Type-Paramecium

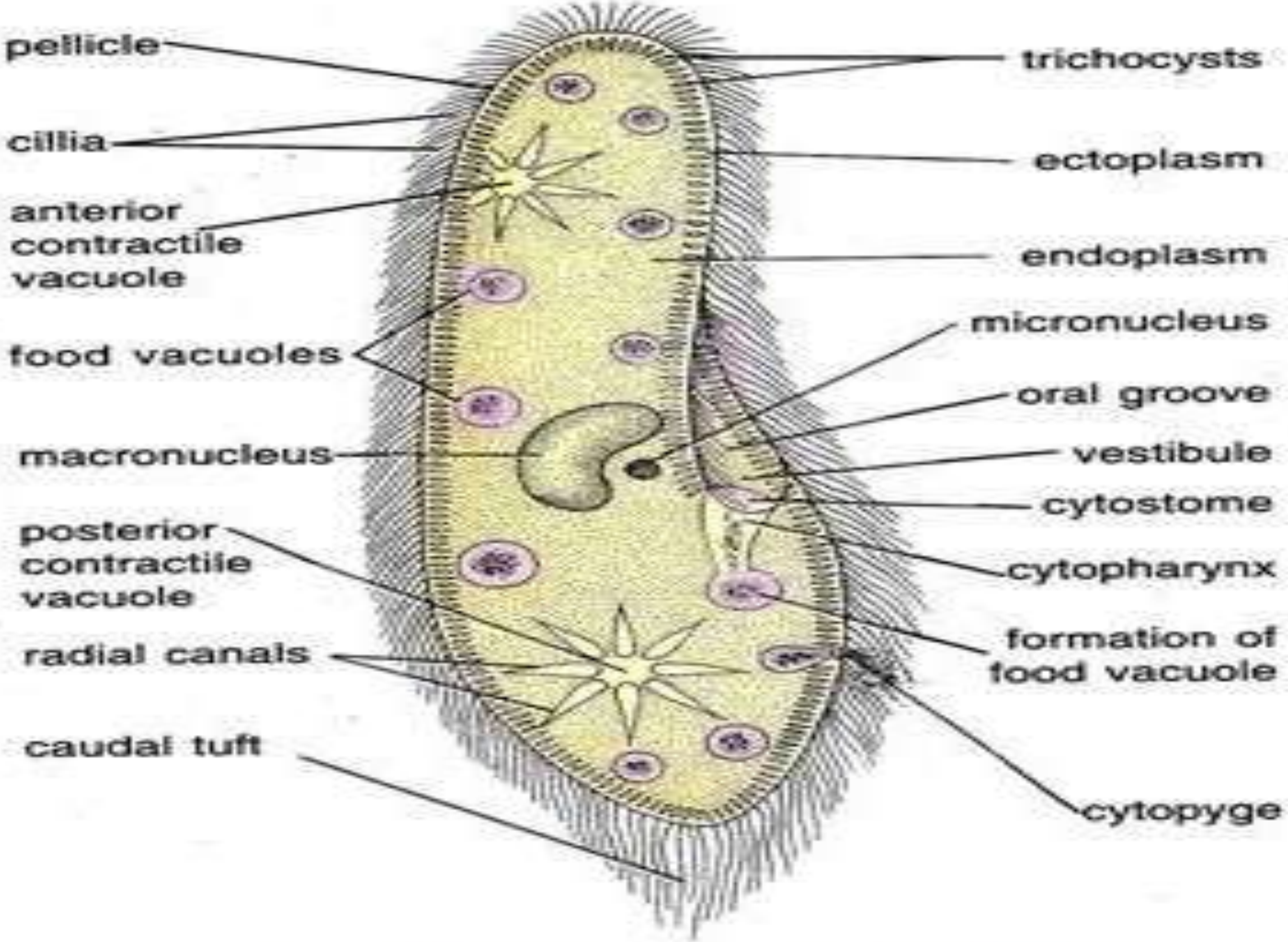


Fig. 20.1. *Paramecium caudatum.*

Habit and habitat

Paramecium caudatum is commonly found in freshwater ponds, pools, ditches, streams, lakes, reservoirs and rivers. It is specially found in abundance in stagnant ponds rich in decaying matter, in organic infusions, and in the sewage water. Paramecium caudatum is a free-living organism and this species is worldwide in distribution.

Nutrition

- In Paramecium caudatum, nutrition is holozoic. The food comprises chiefly bacteria and minute Protozoa. Paramecium does not wait for the food but hunts for it actively.
- It is claimed that Paramecium caudatum shows a choice in the selection of its food, but there seems to be no basis for this though it engulfs only certain types of bacteria; available data suggest that 2 to 5 million individuals of Bacillus coli are devoured by a single Paramecium in 24 hours. It also feeds on unicellular plants like algae, diatoms, etc., and small bits of animals and vegetables.

External features of Paramecium

Size: Paramecium is a unicellular microscopic protozoan. The largest species of this genus is Paramecium caudatum and it measures about 170-290 µ. It is visible to naked eye as whitish or grayish spot. The greatest diameter of the cylindrical body is about two-thirds of its entire length.

Shape: It is elongated, slipper-shaped animal and is commonly called as slipper animalcule due to its shape. The anterior end is rounded and the posterior end is cone-shaped. Ventral or oral surface is flat and the dorsal or aboral surface is convex.

Pellicle

- The body is covered by a thin, double layered, elastic and firm pellicle made of gelatin. The pellicle holds the shape of the animal but is elastic enough to permit contractions.

- The pellicle has double membrane, the outer membrane is continuous with the cilia and the inner membrane with the ectoplasm.

