General Characteristics of phylum Protozoa

1. **Kingdom:** Protista.
2. They are known as acellular or non-cellular organism. A protozoan body consists of only mass of protoplasm, so they are called acellular or non-cellular animals.
3. **Habitat:** mostly aquatic, either free living or parasitic or commensal
4. **Grade of organization:** protoplasmic grade of organization. Single cell performs all the vital activities thus the single cell acts like a whole body.
5. Body of protozoa is either naked or covered by a pellicle.
6. **Locomotion:** Locomotory organ are pseudopodia (false foot) or cilia or absent.
7. **Nutrition:** Nutrition are holophytic (like plant) or holozoic (like animal) or saprophytic or parasitic.
8. **Digestion:** digestion is intracellular, occurs in food vacuoles.
9. **Respiration:** through the body surface.
10. **Osmoregulation:** Contractile vacuoles helps in osmoregulation.
11. **Reproduction:**

- Asexually reproduction is through binary fission or budding.
- Sexual reproduction is by syngamy conjugation.

Classification of Protozoa:

- Phylum protozoa is classified into four classes on the basis of locomotary organs

Class 1 Rhizopoda

- **Locomotary organ:**
- Mostly free living, some are parasitic
- **Reproduction:** asexually by binary fission and sexually by syngamy.
- No conjugation.
- Examples: *Amoeba, Entamoeba*

Class 2 Mastigophora/ Flagellata

- Locomotory organ: Flagella
- Free living or parasite.
- Body covered with cellulose, chitin or silica.
- Reproduction: A sexual reproduction by longitudinal fission.
- No conjugation.
- Examples: *Giardia, Euglena, Trypanosoma*

Class 3 Sporozoa

- Locomotory organ: Absent
- Exclusively endoparasites
- Contractile vacuoles is absent
- Body covered with pellicle.
- Reproduction: Asexual reproduction by fission and Sexual reproduction by spores
- Examples: *Plasmodium, Monocystis*

Class 4 Ciliata

- locomotary organ: Cillia
- Body covered by pellicle.
- Reproduction: Asexual reproduction by binary fission. Sexual reproduction by conjugation.
- Nuclei two types i.e. macronucleus and micronucleus.
- Examples: *Paramecium, Voricella, Blantidium*

General characteristics of Phylum Porifera

1. **Kingdom:** Animalia
2. **Habitat:** Aquatic, mostly marine, few are terrestrial
3. **Habit:** They are solitary or colonial.
4. **Grade of organization:** cellular grade of body
5. **Shape:** Body shape is variable, mostly cylinder shaped
6. **Symmetry:** Asymmetrical or radially symmetrical.
7. **Germ layer:** Diploblastic animals. The adult body wall contains two layers, outer dermal layer and inner gastral layer. In between these two layers, there is a gelatinous and non-cellular mesoglea containing numerous free amoeboid cells.
8. **Coelom:** Absent; acoelomate but spongocoel is present
9. Surface of the body has numerous perforation called ostia (for the entry of water) and a large pore at the apex called osculum (for the exit of water).
10. Water canal system present
11. **Endoskeleton**: Either calcareous spicules (calcium carbonate) or siliceous spicules (silica) or sponging fibers (protein).
12. **Nutrition:** holozoic
13. **Digestion:** Intracellular
14. **Nervous system:** absent
15. **Circulatory system:** absent

16. **Reproduction: Asexual:** by budding or gemmule or regeneration; **Sexual: g**amatic fusion
17. **Fertilization:** Internal

Classification of Phylum Porifera

Based on the type of skeleton system the phylum Porifera is divided into three classes

- Class 1: Calcarea or Calcispongiae
- Class 2: Hexactinellida or Hyalospongiae.
- Class 3: Demospongiae

Class 1: Calcarea or Calcispongiae

(calcarius: lime / calcium))

- Habitat: Exclusively marine
- Habit: Solitary or colonial nature.
- Endoskeleton: calcareous spicules composed of calcium carbonate
- Symmetry: Radially symmetry
- Shape: Cylindrical shape
- Examples: Sycon, *Leucosolenia*

Class 2: Hexactinellida or hyalospongiae:

(Hex: six, actin: ray, idea: terminal)

- Habitat: Exclusively marine (deep sea)
- Habit: Solitary in nature.
- Endoskeleton: six- rayed siliceous spicules.
- Symmetry: Radially symmetry
- Shape: Cylindrical shape.
- Examples: *Euplectella, Hyalonemma*

Class 3: Demospongiae

(Demos: frame)

Habitat: Mostly marine and some are freshwater
Endoskeleton: Siliceous spicules or sponging fibres or both or none
The spicules are monaxon or tetraxon but never six-rayed
Symmetry: asymmetrical.
Shape: Irregular
Canal system complicated.
Spongocoeal is totally absent.

