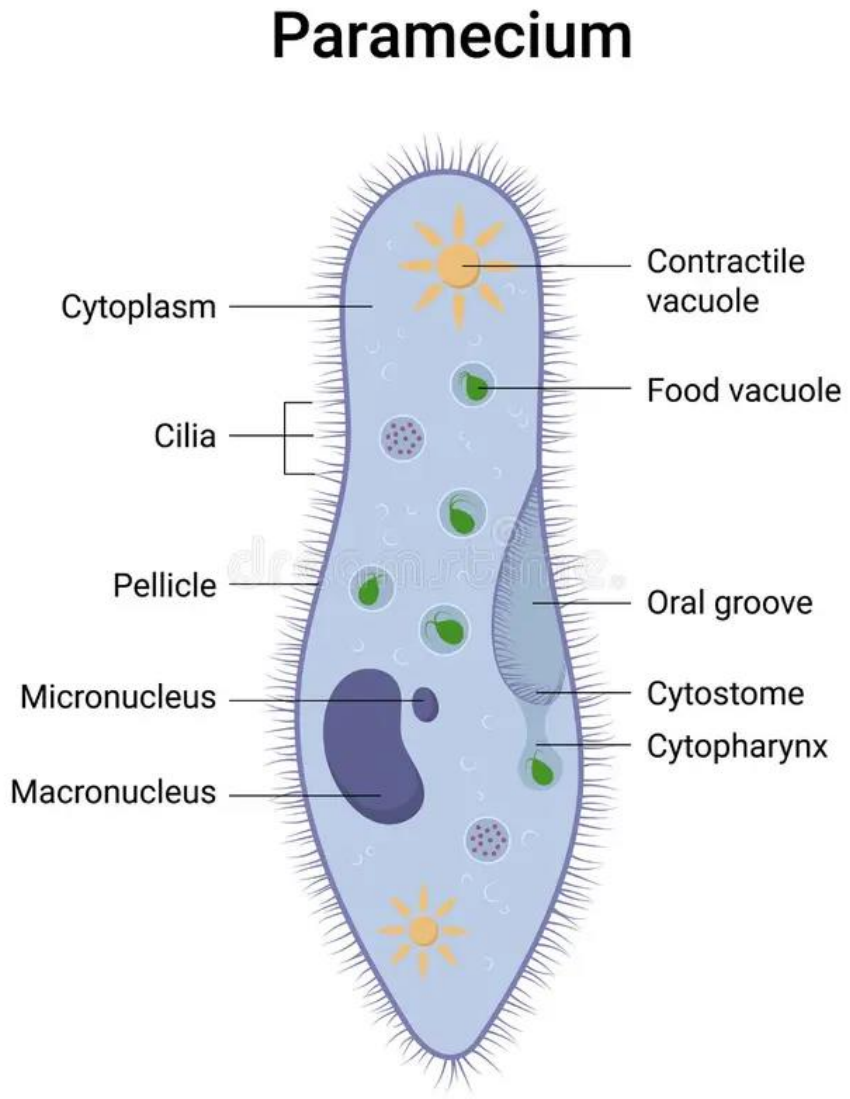
Paramecium

- *Paramecium* is a microscopic and unicellular organism commonly studied as a representative of ciliate protists.
- It is visible to the naked eye as a minute, elongated, slipper-shaped body, which gives it the common name "slipper animalcule."
- *Paramecium* belongs to the group of ciliates, which are characterized by the presence of cilia, nuclear dimorphism, and a unique form of sexual reproduction.
- The genus *Paramecium* is divided into two main groups based on morphology and physiology: the *aurelia* group and the *bursaria* group.



Systematic Position

Kingdom: Protista

Phylum: Protozoa

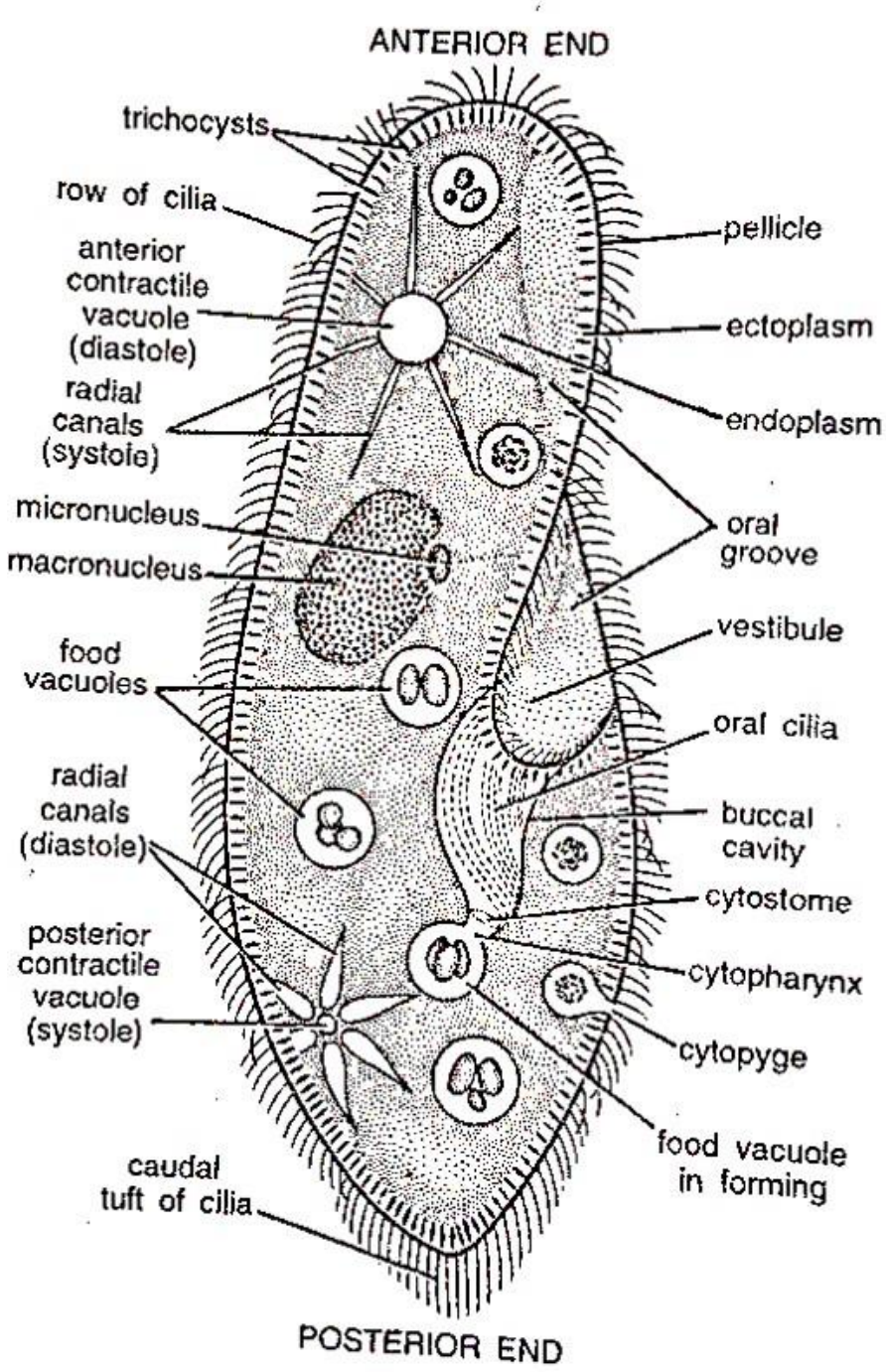
Sub-phylum: Ciliophora

Class: Ciliata

Genus: *Paramecium*

Species: *caudatum*

Common Name: Slipper animalcule



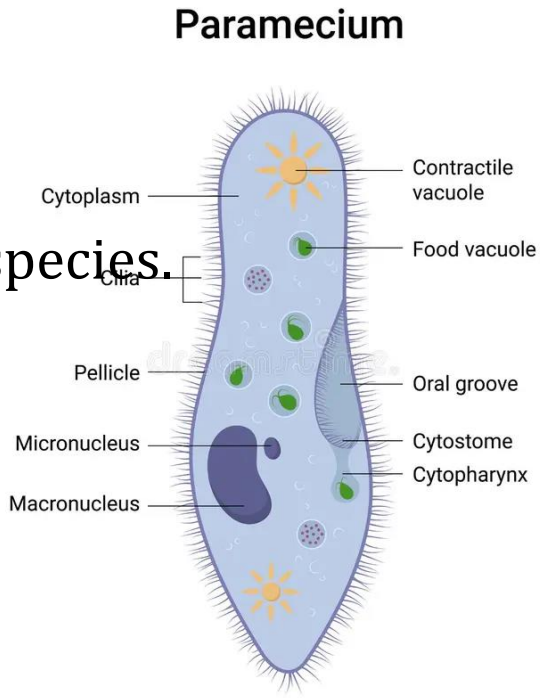
Habit and habitat

- Paramecium is a free-living freshwater ciliate found in ponds, rivers, ditches, rice fields, and other stagnant waters rich in organic matter.
- It actively swims using cilia and captures food from its surroundings.
- It thrives abundantly in stagnant waters where organic debris and microorganisms are plentiful.
- Approximately 10 known species of Paramecium exist, differing in size, shape, and number of micronuclei.

