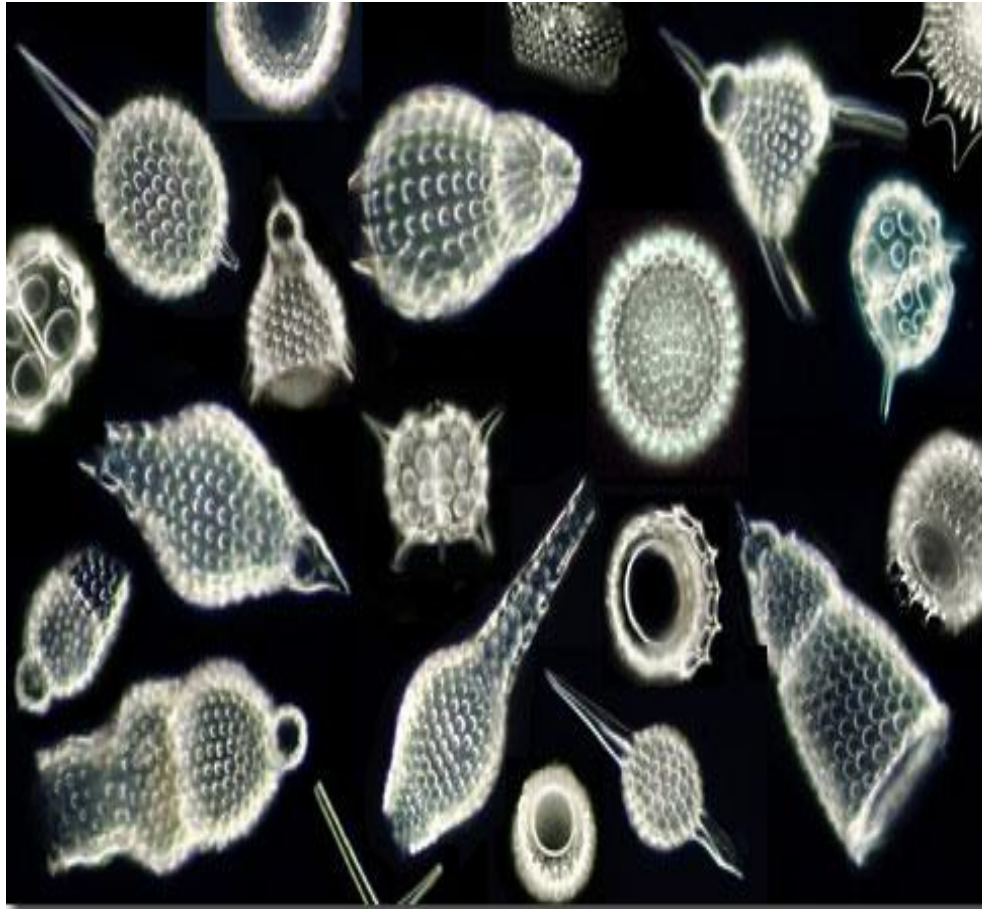
- ▶ Primarily **marine & benthic** (small # is planktonic).
- ▶ **No parasitic sp.** (some are ecto-commensals).
- ▶ **Reticulopodia** is used mainly as a **feeding organ**.
- ▶ **Feeding is on:**
 - Other **protozoans**, small **metazoans**, **fungi**, **bacteria & organic detritus**.
 - Some house **endosymbiotic photosynthesizing organisms (dinoflagellates)**.
 - Others can take up **dissolved organic matter**.

- ▶ **Size:** mostly less than 1mm length.
- ▶ Tests are **well recorded in fossils**. (543 million yrs old)
- ▶ Some fossil tests were 15 cm in diameter.
- ▶ **Fossils are important for:**
 - **Cement industry**
 - **Chalk industry**
 - **Indication for oil**



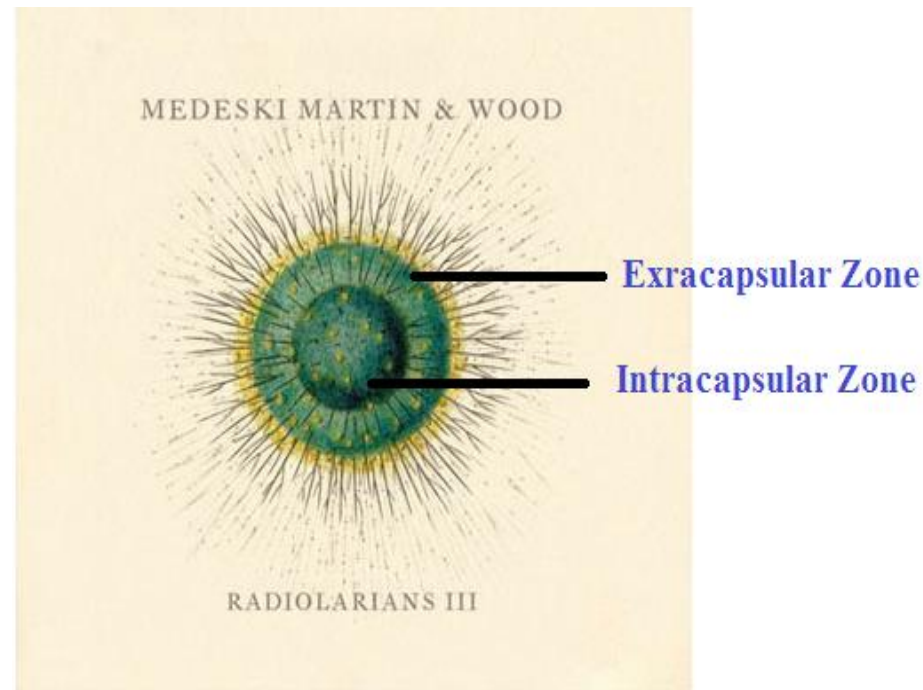
2) Phylum Radiozoa:

- ▶ **Radiolaria: L: ray – animals.**
- ▶ **Defining characteristic:**
- ▶ Body is divided into distinct **intracapsular** and **extracapsular** zones separated by a perforated membrane.
- ▶ Includes **Radiolarians** and **Acantharians**.
- ▶ Support their pseudopodia with thin, radiating, **microtubules** that give a spiny, rayed appearance to many sp.
- ▶ Pseudopodia & microtubular supports are called **axopodia**.



- ▶ Have an endoskeleton of silica as in radiolarians and of strontium sulfate as in acantharians
- ▶ Well recorded in fossils (7700 Radiolarian sp.)
- ▶ 1000 living sp of radiolarians and 160 sp of acantharians.
- ▶ All are planktonic.
- ▶ Many have endosymbiotic algae & are carnivorous.

- ▶ Body is generally **spherical & divided into:**
 - Intracapsular zone.
 - Extracapsular zone.
- ▶ **Food vacuole formation & digestion** take place in the **extracapsular zone.**



3) Phylum Helizoa ??:

▶ Helio . zoa: G. Sun . animals.

- **Defining characteristic:**

- Body is divided into distinct **inner & outer regions**, but regions are **not separated** by any physical boundary.

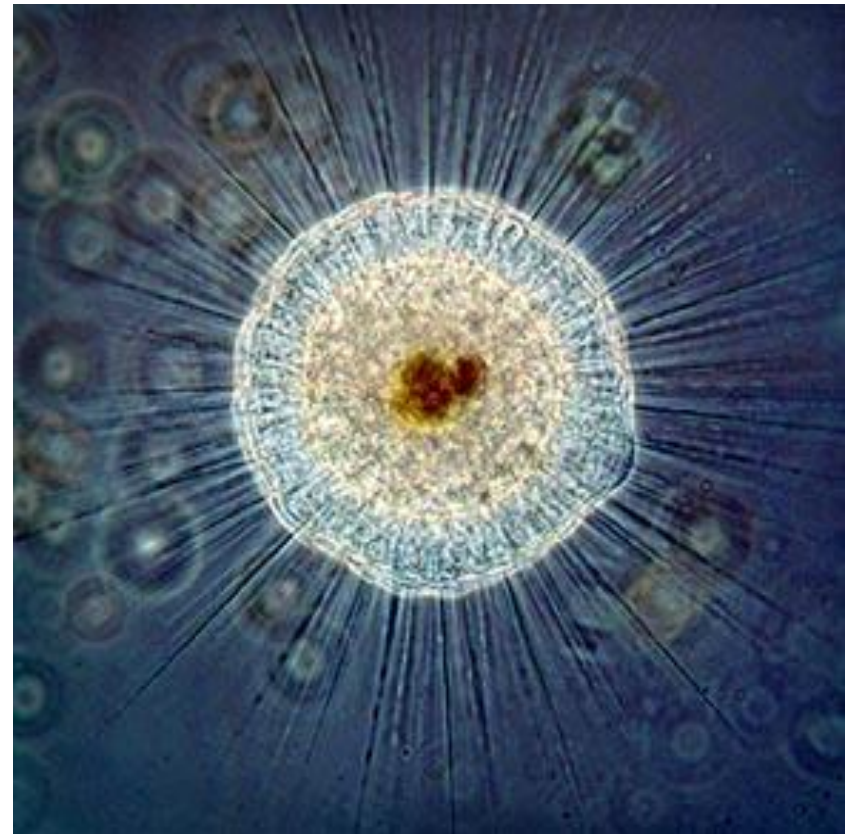
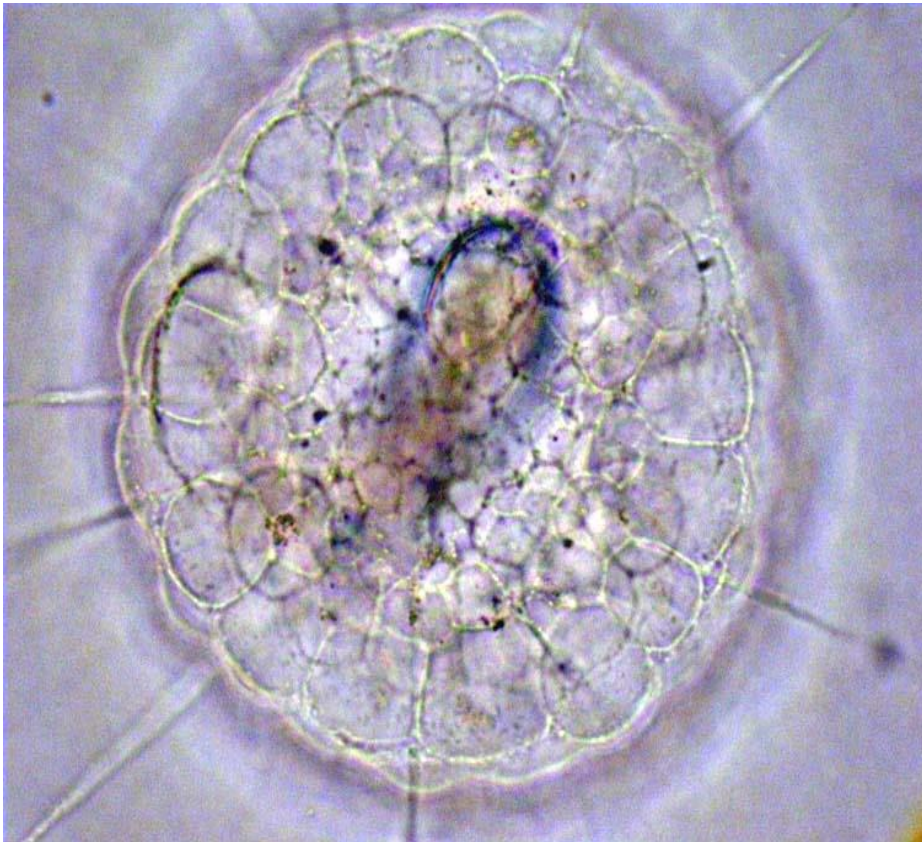
- **The 2 regions are:**