Examples: *Spongilla*.

Characteristics of Coelenterata

- These are mostly aquatic or marine habitat animals.
- These species exhibit a tissue-level organization.
- The mouth is enclosed by thin and short tentacles.
- They are diploblastic animals, in which, the body is made up of two layers of cells:

1. Ectoderm – One layer makes up the cells outside the body
2. Endoderm – the other forms the inner lining of the body.

- They have cavities in their body.
- The body is radially symmetrical.
- The digestion is both intracellular and extracellular.
- The nervous system and the circulatory system is absent.
- They excrete and respire through simple diffusion.
- The mode of reproduction is asexual, which is through budding.

- The sexual mode of reproduction is seen only in a few Coelenterates.

E.g., Hydra, Rhizostoma, Xenia, etc.

Classification of Coelenterata

Coelenterates are classified into three different classes:

- Anthozoa
- Hydrozoa
- Scyphozoa

Hydrozoa

- These are mostly marine species, found exclusively in freshwater.
- Few are found in colonies and few are found solitarily.
- Asexual Polyps is the dominant form.
- Mesogloea is acellular.

E.g., Hydra, Obelia

Scyphozoa

- They are found exclusively in the marine environment.
- Medusa is dominant and umbrella-shaped.
- Polyps are not present.
- Mesogloea is cellular.

E.g., Aurelia aurita, Rhizostoma.

Anthozoa

- They are found exclusively in the marine environment.
- Mesogloea contains fibrous connective tissues and amoeboid cells.
- Medusa is not present.

E.g., Metridium, Xenia.

Classification of Paramecium

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

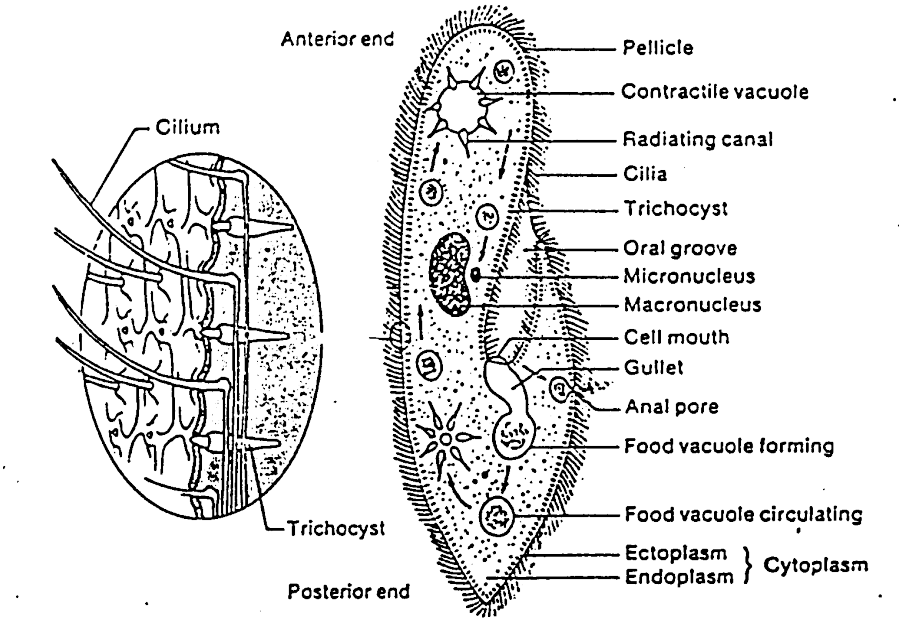
- **Phylum** Protozoa
- **Sub-Phylum** Ciliophora
- **Class** Ciliates
- **Order** Hymenostomatida
- **Genus** *Paramecium*
- **Species** *Caudatum*