Morphology and structure

Body Shape and Size

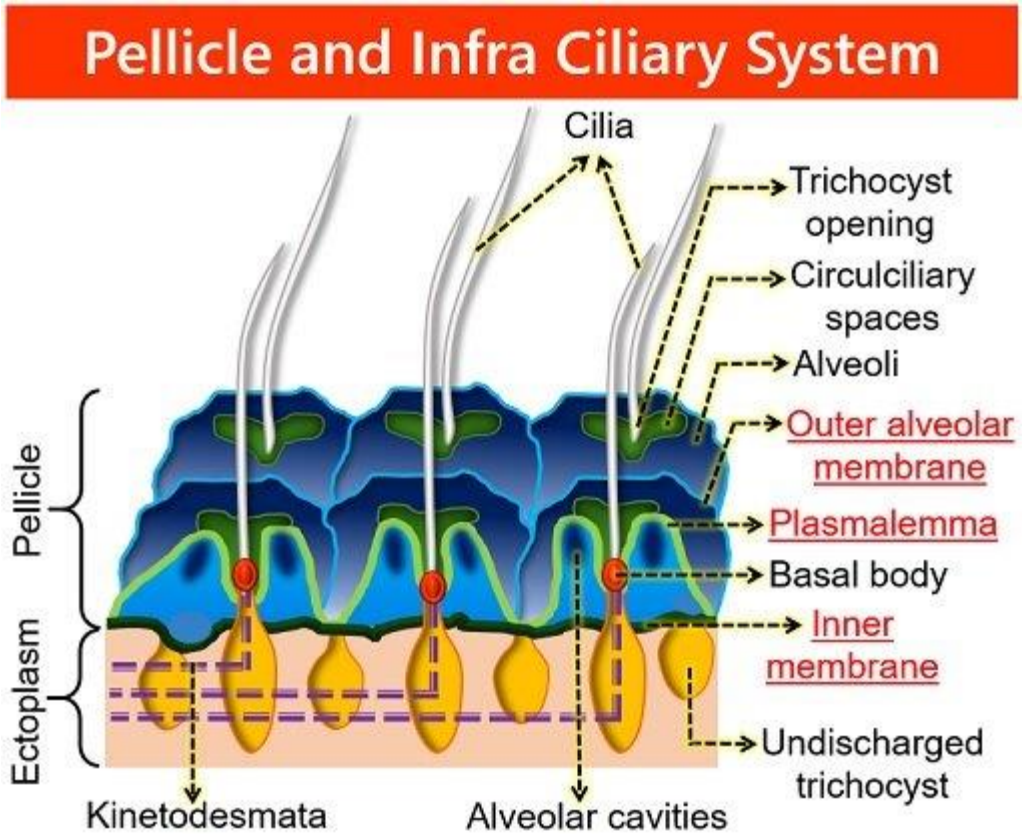
- The body is streamlined with a blunt, rounded anterior end and a thick, pointed posterior end.
- It is asymmetrical, showing a clear differentiation between the oral (ventral) and aboral (dorsal) surfaces.
- *Paramecium* is slipper-shaped, hence the name "slipper animalcule."
- The size of *Paramecium* ranges from 0.06 mm to 0.3 mm depending on species.
  - *P. caudatum:* 0.15 – 0.33 mm
  - *P. aurelia:* 0.12 – 0.25 mm
  - *P. trichium:* 0.06 mm



Morphology and Structure

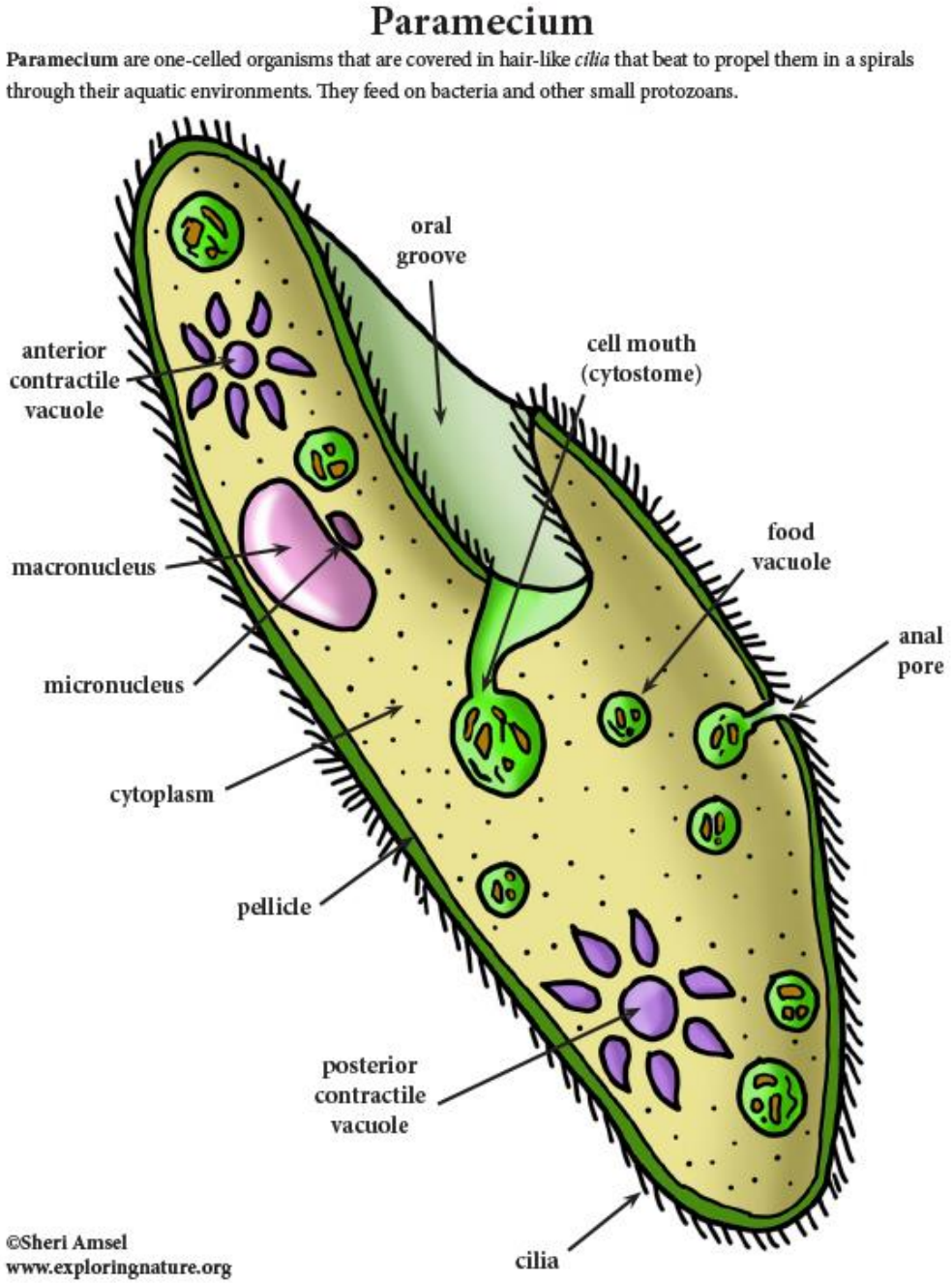
External Structures

- The body is covered by a flexible, elastic, and transparent membrane known as the pellicle, which maintains its shape.
- The pellicle has a pattern of hexagonal depressions, each with a central pore through which a single cilium emerges.
- Openings of trichocysts are located at the anterior and posterior margins of the hexagonal depressions.



External Structures....