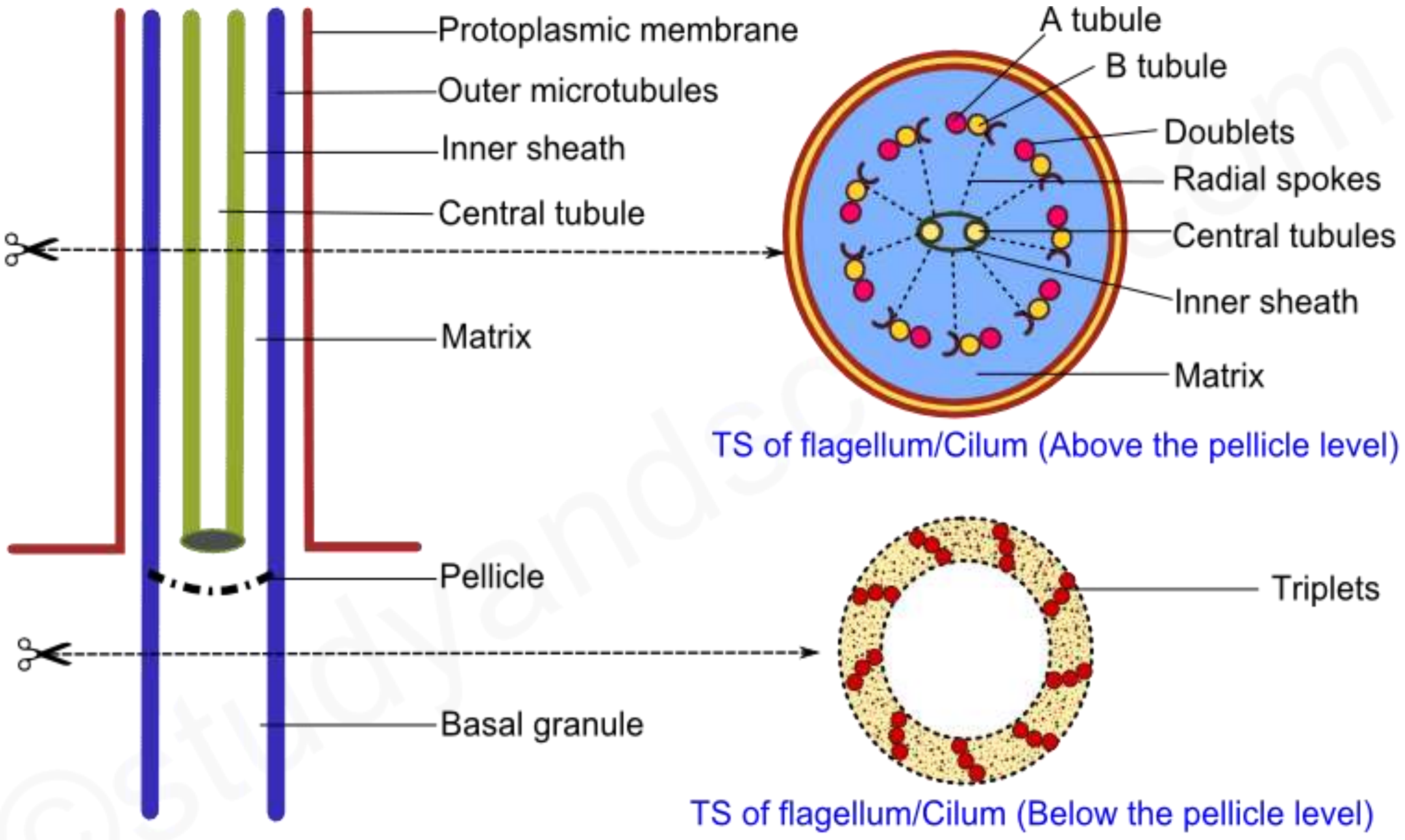
- The electron microscopic study of pellicle revealed that the hexagonal depressions correspond to regular series of cavities, the alveoli. All alveoli collectively form a continuous alveolar layer, which is delimited by an outer alveolar and inner alveolar membranes.
- The outer layer lies in close contact beneath the outer cell membrane. Therefore, pellicle includes outer cell membrane, outer alveolar membrane and inner alveolar membrane.

Oral groove

The ventral surface of the body of this protozoan bears a prominent, oblique and shallow depression. This depression is known as oral groove. It originates from the middle of the body and extends to the left side of anterior end. At the posterior side the oral groove leads into a deeper conical vestibule which in turn communicates with buccal cavity.

Cilia

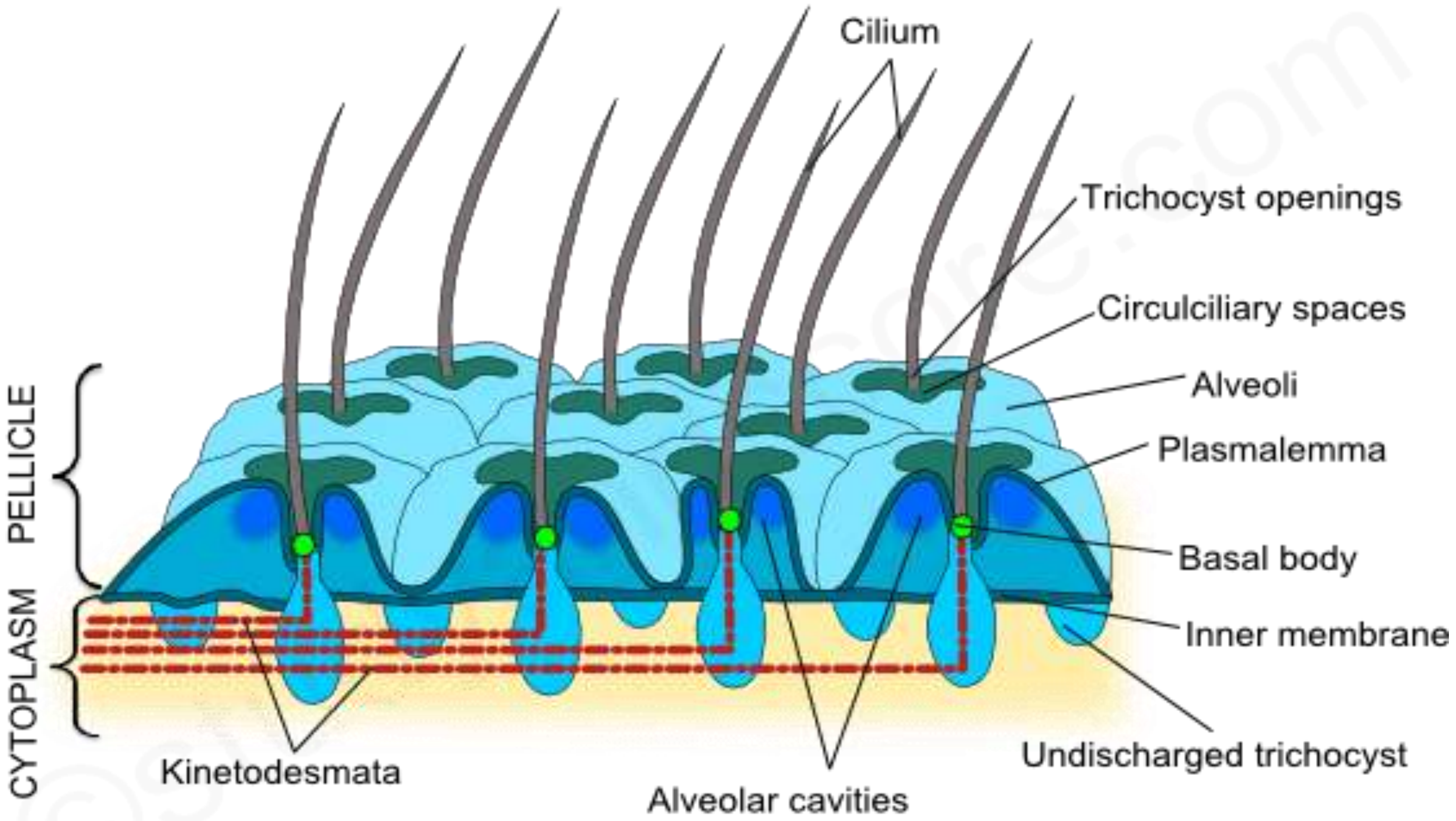
Cilia are short hair like structures present all over the surface of the body. They may be also confined to specific regions of the ciliate protozoan. Cilia help in locomotion as well as in food collection. In Paramecium, the entire body surface is covered by numerous, tiny hair. These cilia are arranged in longitudinal rows throughout the body. The length of the cilia is uniform but a few longer cilia are present at the posterior end. These cilia at the posterior end form the caudal tuft in P. caudatum.