    - 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

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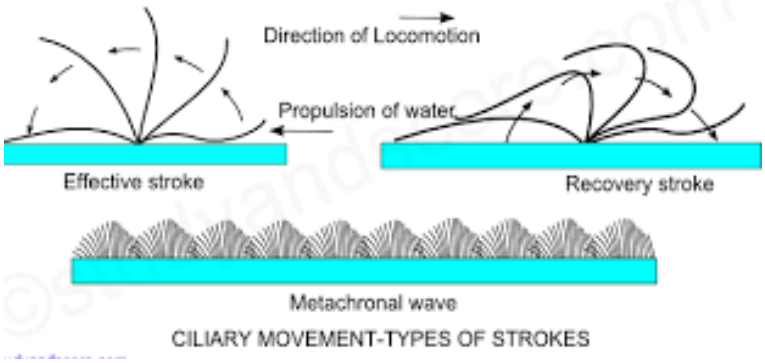
1. Habit and Habitat

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



CILIARY MOVEMENT-TYPES OF STROKES

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.

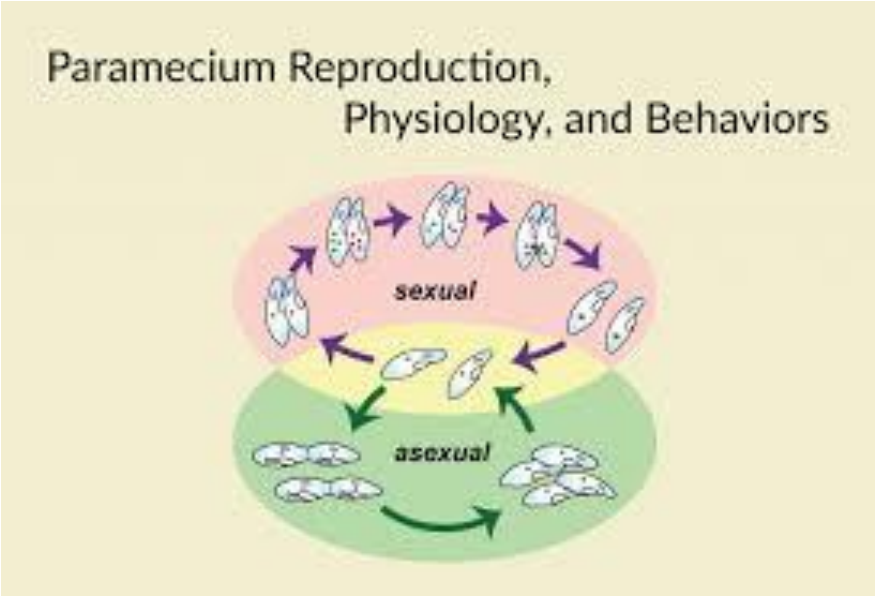
3. Symbiosis

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.

7. Learning

There have been some ambiguous results yielded, based on different experiments regarding whether or not paramecium exhibits the learning behavior.

There was a study published in 2006 which showed that *P. causatum* can be trained to differentiate between levels of brightness through a 6.5 volts electric current. For an organism with no nervous system, this type of finding is cited as a strong possible instance for epigenetic learning or cell memory.

Paramecium Locomotion

The coordinated movement of thousands of cilia propels paramecium. Paramecium can rotate around its axis and move in the reverse direction on encountering an obstacle.

The whole body of this protozoan is covered with fine protoplasmic cilia, which are arranged in definite longitudinal rows; these structures serve as its locomotive organs. The cilia beat in unison against the water in a particular direction, just like oars in a boat. For example, if the organism has to move forward, the cilia beat at a particular angle in the backward direction. This helps them to move forward, spiraling through the water around an invisible axis, in pursuit of food.

Paramecium generally thrusts itself forward, traveling in a straight line through the water. However, it is capable of changing its direction, when it comes in contact with a solid object or a predator. In such a case, the cilia immediately start beating in the opposite direction. This helps the paramecium to go backward, and turn in a direction away from the predator. The spiral movement or the spinning nature allows it to collect food, which is pushed by the cilia into the oral groove. They possess certain chemical sensors, which enable them to locate food sources.

Paramecium Nutrition

They are mostly heterotrophic. They feed on bacteria, algae, yeast and other microorganisms. They are holozoic. The food-laden water is drawn inside by the movement of cilia and it goes to the cytostome and to the gullet (cytopharynx).

The food gets loaded at the posterior end of cytopharynx. It gets surrounded by vacuoles, pinches off and circulates in the endoplasm. The food is acted upon by digestive enzymes present in the food vacuoles.