- The oral groove or buccal groove is a large '8'-shaped depression on the ventral side that leads into the cytopharynx.
- The oral groove consists of the vestibule, cytostome (mouth), and cytopharynx, forming the feeding apparatus.
- The cytopyge or cytoproct is a permanent anal spot used for egestion of undigested food.
- The entire body surface is covered with numerous, uniformly sized cilia arranged in longitudinal rows.
- Cilia at the posterior end are longer and form a caudal tuft, characteristic of *P. caudatum.*



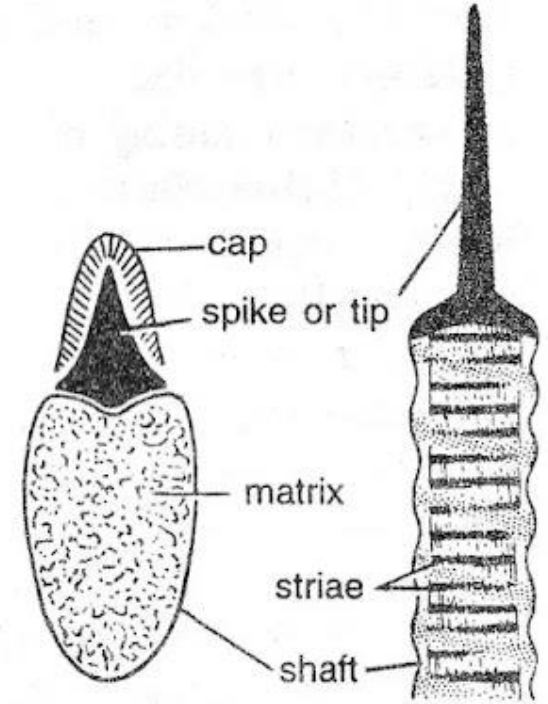
Internal Structures

Ectoplasm

- The outer layer of the cytoplasm is called ectoplasm or cortex.
- It is a clear, dense, thin layer containing trichocysts, cilia bases, and bounded externally by the pellicle.

Trichocysts

- Trichocysts are tiny, spindle- or bottle-shaped organelles embedded in the ectoplasm.
- They are oriented perpendicularly to the body surface and open externally via small pores.
- A trichocyst consists of a cap, spike (head), and shaft filled with dense, refractive material.
- Discharge is triggered by mechanical, chemical, or electrical stimuli.
- Discharged trichocysts appear as long, sticky, nail-like threads and may function in defense, offense, or adhesion.



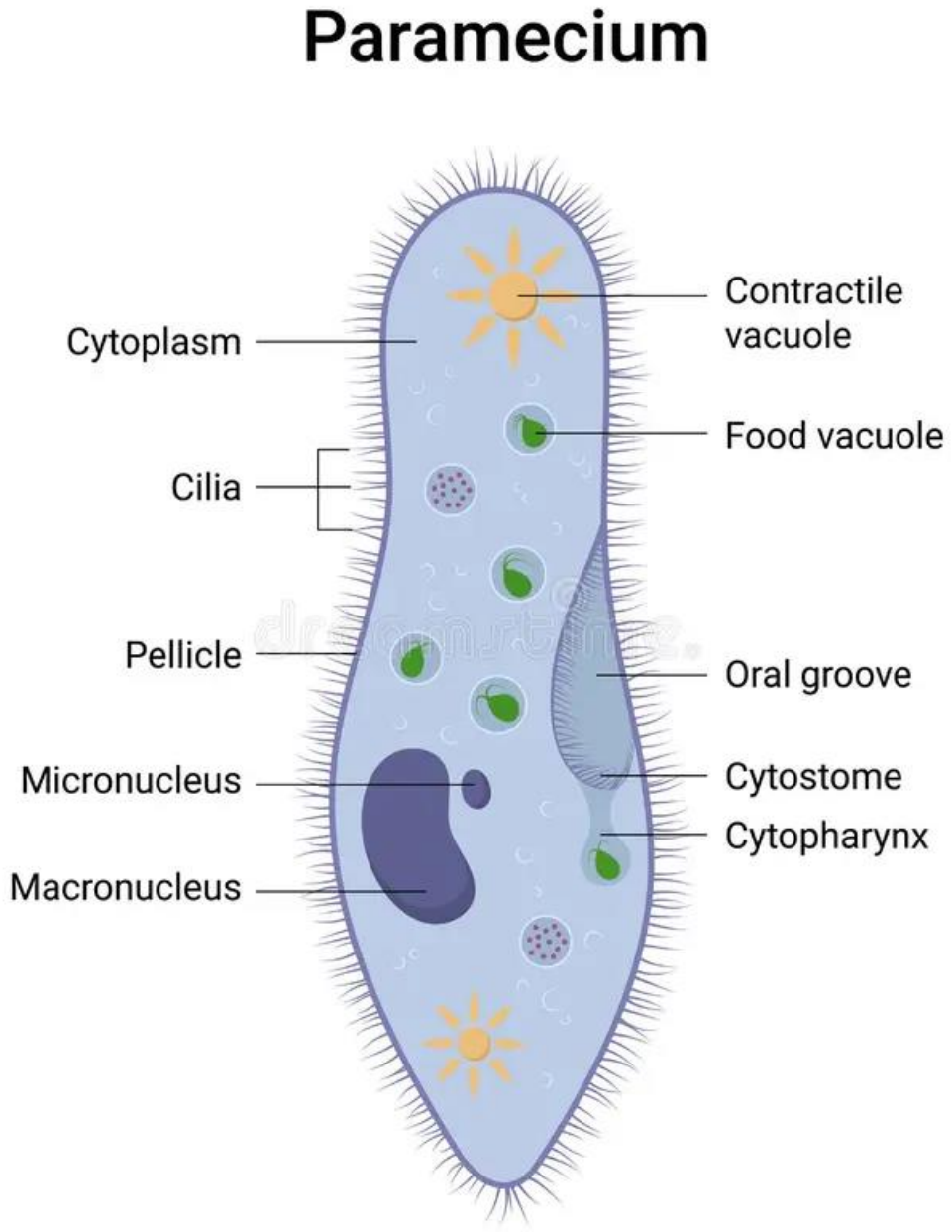
Internal Structures…

Endoplasm

- The inner, granular region of the cytoplasm is the endoplasm.

Nuclear Apparatus

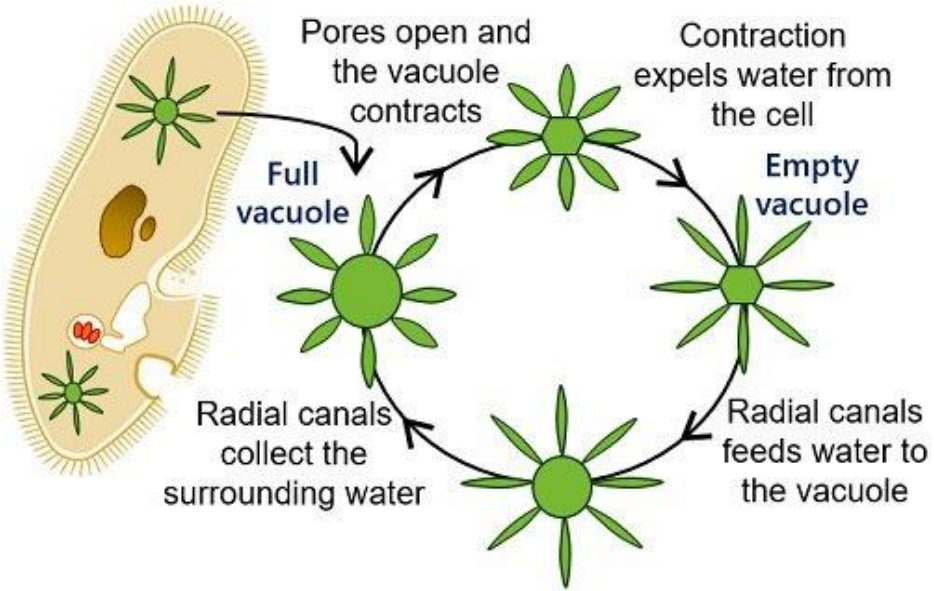
- Paramecium exhibits nuclear dimorphism and is heterokaryotic (has two types of nuclei).
- The macronucleus is large, kidney-shaped, lacks a nuclear membrane, and controls metabolic functions.
- The micronucleus is small, round, has a nuclear membrane, and controls reproductive functions.



Internal Structures

Contractile Vacuoles

- Two contractile vacuoles are present on the dorsal side: one anterior and one posterior.
- These vacuoles are involved in osmoregulation and expel excess water and waste products.
- The posterior vacuole usually functions more rapidly.
- Each vacuole is surrounded by 6 to 10 radial canals.