ULTRA STRUCTURE OF FLAGELLUM/CILIUM

Ultra structure of cilia

- Cilia greatly resemble the flagella in the basic structure. The major difference between the flagella and the cilia is that cilia are smaller compared to the flagella.
- Cilia arise from the kinetosome/basal body. Cilia consist of an axial filament called as axoneme surrounded by the protoplasmic outer sheath.
- Electron microscopic studies of axoneme reveal 9 + 2 organization of the peripheral doublet fibrils and central singlet fibrils.
- The details of the 9 + 2 organization and the presence of the dynein arms are similar to that of the flagellum.
- All these fibrils are embedded in a matrix. The central fibrils are enclosed within a delicate sheath.



ULTRA STRUCTURE OF PELLICLE AND INFRA CILIARY SYSTEM

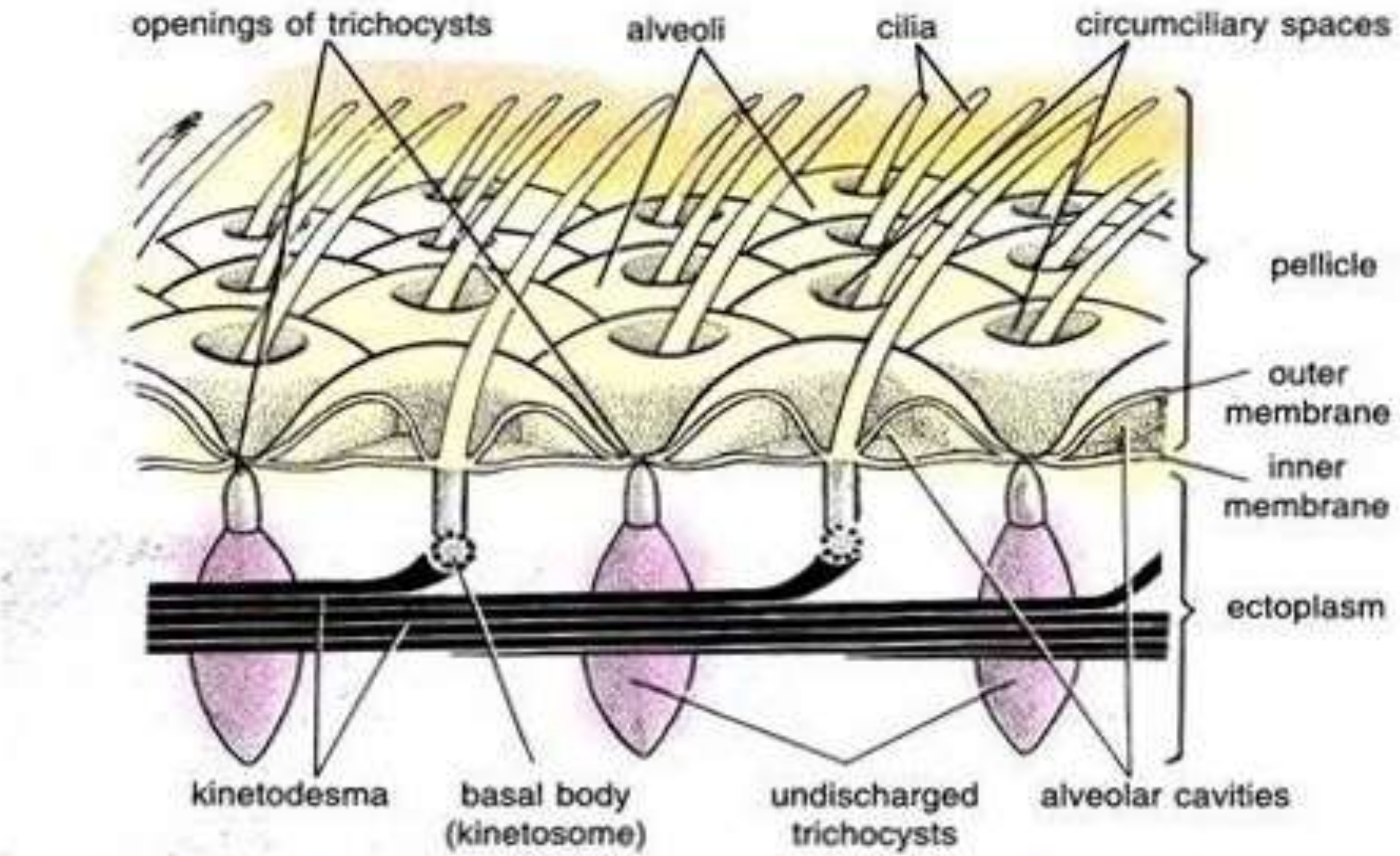


Fig. 20.2. *Paramecium*. Electron structure of pellicle and infraciliary system.

Internal structure

Cytoplasm-

- Ectoplasm/cortex-Infraciliary system and trichocyst
- Endoplasm/medulla

Infraciliary system

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

Infraciliary system

- Basal bodies /kinetosomes
- Kinetodesmata
- Kinety system
- Trichocysts

Trichocysts

They are oval or rod shaped minute bodies. These lie at the right angles to body surface in the ectoplasm. These alternate with the basal bodies. They open outside in the ridges of hexagonal depressions of pellicle. Each trichocyst consists of an elongated shaft and a pointed tip called the barb or spike. The spike remains covered by a cap. The shaft consists of a fibrous protein called trichinin. The shaft shows cross striations and fibrillar pattern under electron microscope.

- Under the higher magnification of microscope, pellicle shows rectangular or hexagonal depressions on its surface- Alveoli.
- Each hexagonal depression is perforated by a central aperture through which a single cilium emerges out.
- The anterior and posterior margins of hexagonal depressions bear the openings of trichocysts.