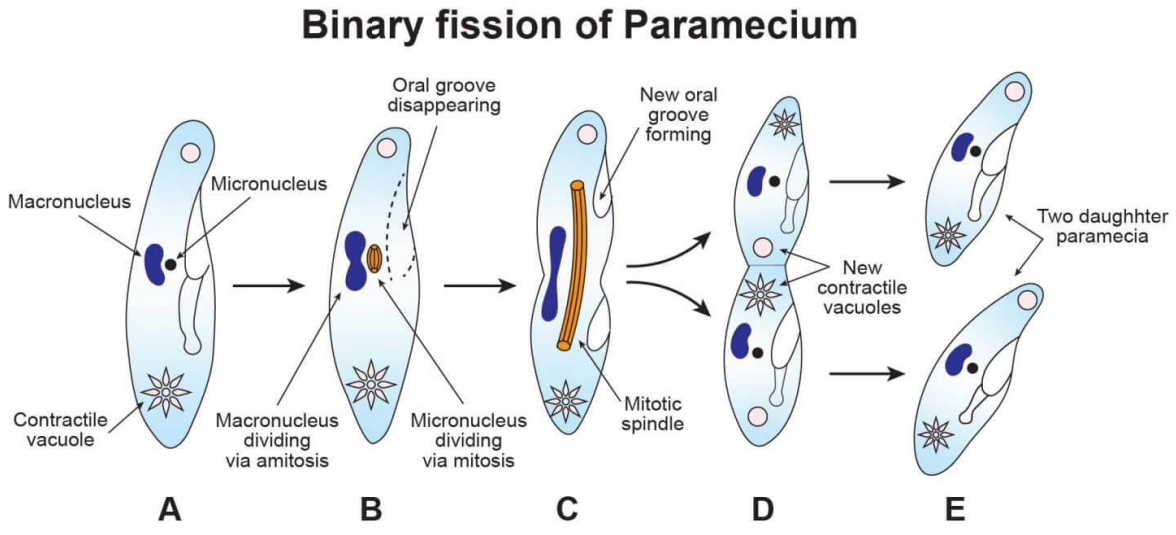
The undigested residue is egested through the temporary anal pore (cytopyge).

Some of the *Paramecium* species, e.g. *Paramecium bursaria, etc.* form a symbiotic relationship with green algae. Algae are present as an endosymbiont and provide food to paramecium by photosynthesis, in turn, the algae get a safe and protective habitat.

Paramecium may have intracellular bacteria known as **kappa particles.** Paramecium with kappa particles has the ability to kill other strains of paramecium.

Paramecium Reproduction

Asexual Reproduction in paramecium is by binary fission. The mature cell divides into two cells and each grows rapidly and develops into a new organism. Under favourable conditions, Paramecium multiplies rapidly up to three times a day.