P. caudatum

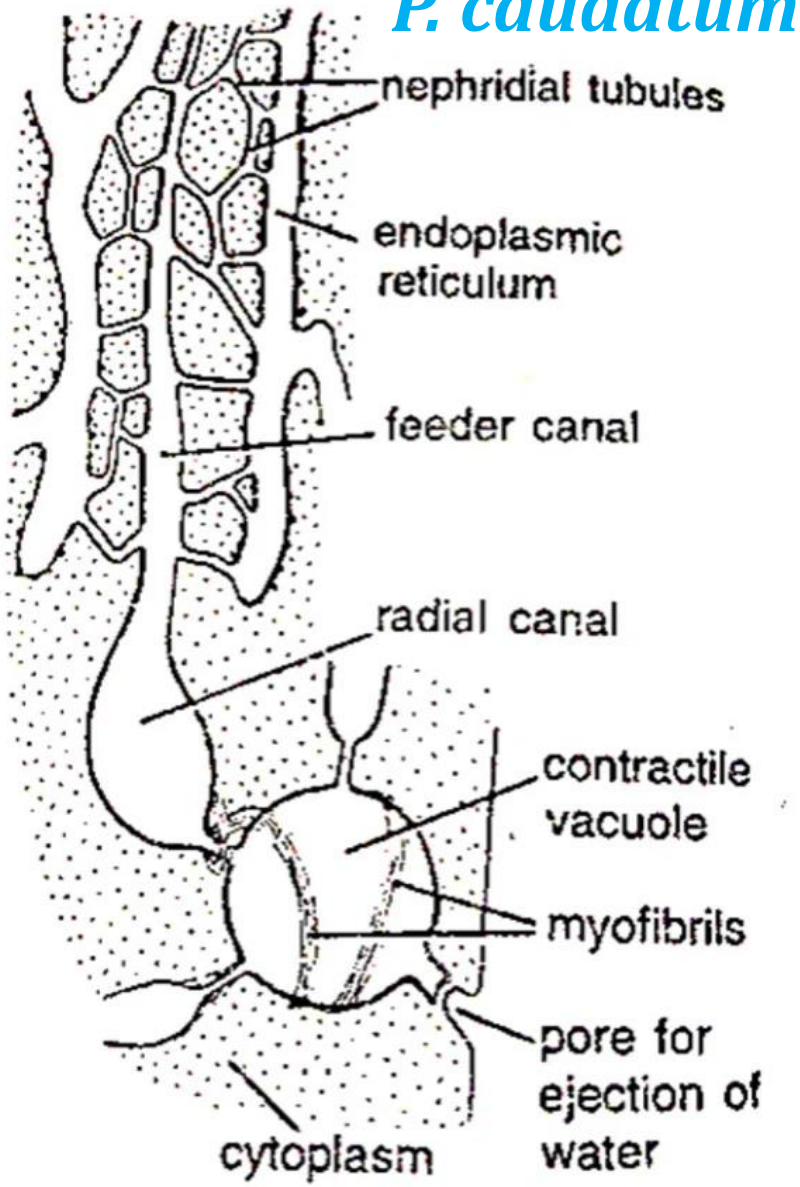


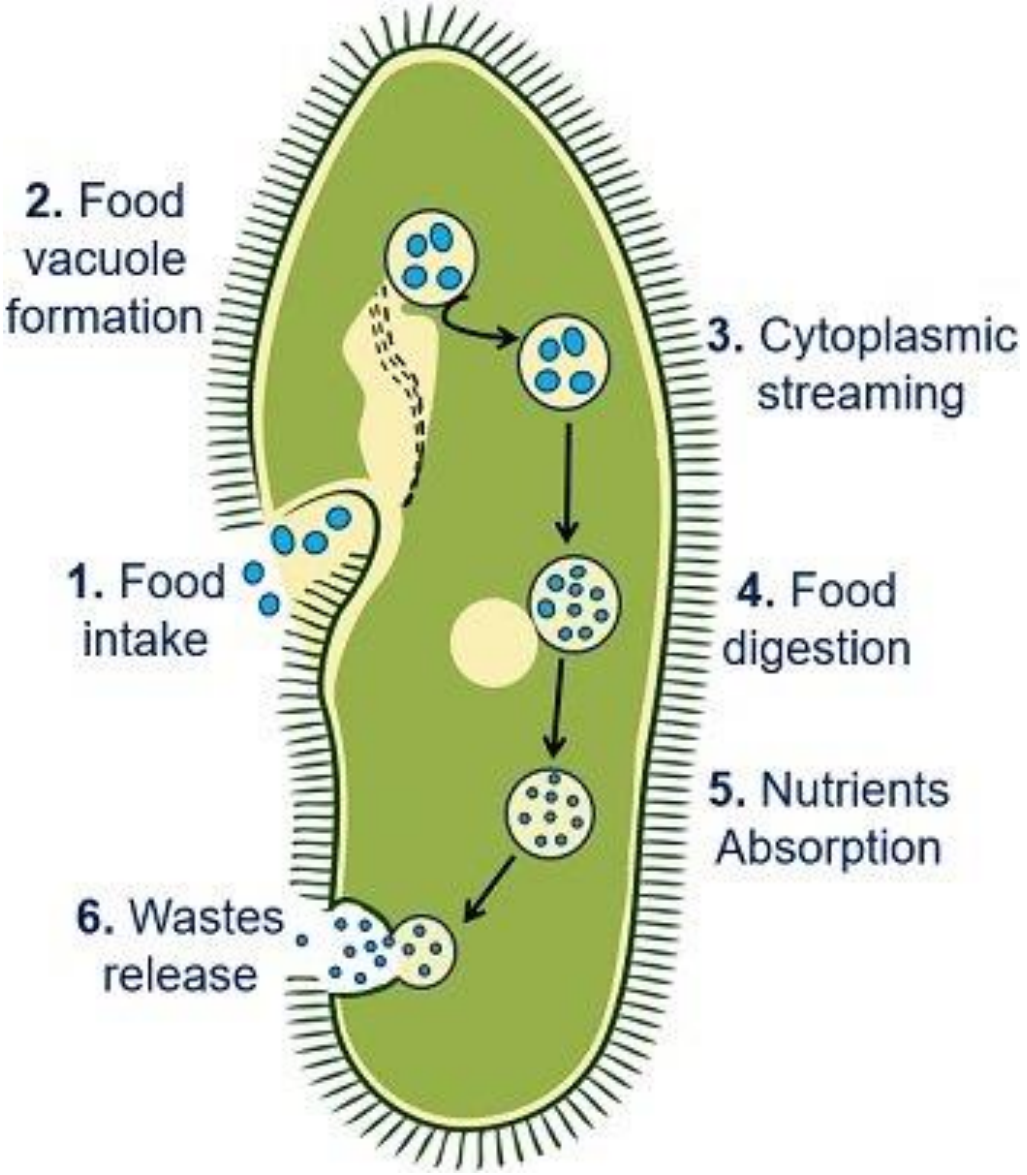
Fig. 7. *Paramecium*. Contractile apparatus.