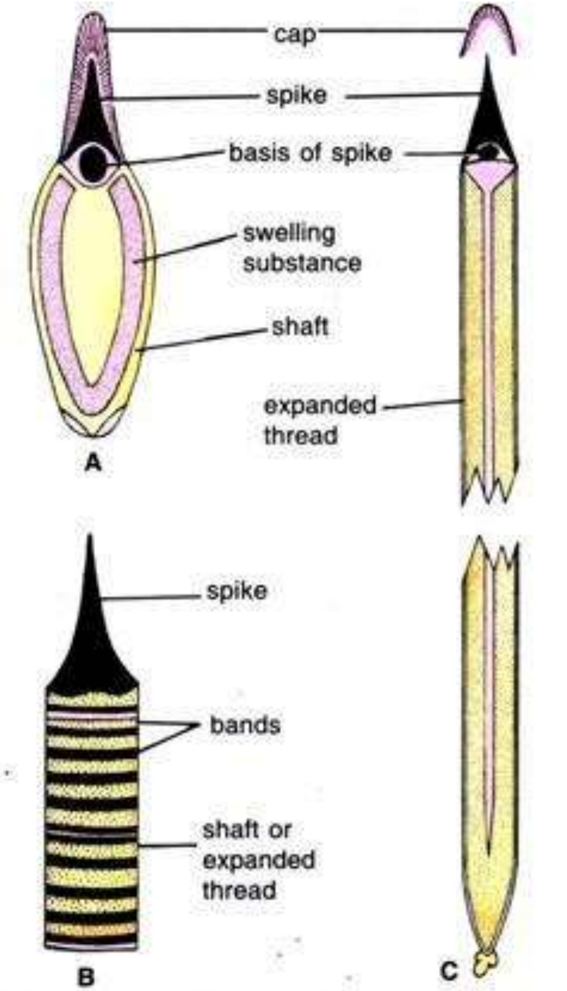


Fig. 20.6. *Paramecium*. Trichocyst. A—L.S. of hypothetical undischarged trichocyst; B—Tip of trichocyst as seen in electron microscope; C—Discharged trichocyst.

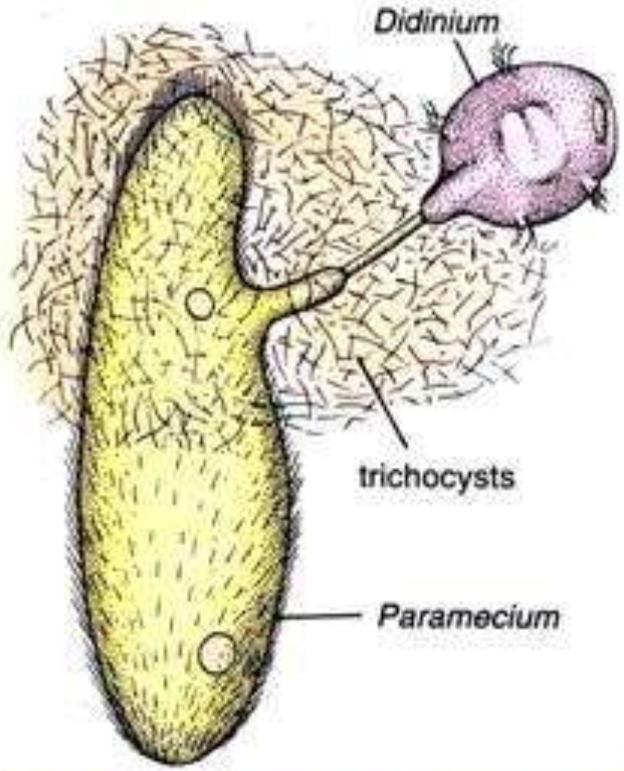


Fig. 20.8. *Paramecium*. Throwing out trichocysts when attacked by a small *Didinium*.

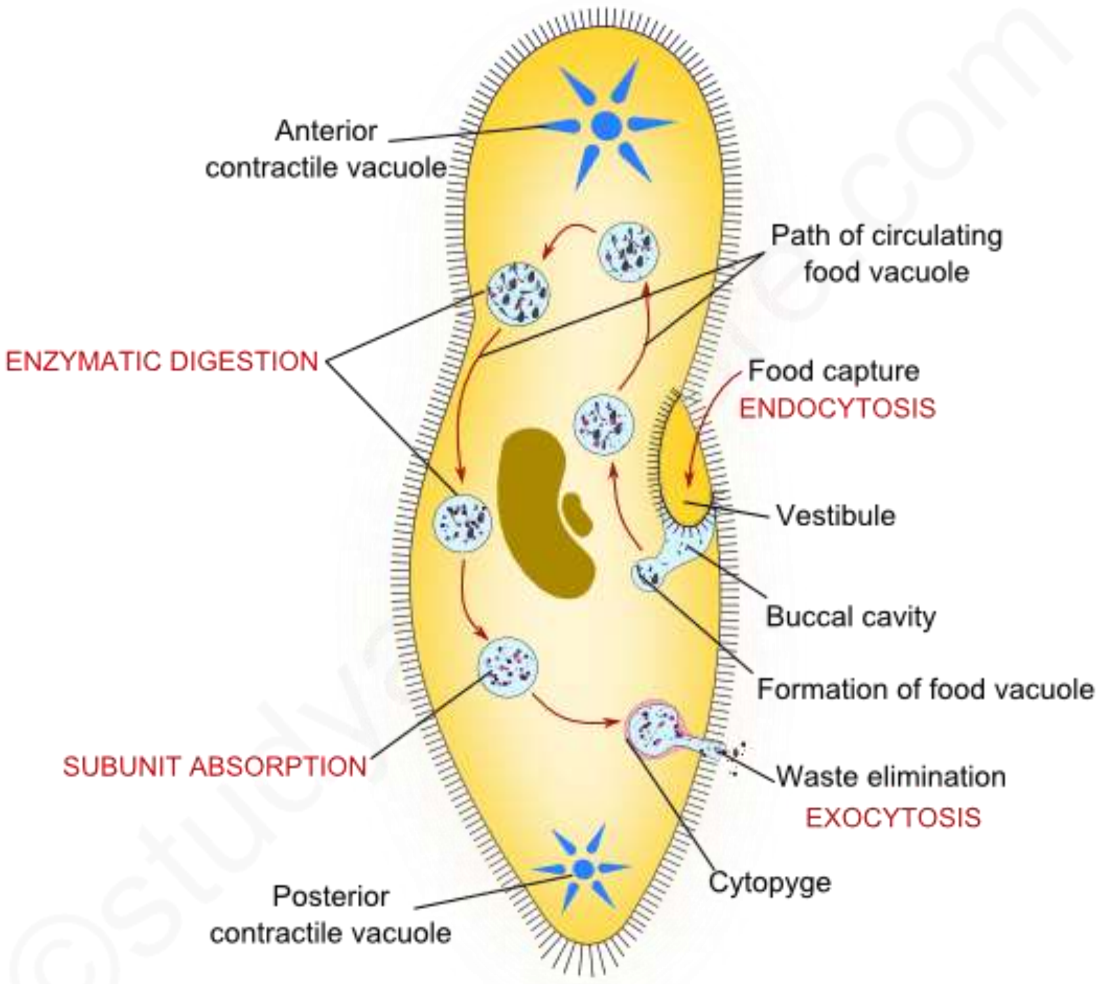
NUTRITION IN PARAMECIUM

- Paramecium feeds on holozoic manner and it is selective feeder. It feeds on bacteria, small protozoans, unicellular algae, diatoms etc. A single Paramecium can feed on 2-5 million bacteria in 24 hours. Feeding of the food is helped by the ciliary action. It feeds on the stationary or slowing swimming animals. The feeding apparatus of Paramecium are Buccal cavity, oral groove, vestibule and cytopharynx.
- While feeding, the cilia of the oral groove beat strongly and thus it produces a current of water which brings in the food particles towards the vestibule. The cilia of the vestibule and buccal cavity pull in food particles. At the same time the unwanted food particles are rejected. The selected food is passed onto the cytopharynx through the route called as selection path. On the other hand the route through which the rejected food particles are sent out is called rejection path.