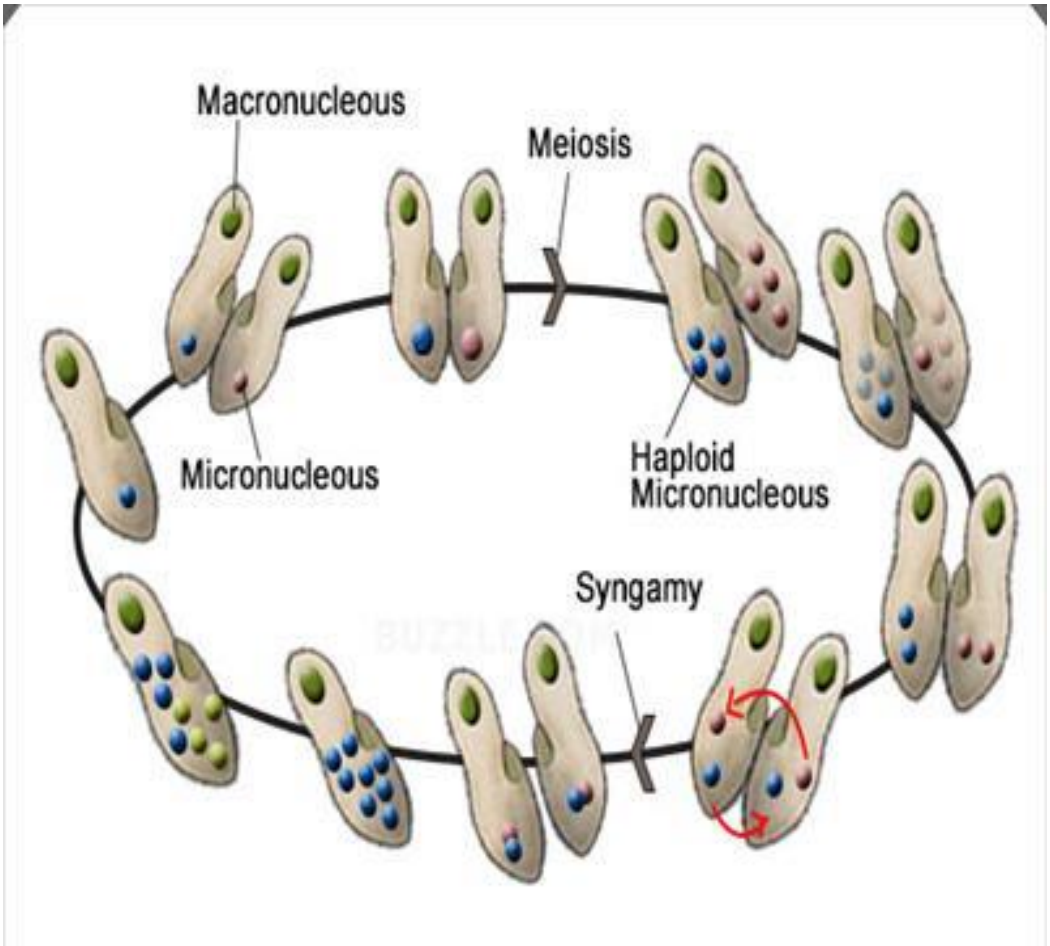


Binary fission divides a cell transversely and followed by mitotic division in the micronucleus. Macronucleus divides amitotically. The gullet also divides into two halves.

Although the favoured mode of reproduction in Paramecium is mostly asexual, they reproduce sexually too, when there is a scarcity of food.

Sexual reproduction in Paramecium is by various methods.

In **conjugation,** two complementary paramecia (syngen) come together and there is a transfer of genetic material. An individual has to multiply asexually 50 times before reproducing by conjugation.



In the process of conjugation, the conjugation bridge is formed and united paramecia are known as conjugants. Macronuclei of both the cells disappear. The micronucleus of each conjugant forms 4 haploid nuclei by meiosis. Three of the nuclei degenerate. The haploid nuclei of each conjugant then fuse together to form diploid micronuclei and cross-fertilization takes place. The conjugants separate to form exconjugants. They are identical, but different from the earlier cells. Each exconjugate undergoes further division and forms 4 daughter Paramecia. Micronuclei form a new macronucleus.

The conjugants attach with each other for several hours during which complicated reorganization and exchange of nuclear material occurs as described below,

Changes in macronucleus: The macronucleus breaks up into fragments and these fragments are later absorbed into the cytoplasm.

Changes in micronucleus: Lot of complicated changes and divisions take place in the micronucleus.

- The diploid micronucleus in each conjugant grows in size and then divides by meiosis (in meiotic division a single cell gives four haploid daughter cells)
- As a result of meiotic division four haploid daughter micronuclei are produced. Out of these four micronuclei, three degenerate and disappear.
- The remaining one micronucleus divides by mitosis to form two unequal pronuclei or gamete nuclei. The smaller gamete nuclei is active in migratory in nature and is called migratory gamete nucleus. The larger gamete is passive and stationary in nature and is called stationary gamete nucleus.
- The migratory gamete nucleus of one conjugant passes through the protoplasmic bridge into other conjugant and fuses with its stationary gamete nucleus. This fusion results in the formation of a single diploid zygote nucleus. This zygote nucleus is also known as synkaryon. And this process of complete fusion of two nuclei from two different individuals to form a zygote nucleus is called as amphimixis.
- After the formation of zygote nucleus, the attached conjugants separate and now they are called ex-conjugants.
- The zygote nucleus in each exconjugants divides thrice by mitosis finally forming eight nuclei.
- Four of these eight nuclei grow in size to become macronuclei. The remaining four small nuclei are called micronuclei.
- Out of the four micronuclei, three degenerate and disappear. And the remaining one micronucleus divides mitotically into two. Simultaneously the exconjugants also divide into two daughter paramecia.
- Each daughter paramecia thus obtained from exconjugants has 2 macronuclei and 1 micronucleus.