P. caudatum

Internal Structures

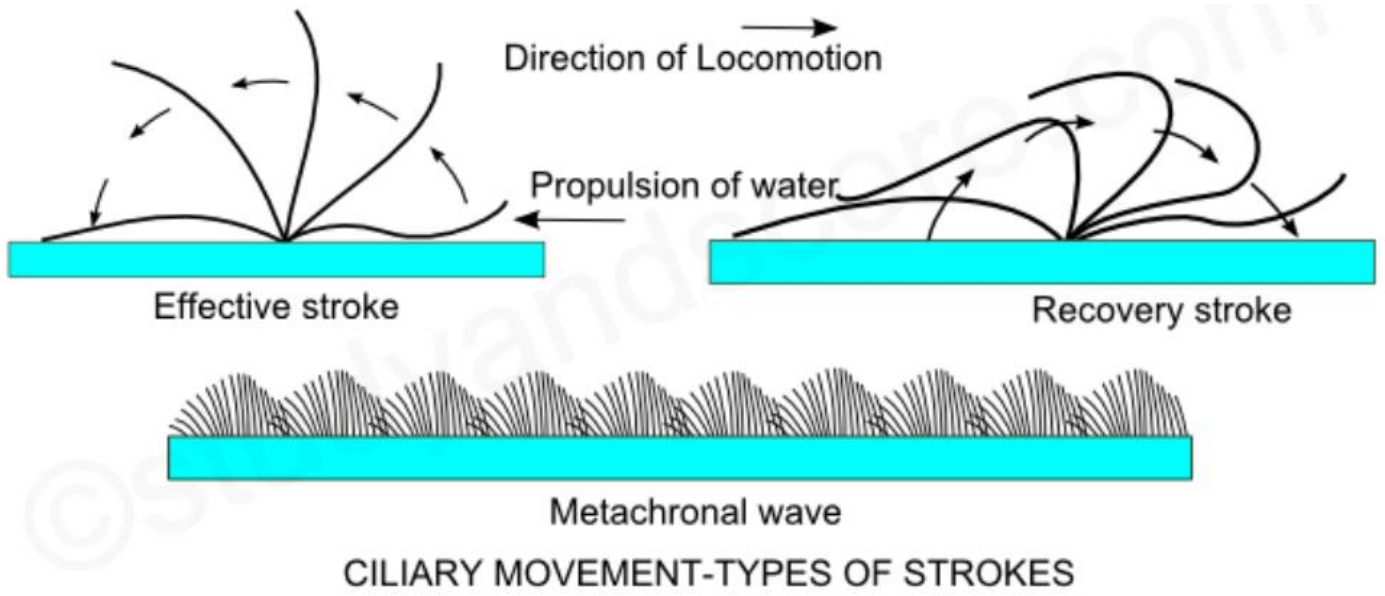
Food Vacuoles…

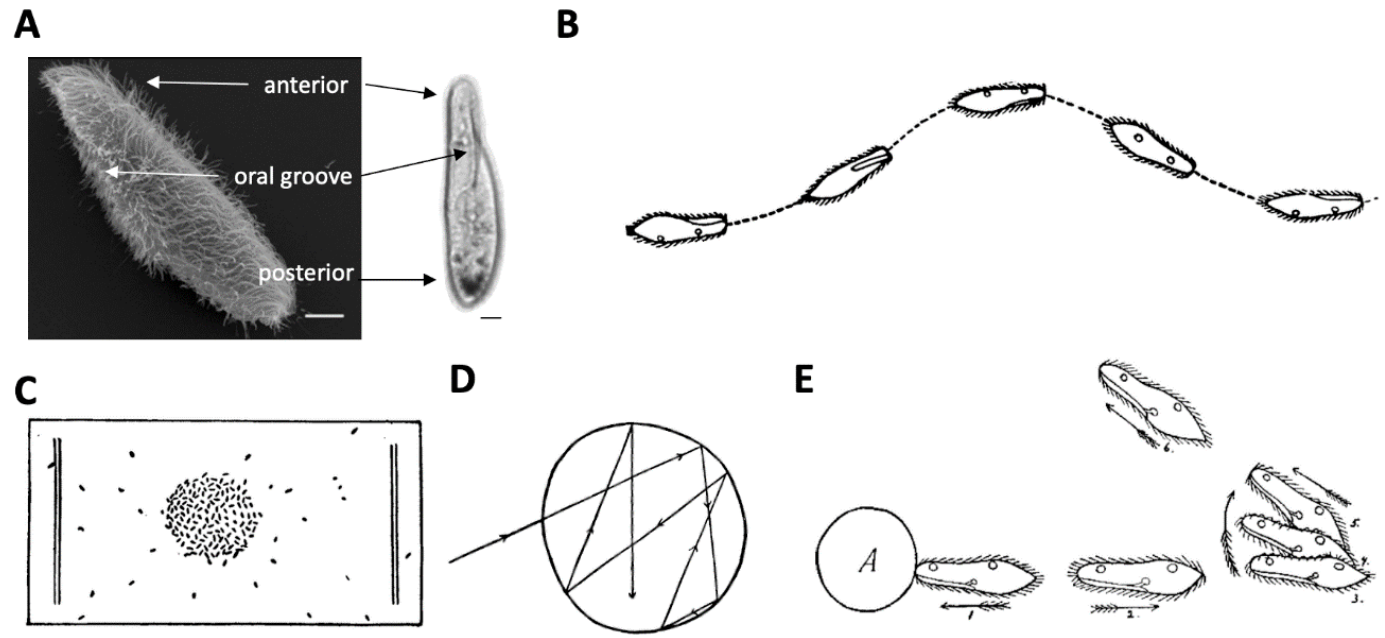
- Food vacuoles, also known as **gastrioles**, are numerous and serve as digestion sites.
- They move in the endoplasm by cyclosis, aiding in distribution of nutrients.
- The shape and size of food vacuoles change with food content.
- Digestion begins acidic and then becomes alkaline to break down proteins, carbohydrates, and fats.



Locomotion

- *Paramecium* uses cilia for movement and is coordinated by infraciliary and neuromotor systems.
- Two types of locomotion are observed:
  - **Creeping locomotion:** The organism glides along surfaces using oral cilia and flexible pellicle.
  - **Swimming locomotion:** Coordinated ciliary beats propel it forward; cilia tilt backward during movement.





Locomotion…

- **Effective stroke:** cilium bends and beats against water, propelling the body forward and pushing water backward.
- **Recovery stroke:** cilium returns to original position by moving backward with minimal resistance.
- Not all cilia move simultaneously.
  - **Synchronous rhythm:** cilia beat simultaneously in a transverse row.
  - **Metachronous rhythm:** cilia beat one after another in a longitudinal row.
- Cilia beat somewhat obliquely, not directly backward, and in a coordinated row beat towards the right, causing the animal to rotate over its long axis while swimming.
- The cilia at the oral groove strike obliquely and more vigorously to turn the anterior end away from the oral side, causing the animal to swim in a spiral or corkscrew path rather than a straight line.

P. caudatum

Nutrition

- Nutrition in Paramecium is **holozoic**, involving ingestion of solid food particles. Food include **bacteria, unicellular algae, diatoms, and yeasts.**
- Oral groove cilia generate a water current that transports food to the vestibule.
- Larger particles are rejected while smaller ones are ingested, making Paramecium a **filter feeder**.
- Food enters via cytostome into the cytopharynx, and collects at the bottom of the cytopharynx into a membranous vesicle, which pinches off as a **food vacuole**.
- The contents of food vacuoles are first acidic and then become alkaline.
- Digestion occurs intracellularly using lysosomal enzymes.
- Nutrients are circulated by cyclosis, and undigested materials are expelled via cytopyge.