- **Ectoplasm**: with vacuoles & site of digestion.
- **Endoplasm**: less vacuoles & contains the nucleus.

➤ Primarily **planktonic** (about 100 sp)

➤ Have **axopodia**.

➤ Largely restricted to **freshwater habitats**.



D) The Excavata: Flagellated Protozoans:

- ▶ Called the **mastigophorans**.
- ▶ Have **one – many flagella**.
- ▶ Although they differ from amoebae in morphology, molecular biology revealed that **flagellates are ancestors of all amoeboid species**.
- ▶ Have a **pellicle**.
- ▶ Mostly **free-living & motile**.
- ▶ Some have a **cytostome**.

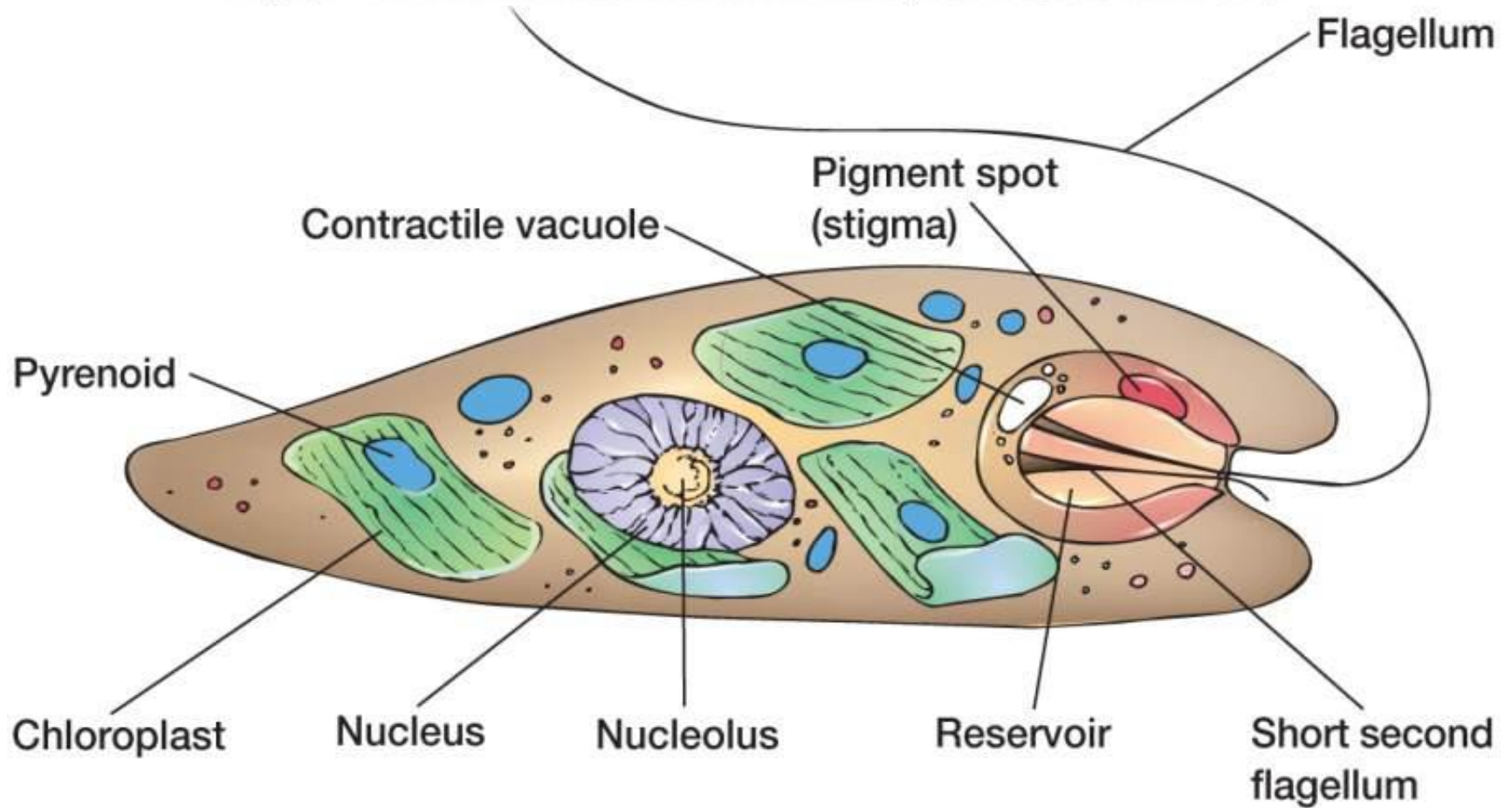
- ▶ Have **contractile vacuoles**, especially in freshwater species. (Their position is fixed within the cytoplasm).
- ▶ Divided according to lifestyle into: **photosynthesizing, particle feeding** and **parasitic sp.**
- ▶ Divided into **2 groups**:

Group I: The Phytoflagellated Protozoans:

Group II: The Zooflagellated Protozoans:

Group I: The Phytoflagellated Protozoans:

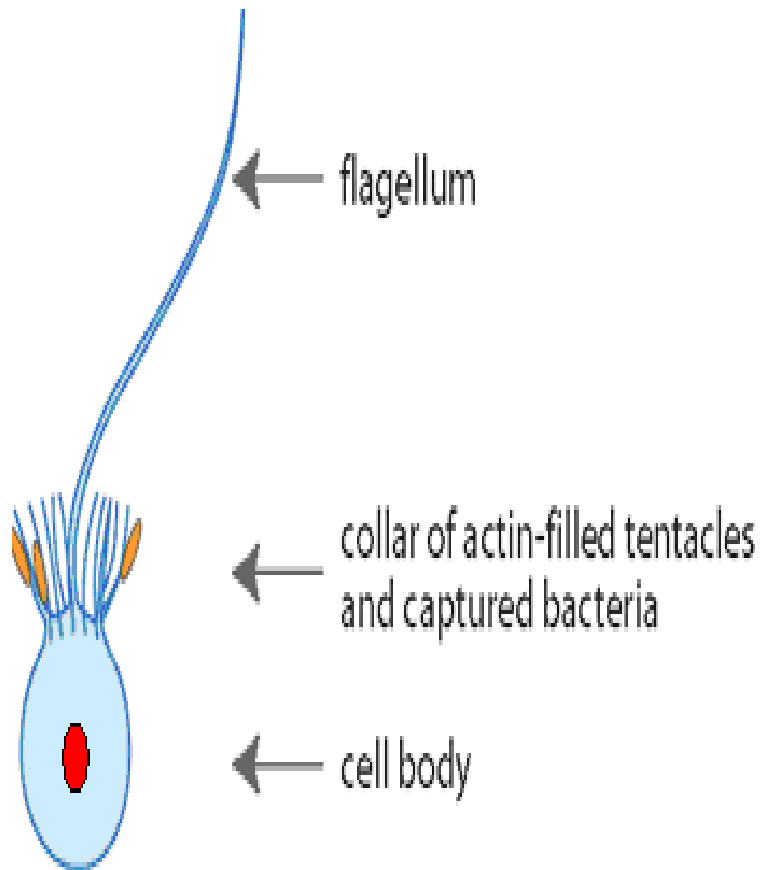
- ▶ Includes the **plant-like protozoa**.
- ▶ Some, like *Euglena*, have **chlorophyll** and do photosynthesis; others need some dissolved organic matter in addition to photosynthesis.
- ▶ **Neither have food vacuoles or cytostome.**
- ▶ If kept in darkness $\Rightarrow$ many euglenids become **holozoic** instead of being autotrophic.
- ▶ Many have a photosensitive organelle called the **stigma (eye spot)**.