Oral groove → vestibule → buccal cavity → Cytopharynx → down towards the posterior end

↓

Finally to Cytopyge ← Backward ← towards anterior part ← Upwards to become dorsal



FORMATION OF FOOD VACUOLE AND PROCESS OF CYCLOSIS IN PARAMECIUM

The food vacuoles are circulated around the body by the streaming endoplasm along a definite course. This streaming movement is called cyclosis. Several food vacuoles may be seen circulating in the endoplasm. The route of the food vacuole is as under:

The digestion of the ingested food occurs during cyclosis. Each of the food vacuole contains food particle and a little of water. The digestion is made by means of acids, alkalis and enzymes secreted from the surrounding endoplasm. Often mitochondria become associated with the food vacuoles to help in the digestion process. The food vacuole is initially acidic and in this acidic phase the prey is killed. The acid is hydro chloric acid. Later the vacuole becomes alkaline and most of the digestion occurs during this alkaline phase. Proteases, carbohydrates and lipases digest the food. The digested products are diffused into the endoplasm.

Osmoregulation in Paramecium Caudatum:

- Paramecium caudatum has two contractile vacuoles, one anterior and one posterior.
- Function - osmoregulation, to regulate the water contents of the body and may serve also in excretion of nitrogenous wastes such as urea and ammonia.
- Excess of water (because of continuous endosmosis) within cytoplasm is collect into a series of 6 to 11 radiating canals that converge toward and discharge into each vacuole.

- When each vacuole is swelled (diastole) to a certain size, it contracts (systole) and discharges to the exterior probably through a pore. The contractile vacuoles contract alternately, at intervals of 10 – 20 seconds.
- The posterior contractile vacuole works faster than anterior vacuole because of intake of large amount of water into the posterior region by the cytopharynx. The contractile vacuoles maintain an optimum concentration of water in the body cytoplasm by disposing of the excess.

Nucleus:

- This protozoan is heterokaryotic in other words it has two nuclei. One of these is larger than the other. The larger nucleus is called as macro nucleus and the smaller one is called as the micronucleus.
- Macro nucleus is bean-shaped and contains many nucleoli. This nucleus is polyploid and controls all the metabolic activities of the animal. This nucleus divides amitotically during binary fission. The old macronucleus disappears and the new one is reorganized during conjugation. The macronucleus may contain 500 times more nucleus than that of the micronucleus.
- Micronucleus lies in the depression of the bean shaped macronucleus. It is spherical, diploid and also contains a nuclear membrane. It controls the reproductive activities of the animal.

LOCOMOTION IN PARAMECIUM

- *Paramecium* has a streamlined body which helps it to swim in the water which less friction. The rapid swimming is facilitated by the beating of fine and hair-like cellular organelles called cilia. Cilia cover the entire body surface of this protozoan.
- The back and forth movements of the cilia are called as effective and recovery strokes respectively. Cilium moves just like a pendulum or a paddle. The cilium moves the water parallel to the surface of its attachment like that of paddle stroke movement. The movement of water is perpendicular to the longitudinal axis of cilium.

Ciliary movement

- In *Paramecium* locomotion mainly occurs by movement of cilia. It can move forward and backward.
- While moving forward, cilia strongly move from anterior to posterior. Similarly, for backward movement cilia strongly move from posterior to anterior.
- All the cilia do not move at a time. Cilia of transverse row move at the same time. It is called synchronous rhythm
- whereas cilia of longitudinal row move one after another. It is called Metachronous rhythm.

Locomotion

- Effective stroke
- Recovery stroke
- Metachronal rhythm

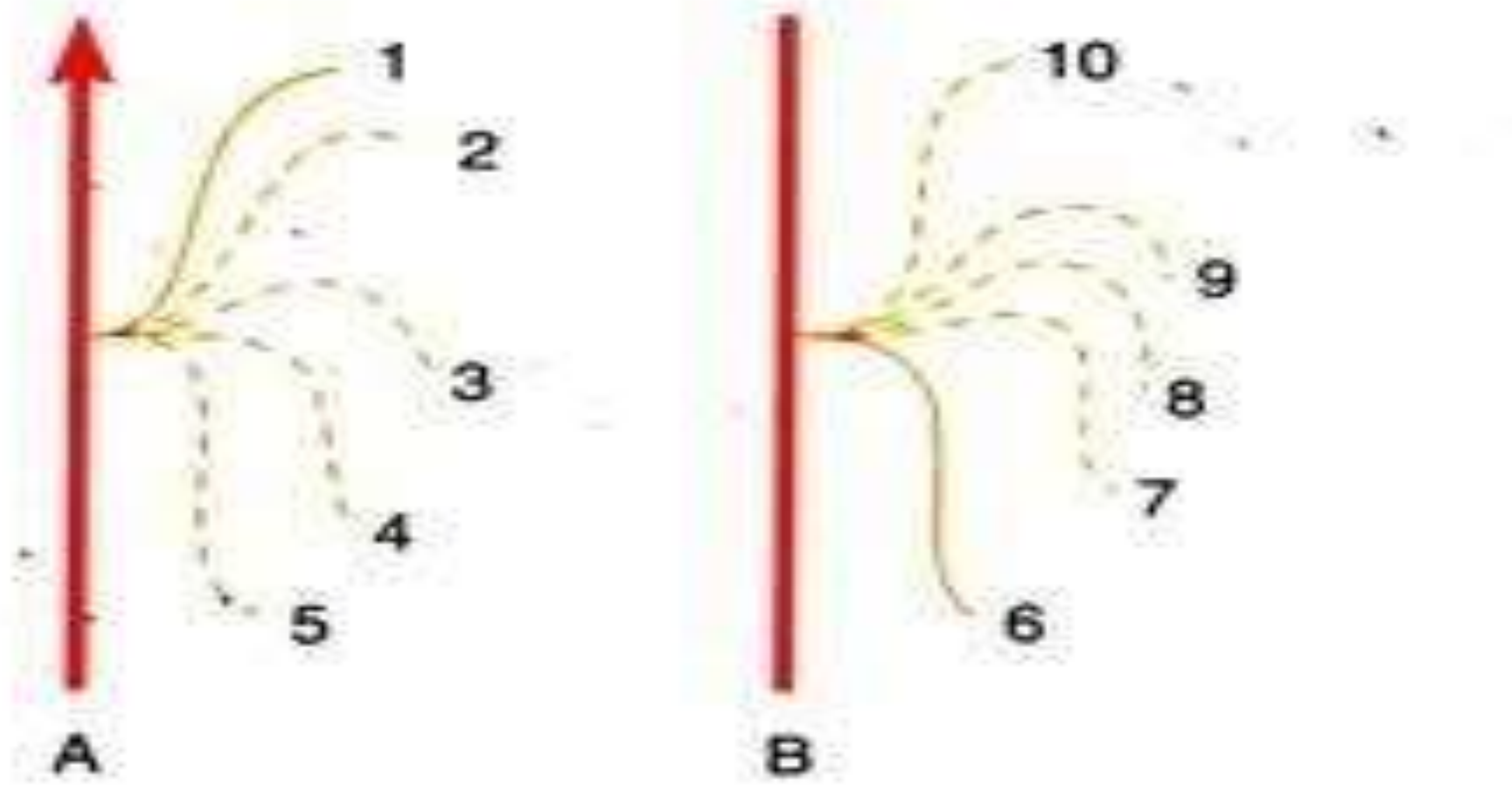


Fig. 20.12. Diagrams illustrating ciliary movement of a single cilium. A—Effective stroke; B—Recovery stroke.