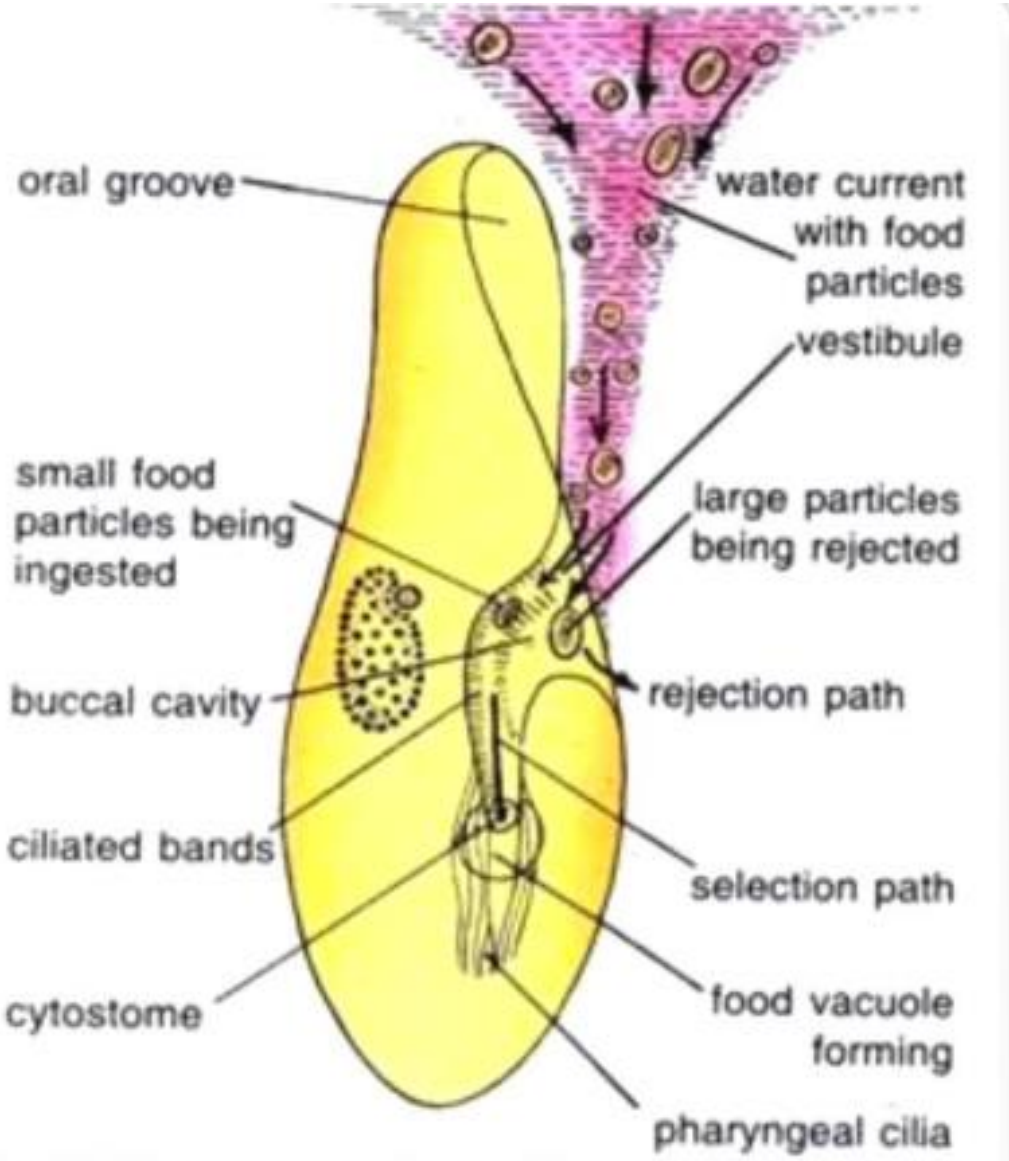
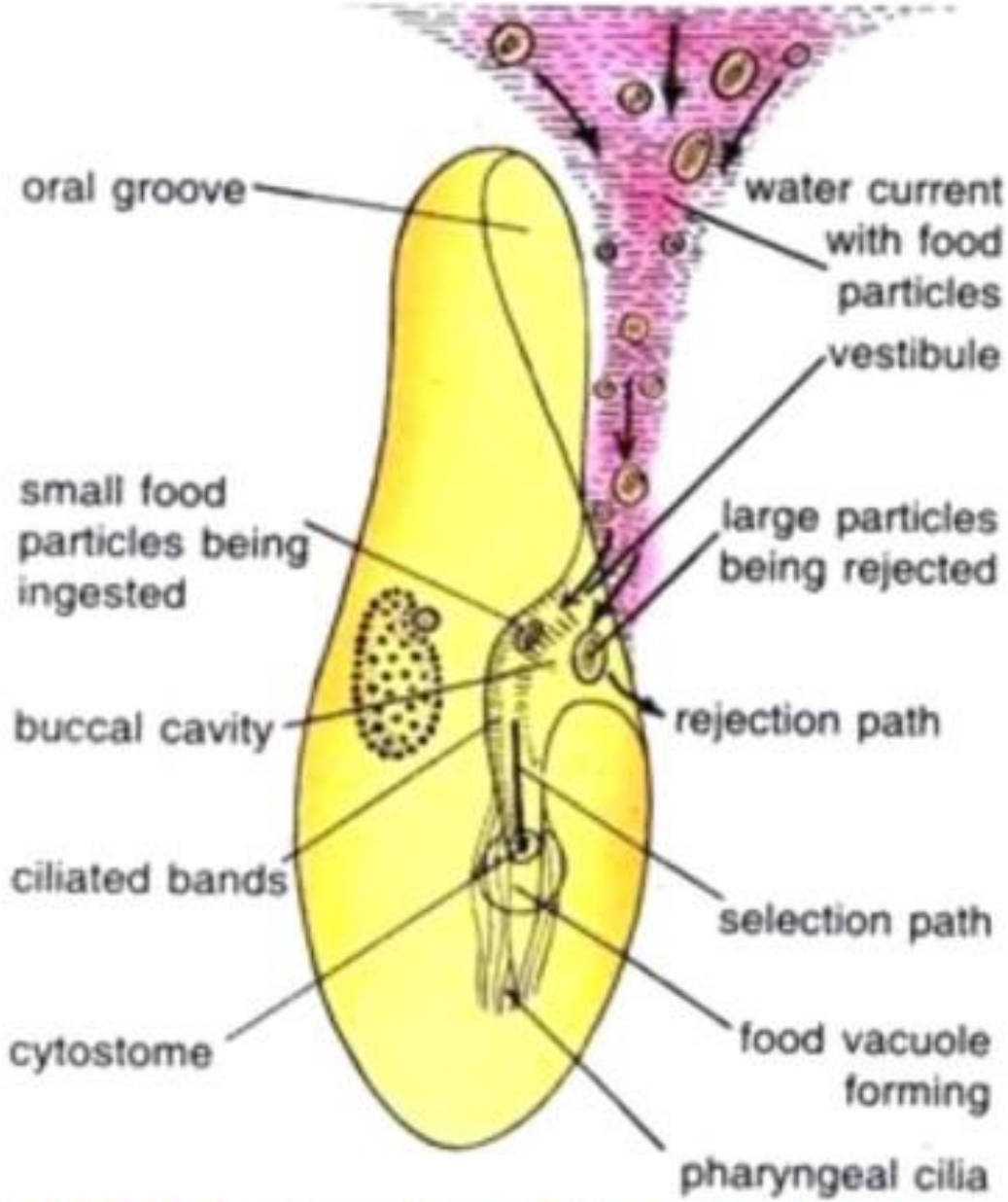


Fig. 20.16. *Paramecium*. Ciliary action creating vortex and drawing food particles into the oral groove with the water current.



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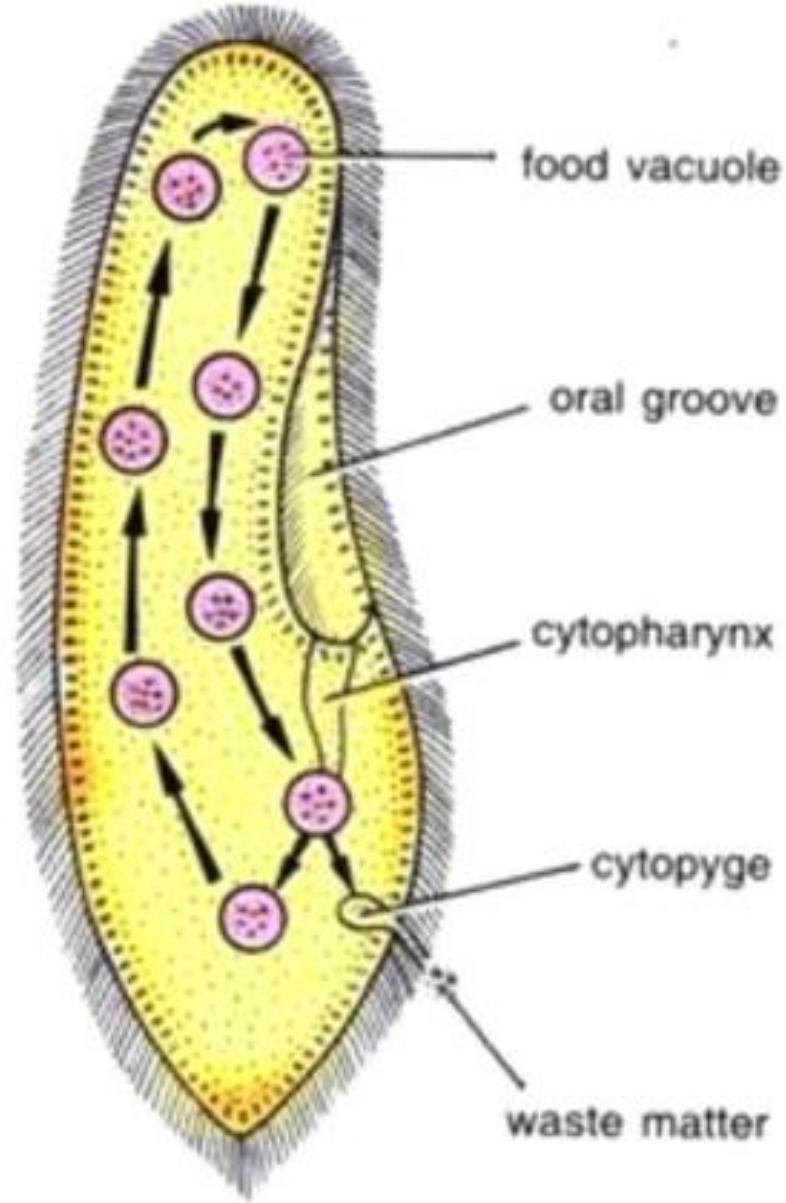


Fig. 20.17. *Paramecium*. Showing cyclosis and the course of food vacuoles in the endoplasm.