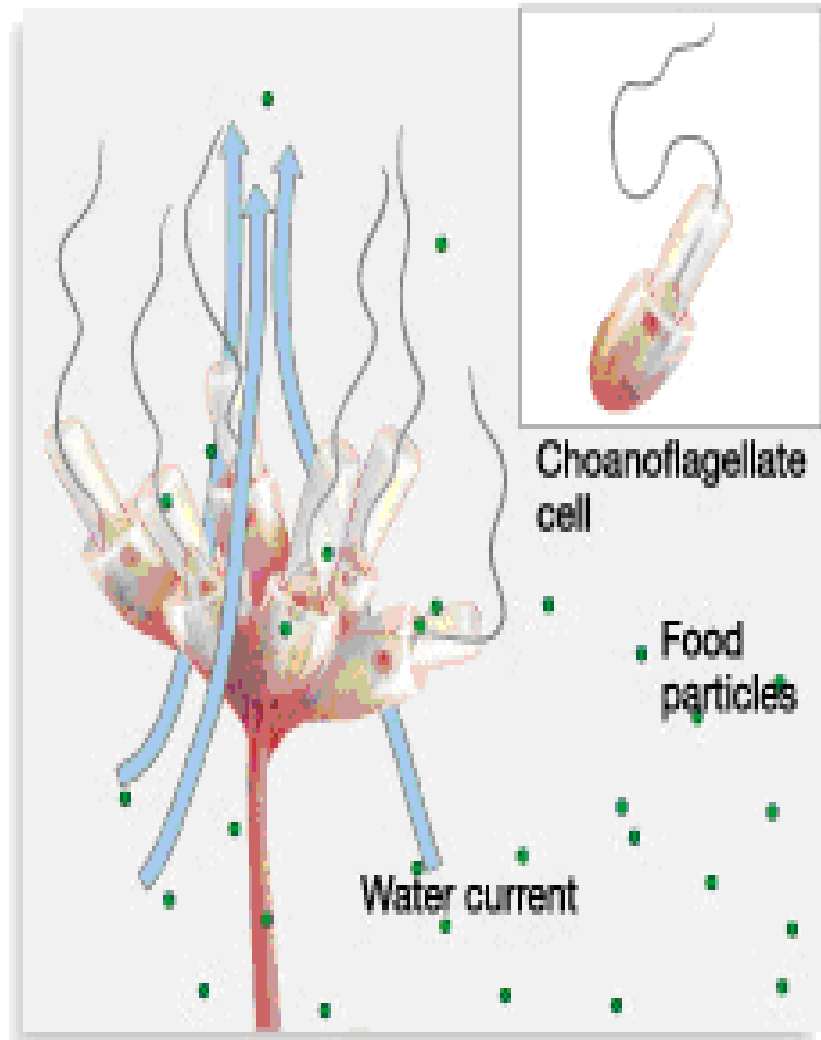
Group II: The Zooflagellated Protozoans.

The free-living forms:

- ▶ Live in fresh and marine water or soil.
- ▶ One interesting group is called the **Choanoflagellates**:
 - These are **freshwater organisms**.
 - **Sessile**, attached to substrates.
 - Each bears a **single flagellum** that extends for a part within a **collar** of protoplasmic strands called **microvilli**.
- ▶ Mostly **colonial** and **immobile** ⇒ several hundreds of cells.
- ▶ **They are similar to sponges??** An evolutionary relation is not certain!!



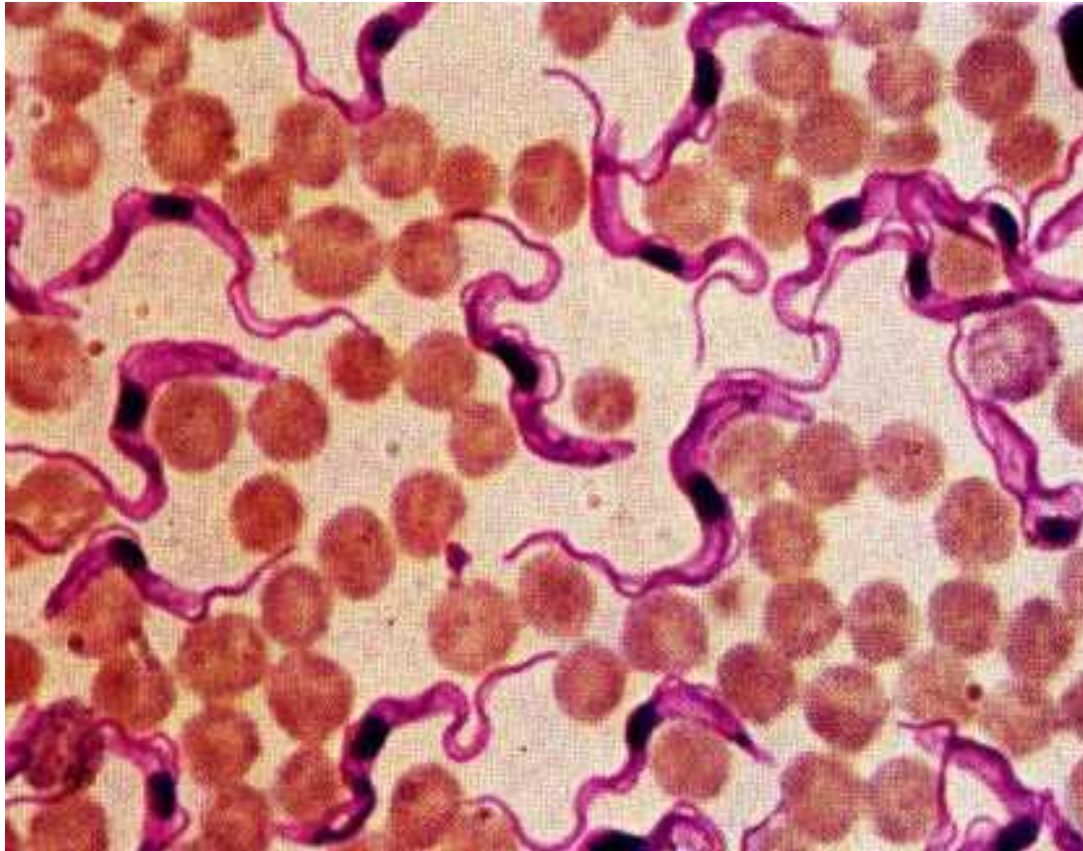
(a) Choanoflagellate (a protist)