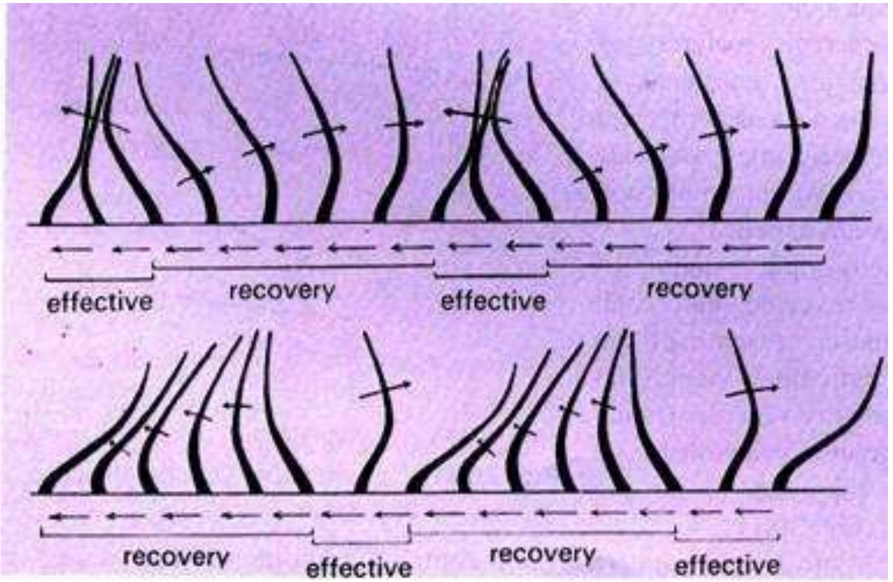


Fig. 20.14. Cilia indicating effective and recovery strokes.

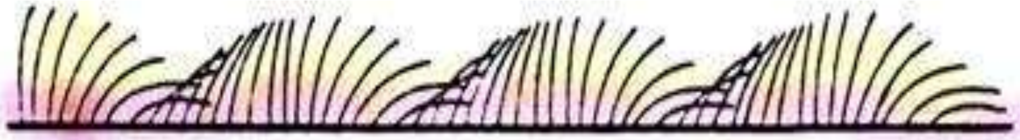


Fig. 20.13. A longitudinal row of cilia showing metachronal movement.

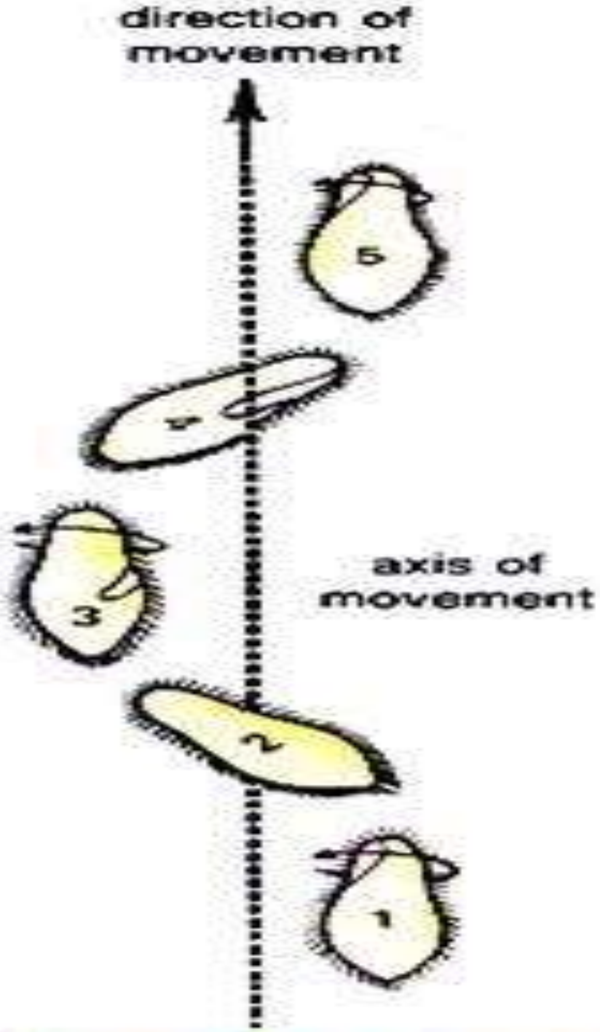


Fig. 20.15. *Paramecium*. Spiral path of movement.

- Food ingestion-cytostome
- Constant lashing movement of the cilia of oral groove
- Current of water with food particles
- Rest rejected-rejection path
- Path of ciliary action drives food –selection path
- Beating of cilia of buccal cavity to cytostome to cytopharynx
- Membraneous vesicle nipped of from the cytophryx
- Another food vacuole may be formed with 1-5 minutes
- Cyclosis

- Vacoules –movement
- Digestion and assimilation
- Lysosome-proteases, carbohydrates, esterases secreted in to the food vacuoles
- Contents-alkaline-acidic –alkaline
- Vacuole gradually become smaller ,digestion and absorption proceed
- Undigested matter-egestion through cytopyge or anal spot

Respiration and Excretion of Paramecium caudatum:

The exchange of gases (oxygen and carbon dioxide) takes place through the semi-permeable pellicle like other freshwater protozoans by the process of diffusion. Paramecium caudatum obtains its oxygen from the surrounding water. Carbon dioxide and organic wastes like ammonia resulting from metabolism are probably excreted by diffusing outward into the water in the reverse direction.

Behaviour

The way in which an organisms relation with environment

Responses of Paramecium to various kinds of stimuli such as light, temperature, concentration of CO_2,O_2 and different chemicals.