Excretion

- Excretion occurs through the general body surface and the cytopyge.
- Paramecium is ammonotelic and removes nitrogenous waste as ammonia.
- Contractile vacuoles play a role in osmoregulation:
  - **Diastole:** Water enters and vacuole expands.
  - **Systole:** Water is expelled as the vacuole contracts.

Respiration

- Gaseous exchange occurs through diffusion across the general body surface (pellicle).
- Oxygen is absorbed from water, and carbon dioxide is expelled.

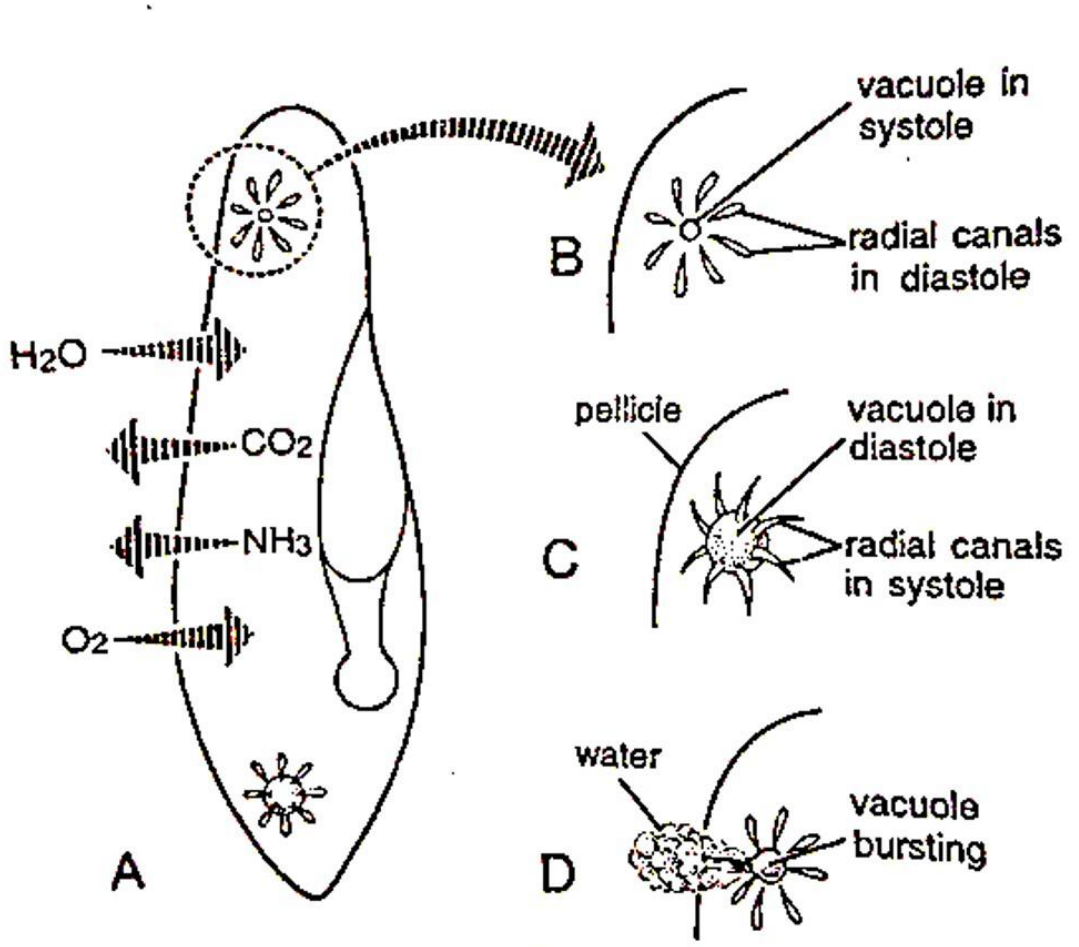


Fig. 14. *Paramecium.* Diagrammatic representation of respiration, excretion and osmoregulation.

Reproduction

- *Paramecium* reproduces both asexually and sexually.

Asexual Reproduction: By transverse binary fission

- Under favorable conditions, Paramecium reproduces rapidly by transverse or horizontal binary fission, which is at right angles to the longitudinal axis of the body.

Steps

- Paramecium stops feeding and the oral groove and buccal structures begin to disappear.
- While this happening, the **micronucleus** starts dividing by the complex process of **mitosis**, forming the spindle apparatus and chromosomal arrangement in the metaphase plate.
- Simultaneously, the **macronucleus divides amitotically** by elongation and constriction in the middle.

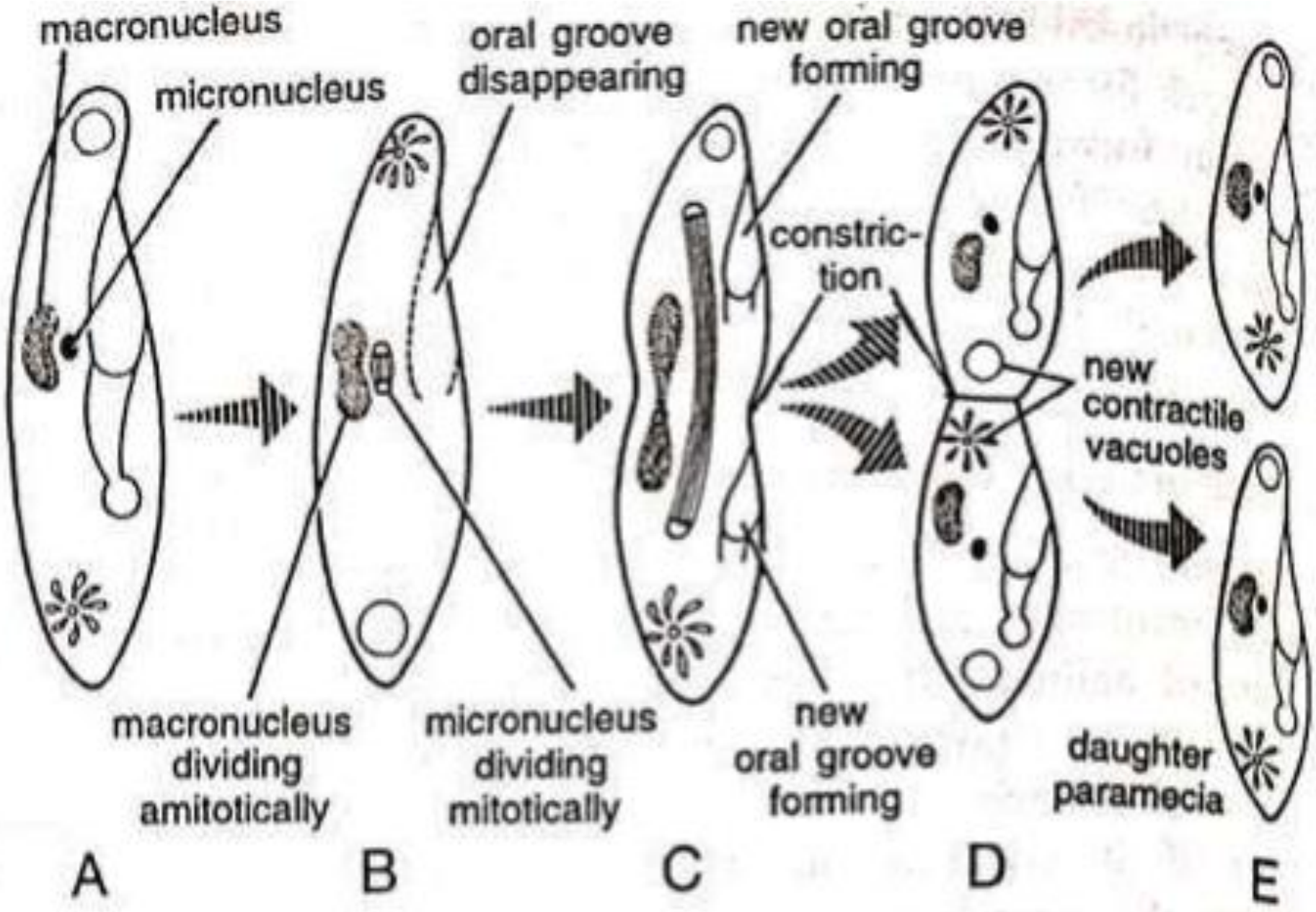


Fig. 17. *Paramecium.* Stages showing binary fission.