The Parasitic Forms:

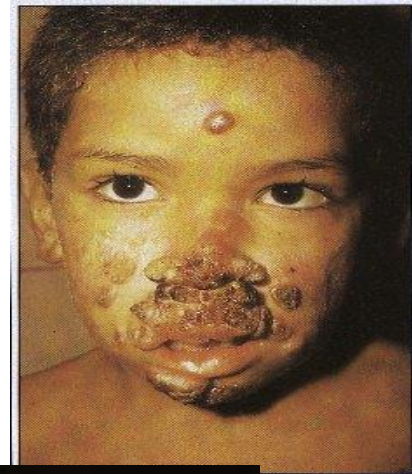
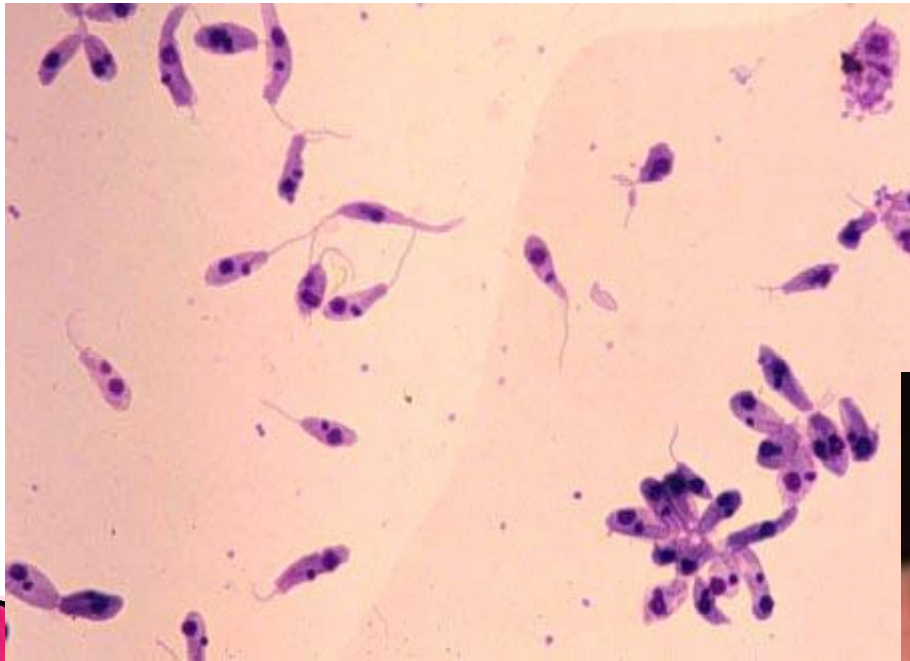
- ▶ About 25% of zooflagellates (including commensals)
- ▶ Have a **complex life cycles** and a **complex structure & function**.
- ▶ Need **intermediate hosts (vectors)** to reach the **final definitive hosts**.
- ▶ **Examples:**
- ▶ *Trypanosoma*:
 - A human parasite that causes **African sleeping sickness**.
 - Has a disc of DNA called **kinetoplast** located within a **single mitochondrion**.