Positive and Negative

Avoiding reaction-strikes a solid object

Negative reaction

Trial and error reaction

- Involve a series of experiments
- Water testing-Drawing water to oral groove –cone
- According to tem, chemicals –avoidance reaction
- Repetitive, anterior posterior swinging movements.
- Rotatory movements different directions
- Help the animal to avoid undesirable environment.
- Thermotaxis, phototaxis, thigmotaxis, chemotaxis, rheotaxis(water current),galvanotaxis, Geotaxis(gravity)

Paramecium reproduces both asexually and sexually

Asexual

- Transverse or horizontal binary Fission

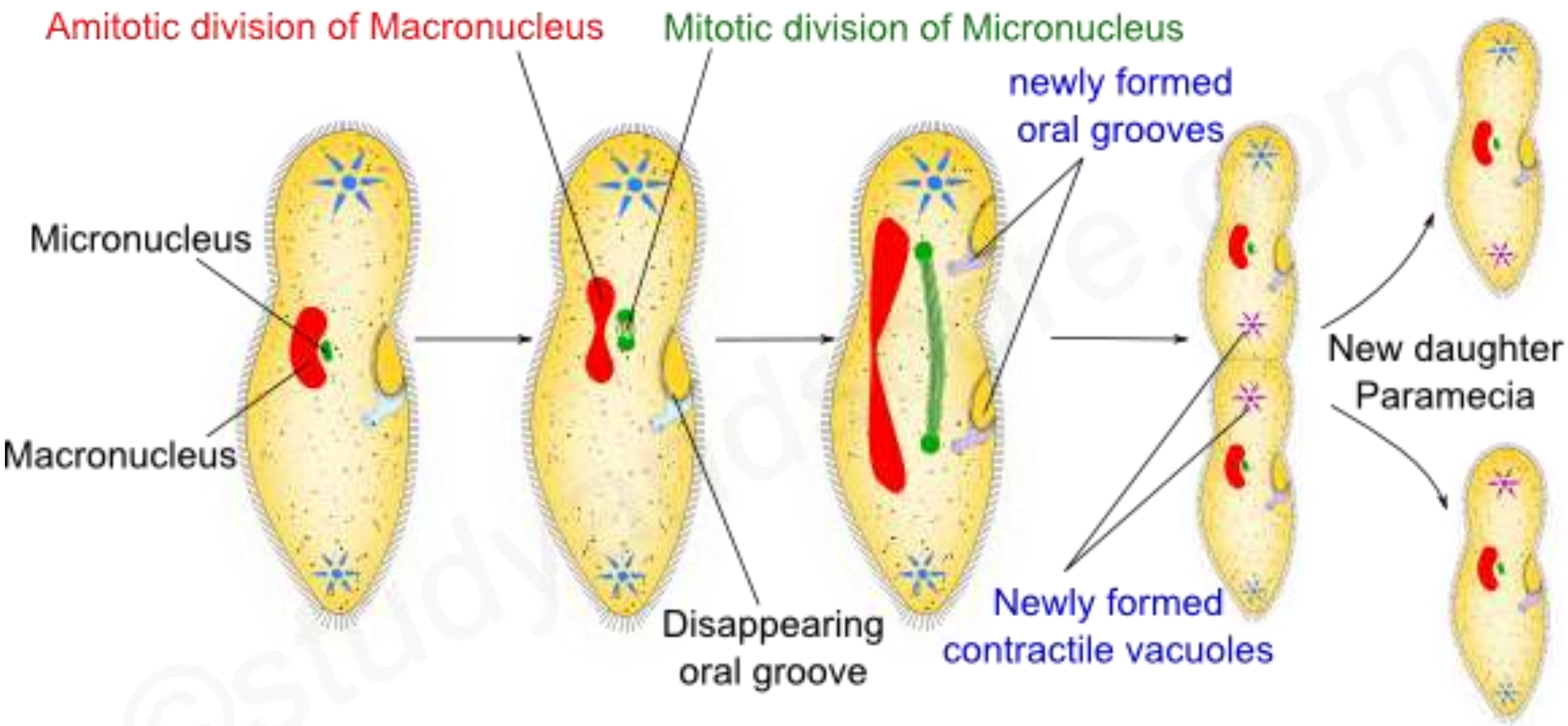
Sexual

- Nuclear reorganisations(conjugation, cytogamy,endomixis,autogamy)

VARIOUS PROCESSES OF REPRODUCTION IN PARAMECIUM

Binary Fission

- Paramecium stops feeding-oral groove and buccal structures begin to disappear.
- The macronucleus splits by a type of amitosis, micronucleus starts dividing by complicated process of mitosis
- Nuclear membrane remain intact.
- Micronucleus increase in size and chromosomes start to divide prophase-metaphase-anaphase-telophase-
- Resulted in two micronuclei.
- Daugters separarate.



STEPS IN TRANSVERSE BINARY FISSION IN PARAMECIUM

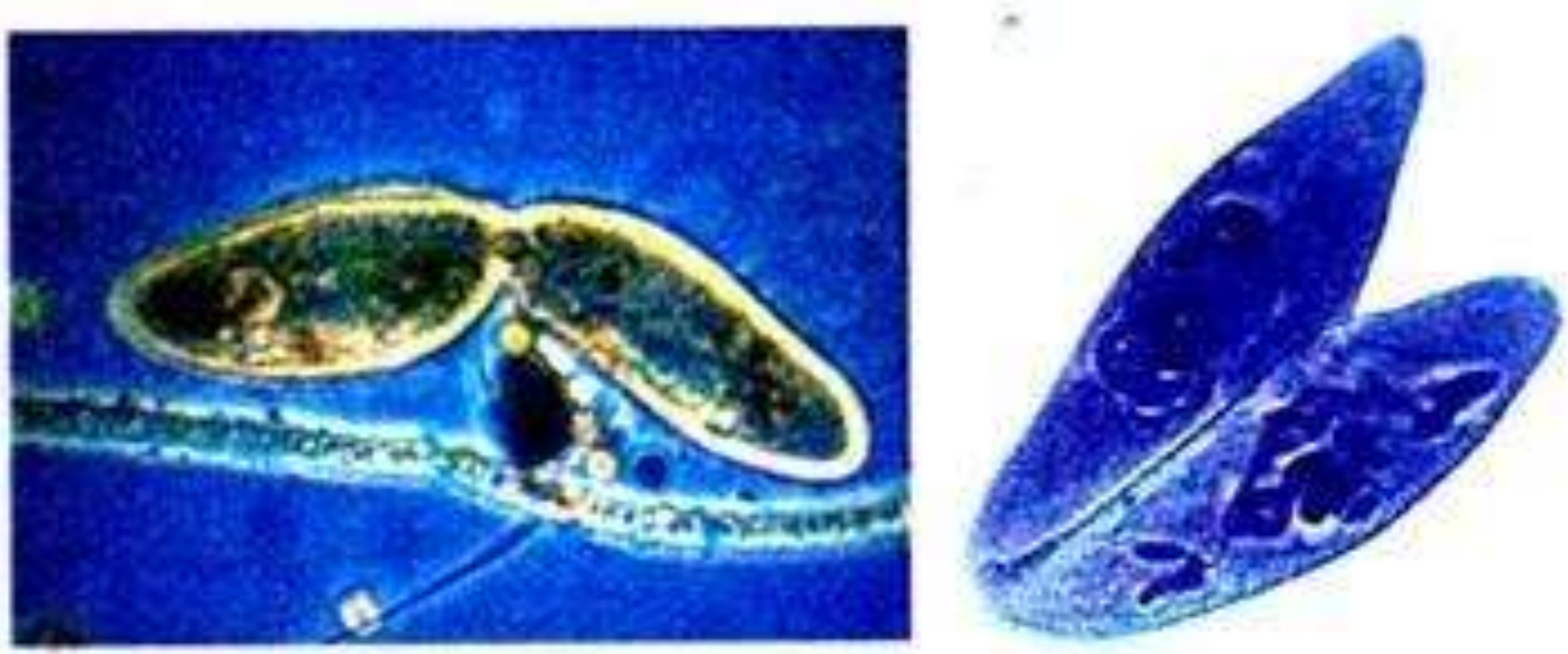
- Macron divide amitotically-elongation, constriction
- Two oral grooves anterior,posterior
- Contractile vacoules divide ..two new ,2 old
- Constriction furrow at middle
- 2 paramecium
- Anterior-proter
- Posterior-opisthe
- Grow full size divide again by fission