- A micronucleus of daughter individuals again divides mitotically with the division of cytoplasm to produce four daughter individuals each with one macronucleus and one micronucleus.
  In this way, 8 paramecia are produced as a result of conjugation four from each mating conjugant.

Significance of conjugation

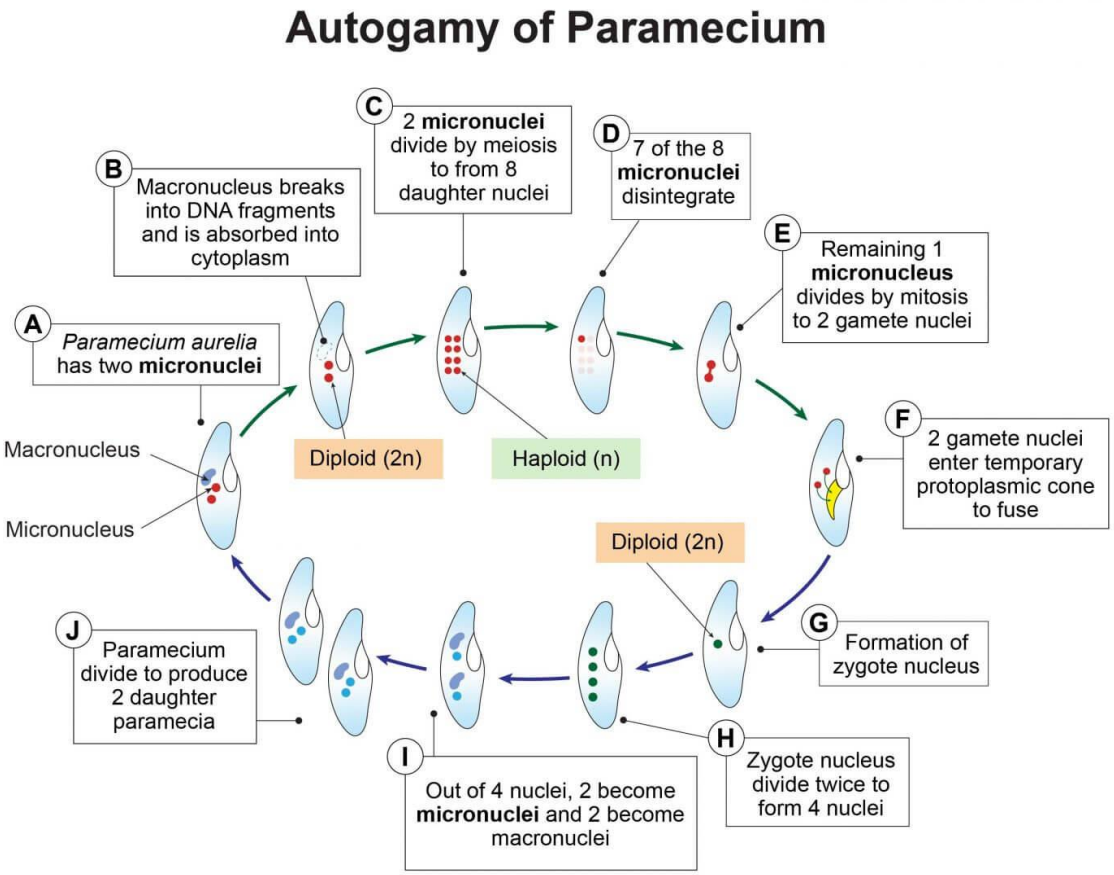
Nuclear Reorganization: In conjugation new and metabolically active macronucleus is produced by reorganization of micro nuclear materials.
Rejuvenation: In conjugation old, weak and defective macronucleus is replaced by new one which can control metabolism growth and the environment. Because of this paramecium is rejuvenated i.e. it gains the previous vigor.

Paramecium also shows **autogamy** i.e. self-fertilization. A new macronucleus is produced, which increases their vitality and rejuvenates them.

W. F Diller in 1936 described Autogamy in *Paramecium aurelia*. The nuclear changes occurring in both conjugation and autogamy are much similar but nucleus is not exchanged in autogamy. Moreover autogamy occurs within a single individual. Autogamy occurs in the following way,

- Macronucleus grows in size and breaks open into fragments which are absorbed by the endoplasm
- Two diploid micronuclei divide meiotically and produce eight haploid daughter nuclei. Out of these eight, seven disintegrate. (note that *P. aurelia* consists of one macronucleus and two micronuclei)
- The remaining one nucleus divides by mitosis and produces two nuclei, now called as gamete nuclei.
- A temporary protoplasmic cone develops near the mouth. The two gamete nuclei enter this cone and fuse together to produce a diploid zygote nucleus or synkaryon. This zygote nucleus contains all genes in homozygous condition.