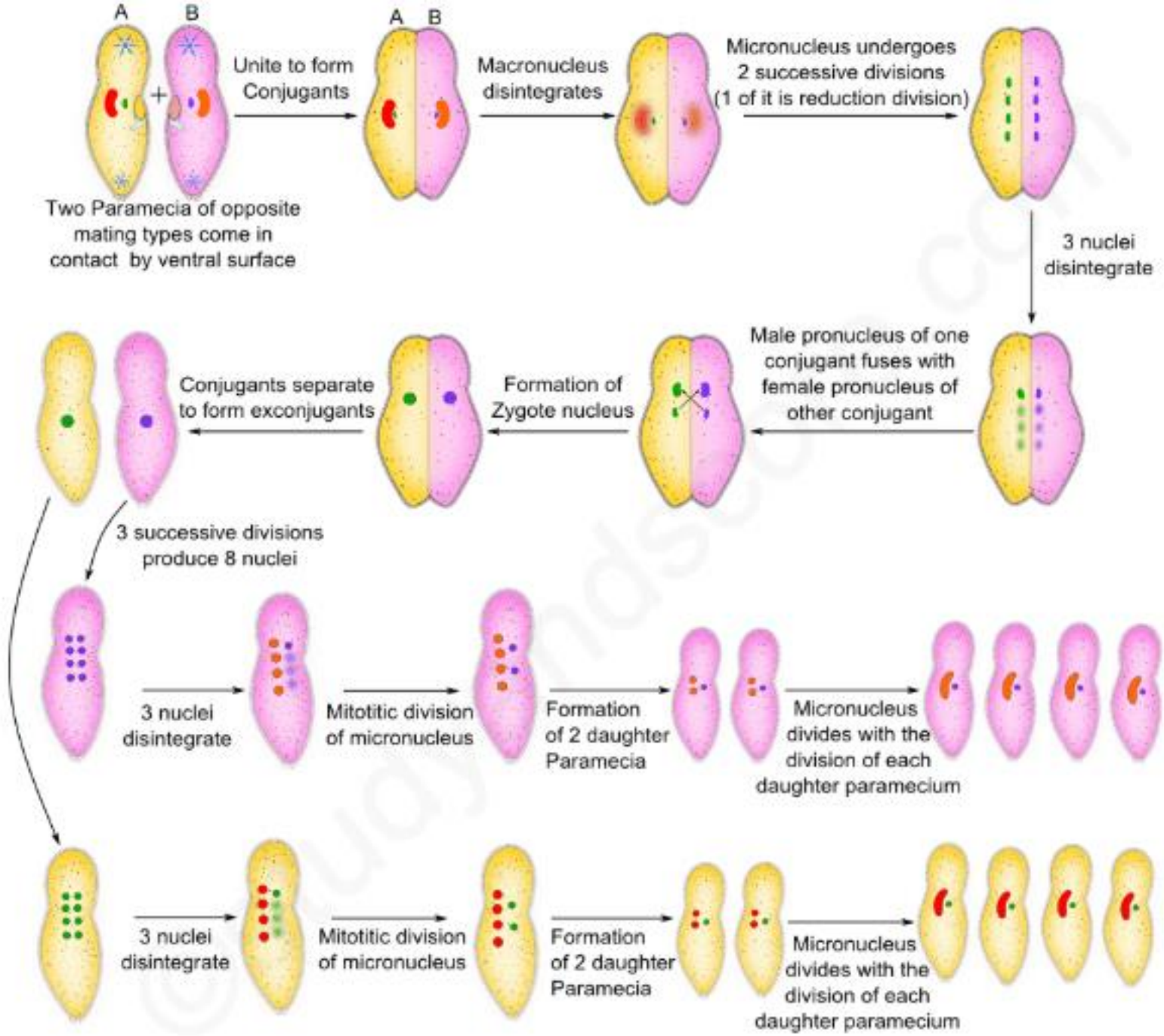
Asexual reproduction…

Steps…

- Two oral grooves begin to form: one in the anterior half and another in the posterior half of the dividing parent.
- Two original contractile vacuoles remain—one in each half of the parent cell and two new contractile vacuoles later develop in the daughter cells.
- In the mean time, a constriction furrow forms near the middle of the body. The furrow deepens and eventually divides the cytoplasm completely, resulting in two daughter Paramecia.
- Of the two daughter Paramecia, the anterior one is called the **proter**, and the posterior one is called the **opisthe**. Both daughter cells grow to full size and divide again by binary fission.
- Paramecium divides 2–3 times per day by binary fission. The entire process takes about 30 minutes, though complete separation may take an hour or more.
- All individuals produced asexually from one parent are called a **clone**. All members of a clone are genetically identical.

Sexual reproduction

- Sexual reproduction takes place by **conjugation.**
- Conjugation is the temporary union of two individuals to exchange their nuclear materials (micronucleus) which later become separate.
- Paramecia which are ready to conjugate are called **conjugants or gametocytes.**
- Sexual reproduction takes place by temporary union of two individuals which are morphologically similar and physiologically different.
- The mating partners come near each other with their ventral surface. They stop feeding and their feeding apparatus disappears.
- Both are adhered together by a sticky substance secreted by the cilia. Pellicle disappears and a cytoplasmic bridge is formed between their buccal apparatus.



STEP WISE REPRESENTATION OF CONJUGATION PROCESS IN PARAMECIUM

Sexual reproduction…

- The macronucleus disintegrates.
- The micronucleus first grows in size and then divides by meiosis thus forming four haploid nuclei.
- Out of the four haploid nuclei, three degenerate and disappear in each conjugant, while the remaining one divides by mitosis forming 2 unequal pronuclei or gamete nuclei.
- The smaller one is the active migratory gamete nucleus and the bigger one is the passive stationary gamete nucleus.
- The migratory nucleus of one conjugant then passes through the protoplasmic bridge into the other individual and fuses with its stationary nucleus, forming a single diploid zygote nucleus or **synkaryon.**
- The complete fusion of two nuclei from two different individuals forming a zygote nucleus is termed **amphimixis.**

Sexual reproduction…

- The hereditary materials of both Paramecia are transferred to each other. The protoplasmic bridge disintegrates and the two Paramecia become separate, known as **ex-conjugants**.
- In each exconjugant, the zygote nucleus divides by mitosis three times in rapid succession producing 8 nuclei, of which 4 enlarge to become macronuclei and the other 4 become micronuclei.
- Three micronuclei disintegrate and disappear, while the remaining micronucleus divides, with binary fission of exconjugant.
- Thus, from each exconjugant two daughter paramecia are obtained, each containing 2 macronuclei and one micronucleus.
- The micronucleus again divides with the division of each daughter *paramecium*, forming two individuals each containing one macronucleus and one micronucleus.
- Thus, each conjugant produces four daughter individuals at the end of conjugation. In this way, eight Paramecia are formed after conjugation.

Significance of Conjugation

Rejuvenation:

- In conjugation old, weak and defective macronucleus is replaced by new one which can control metabolism growth and the environment. Because of this paramecium is rejuvenated i.e. it gains the previous vigor.

Multiplication:

- *Paramecium* multiplies through conjugation and produces 8 daughter paramecia from two conjugants.

Genetic variation:

- In conjugation, genetic materials are exchanged between Paramecia of opposite mating types. It brings variation in daughter individuals due to genetic recombination.

Nuclear Reorganization:

- In conjugation new and metabolically active macronucleus is produced by reorganization of micro nuclear materials.

Autogamy

- Self-fertilization via fusion of pronuclei in the same individual.
- Macronucleus breaks down; micronuclei divide meiotically and mitotically to form 8 haploid nuclei.
- Seven micronuclei degenerate; one divides into male and female pronuclei.
- Pronuclei fuse to form diploid synkaryon, which divides twice, producing two daughters.
- Each of them receives one macronucleus by distribution and two micronuclei by their division.
- Autogamy rejuvenates Paramecium. Example: *Paramecium aurelia.*

Endomixis

- Internal nuclear reorganization without conjugation.
- Macronucleus disintegrates; micronuclei divide by mitosis into 8 nuclei.
- Out of these nuclei, 6 or 7 disintegrate. Now, the animal itself divides into two daughters, each receiving a single nucleus.
- This nucleus divides into 4 daughter nuclei, of which two become macronuclei and two become micronuclei.

Cytogamy

- Sexual process without nuclear exchange.
- Small Paramecia unite by oral surfaces temporarily.
- Male and female pronuclei of same individual fuse like autogamy.

Hemixis

- Reconstitution of macronucleus without micronucleus involvement.
- Purifies and increases metabolic function of the nucleus.