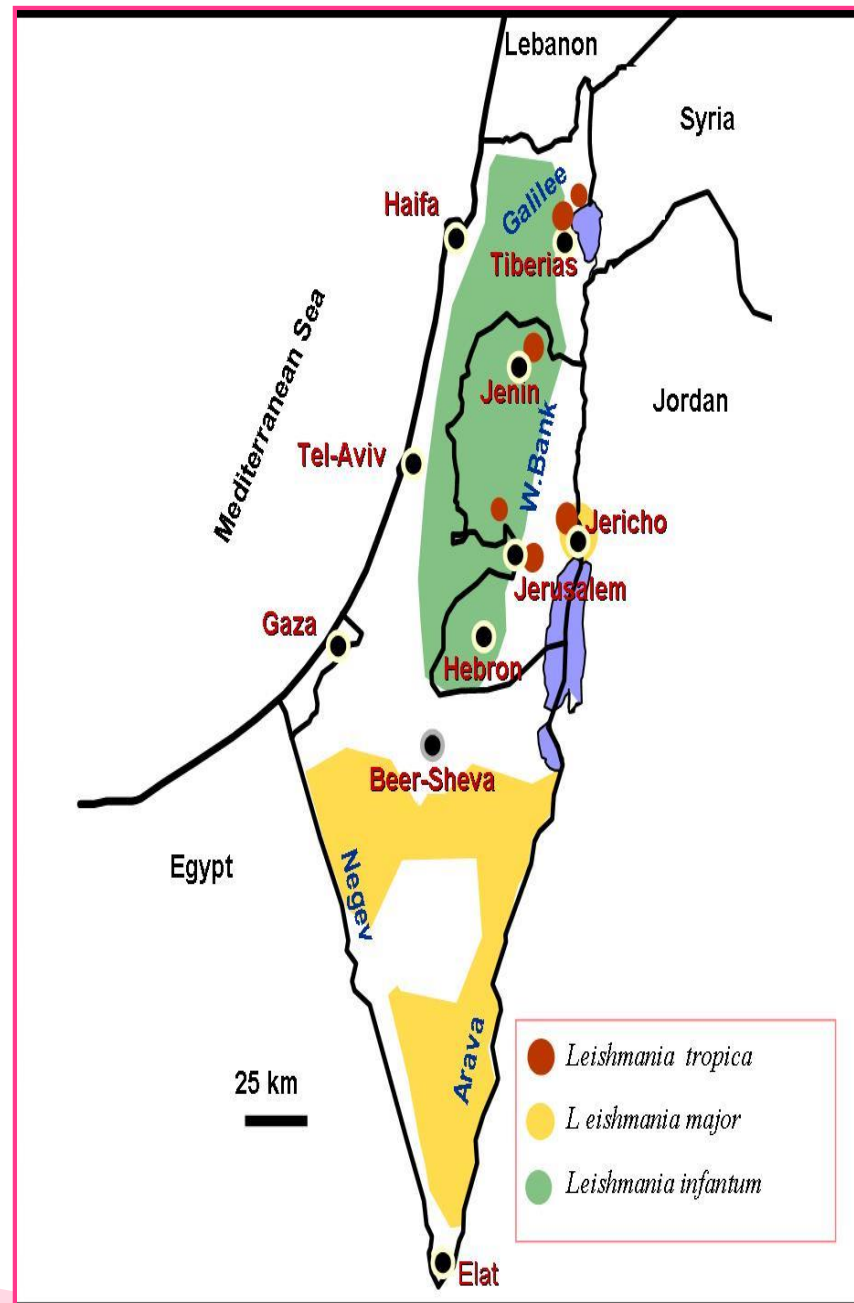
- About 15 million infections/yr.
- Transmitted by **Tsetse fly**.
- Parasite can **avoid the immune system**.



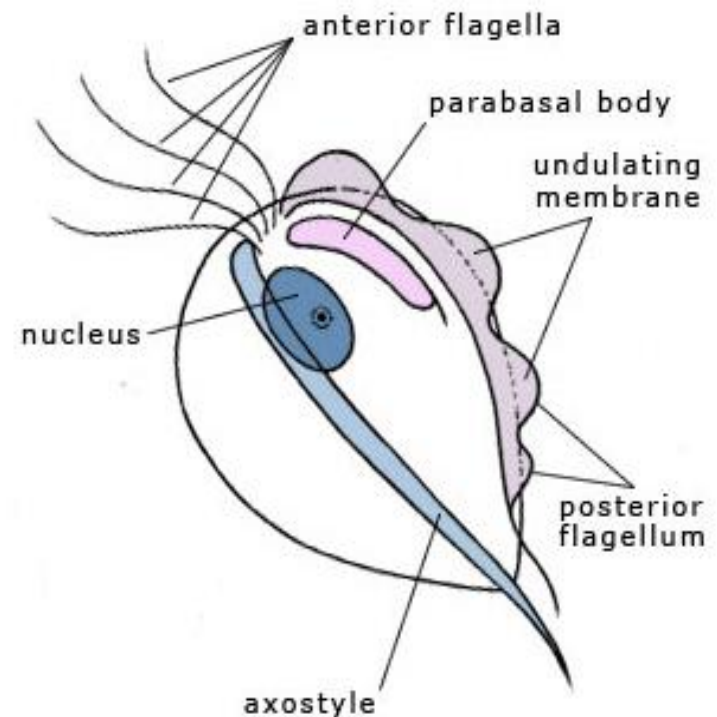
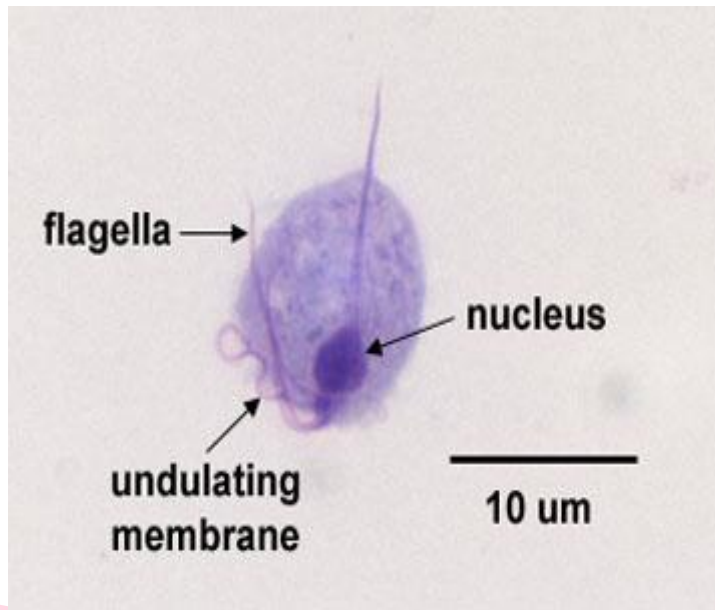
► *Leishmania donovani*:

- Causes extreme **disfigurement & death of humans** (95% death rate).
- 12,000,000 infected Worldwide.
- Transmitted by **sand fly**.
- Can change surface antigen to **avoid the immune system**.

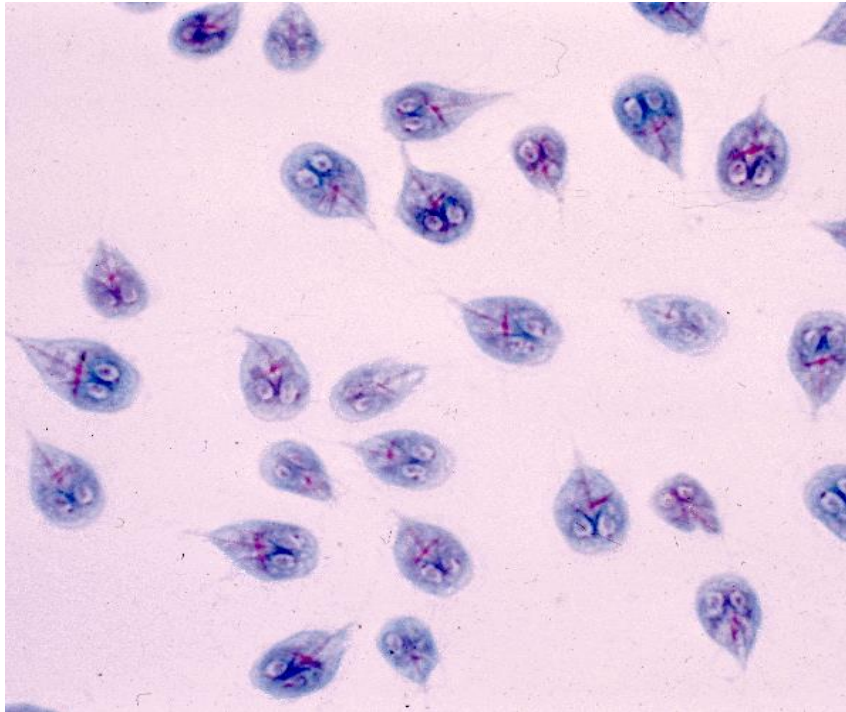




- ▶ *Trichomonas vaginalis*:
- ▶ A parasite in human **vagina, urethra & prostate**.
- ▶ Causes little or no discomfort in men, but causes **considerable inflammation and irritation in women**.



- ▶ *Giardia lamblia*:
- ▶ Causes **intense nausea, diarrhea** and **cramps in humans**.
- ▶ Infection is through drinking contaminated water.



Classification summary:

The Alveolata

Phylum Ciliophora. Examples: *Paramecium*,
Stentor, *Vorticella*.

Phylum Dinozoa. Example: Dinoflagellates like
Ceratium.

Phylum Apicomplexa. Example Malaria
parasite; *Plasmodium*.

The Amoebozoa

The Gymnamoeba. Example: *Amoeba*;
Entamoeba.

The Rhizaria

Phylum Foraminifera. Examples: Foramineferal shells.

Phylum Radiozoa. Examples: Radiolarian shells.

The Excavata

Phylum Parabasalia: Examples: Trichomonas;
Trichonympha.

Phylum Euglenozoa. Examples: Euglena;
Trypanosoma;
Leishmania.

Phylum Heterolosea: Example: Giardia.

End of Chapter