- Zygote nucleus divides twice by mitosis to produce four nuclei.
- Two of these nuclei grow to become two macronuclei and remaining two become micronuclei.
- Each micronucleus and the body of paramecium now divide and produce two daughter paramecia, each with a new macronucleus and two micronuclei.



Significance of autogamy

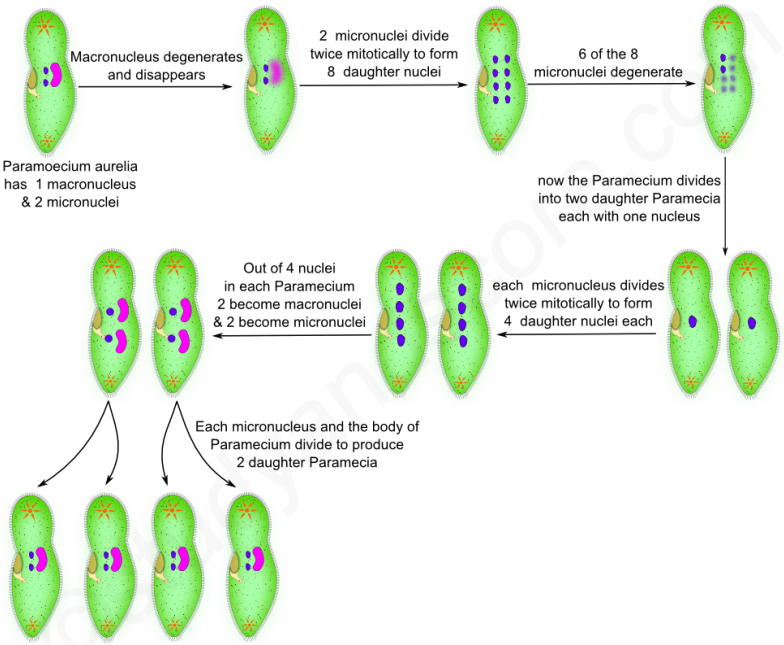
1. As a result of autogamy, a new macronucleus is formed which rejuvenates paramecium by increasing its vitality.
2. It is a type of sexual reproduction in which self-fertilization takes place and homozygous offsprings are produced.

SEXUAL REPRODUCTION: ENDOMIXIS

Woodruff Erdmann reported endomixis in *Paramecium aurelia*. It is one of the methods of nuclear organization. There is no meiosis and no nuclear fusion in this process.

It occurs in single individual in the following way,

- The macronucleus degenerates and disappears.
- The two micronuclei divide twice by mitosis and produce eight nuclei. Six of these eight degenerate.
- The Paramecium divides into two. Each daughter Paramecium contains one nucleus.
- The nucleus divides again twice by mitosis to produce four nuclei. Two nuclei enlarge and become macronuclei and two become micronuclei
- Each micronucleus and the body of Paramecium divide and produce two daughter Paramecia. Paramecium gets one macronucleus and two micronuclei.
- At the end of endomixis four daughter Paramecia are produced from a single individual.



STEP WISE REPRESENTATION OF ENDOMIXIS IN PARAMECIUM

Significance of endomixis

1. As a result of endomixis a new macronucleus is formed which rejuvenates Paramecium.
2. A single individual produces four daughter individuals.

SEXUAL REPRODUCTION: CYTOGAMY

- R. Wichterman in 1940 reported Cytogamy in *Paramecium caudatum*. Generally cytogamy is less frequent.
- In cytogamy two Paramecia form a pair and become attached at their oral surface as in conjugation.
- Early nuclear divisions are similar to that of conjugation but there is no nuclear exchange between the individuals called as cytogamonts.
- Two haploid gamete nuclei in each of the individual, fuse to form a synkaryon.
- The individuals now separate and divide as in conjugation. Also a new macronucleus is formed as in conjugation.

Significance of cytogamy

- A new macronucleus is formed which rejuvenates *Paramecium*
- Self- fertilization occurs in this process also and completely homozygous offsprings are produced