They are of equal size and contain a complete set of cell organelles as in parents. Oral groove and cytopharynx are newly formed in both the daughters. One contractile vacuole goes to protor and another to opisthe. Other two are newly formed. The whole process is completed within 2 hours and may occur one to four times a day.

Reproduction

The degeneration of old macronucleus and the formation of the new one by fusion of micronuclei is called as nuclear organization. Replacement of the imbalanced macronucleus thus is very important.

1. Conjugation
2. Autogamy
3. Endomixis
4. Cytogamy
5. Hemimixis



Conjugation in *Paramecium*.

CONJUGATION

In *Paramecium,* Conjugation is a form of sexual reproduction. It is a temporary union of two individuals of same species for mutual exchange of genetic materials. Continuous multiplication by binary fission is interrupted by conjugation

Conjugation inducing factors:

Unfavourable conditions like some degree of starvation, shortage of food, a particular bacterial food, a certain range of light and temperature and certain chemicals induce conjugation.

Also conjugation is induced after certain number of asexual binary fissions

Sexual conjugation

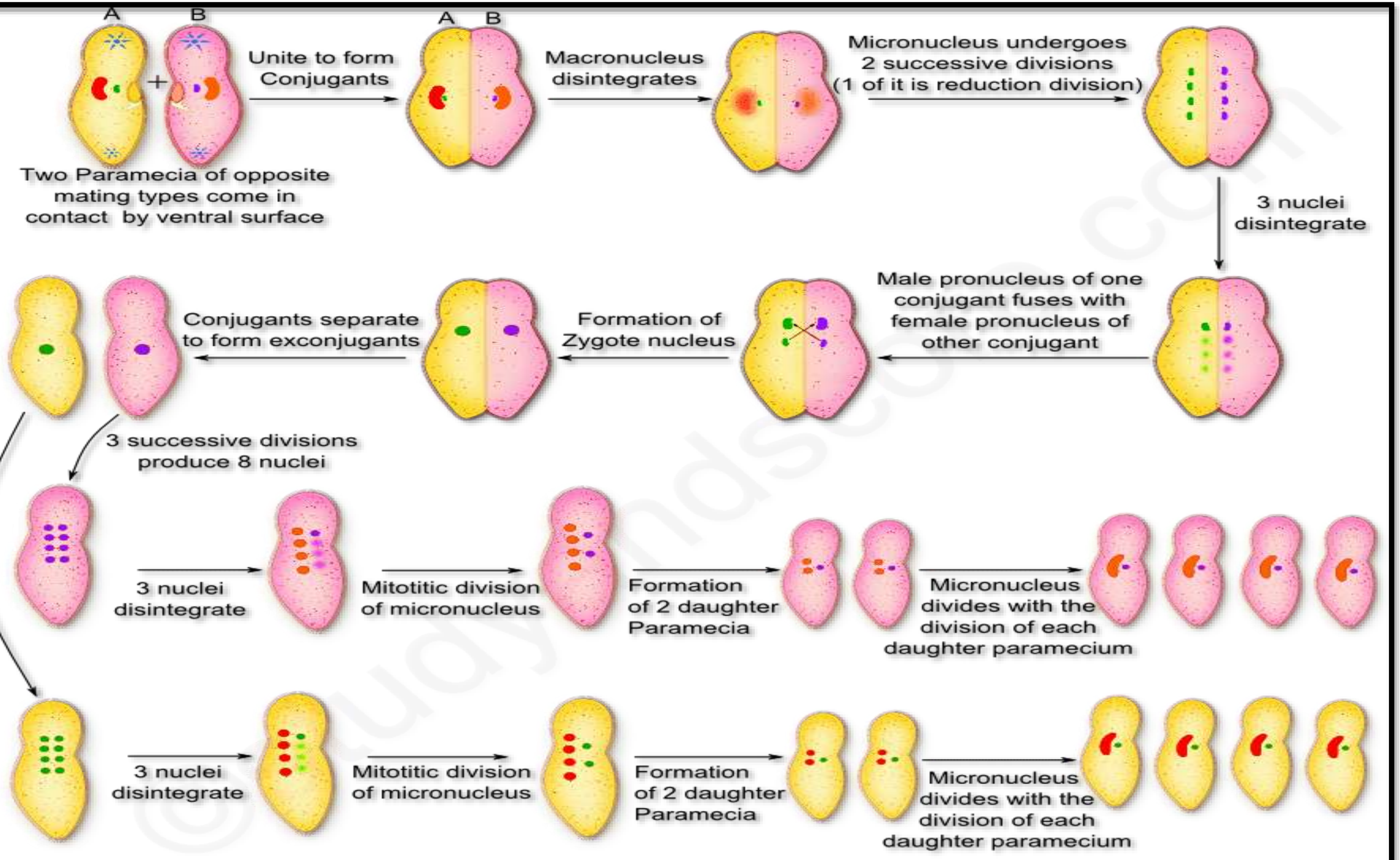
- Temporary union of two –same species
- Different types-chemically
- Exchanging micro-nuclear material
- Occurs frequently between binary fissions
- A large, macronucleus is essential for its survival, while one or two smaller micronuclei are necessary for sexual reproduction. Occasionally, two organisms will exchange nuclear material through conjugation, a form of sexual reproduction.

Types of mating systems in paramecium:

- Each variety of the species of paramecium has two mating types which differ in chemical characteristics of their surface membranes. Conjugation can occur only between different mating types of the same variety or syngen.

Conjugation process:

- The two P*aramecium* of opposite mating types come in contact by their ventral surface during swimming. They stick together through their oral groove region. Following this attachment their cilia, Trichocysts, feeding apparatus degenerate. Pellicle and ectoplasm degenerate at the point of contact and a cytoplasmic bridge. This cytoplasmic bridge is also known as protoplasmic bridge or Conjugation Bridge. These united paramecia are called conjugants.



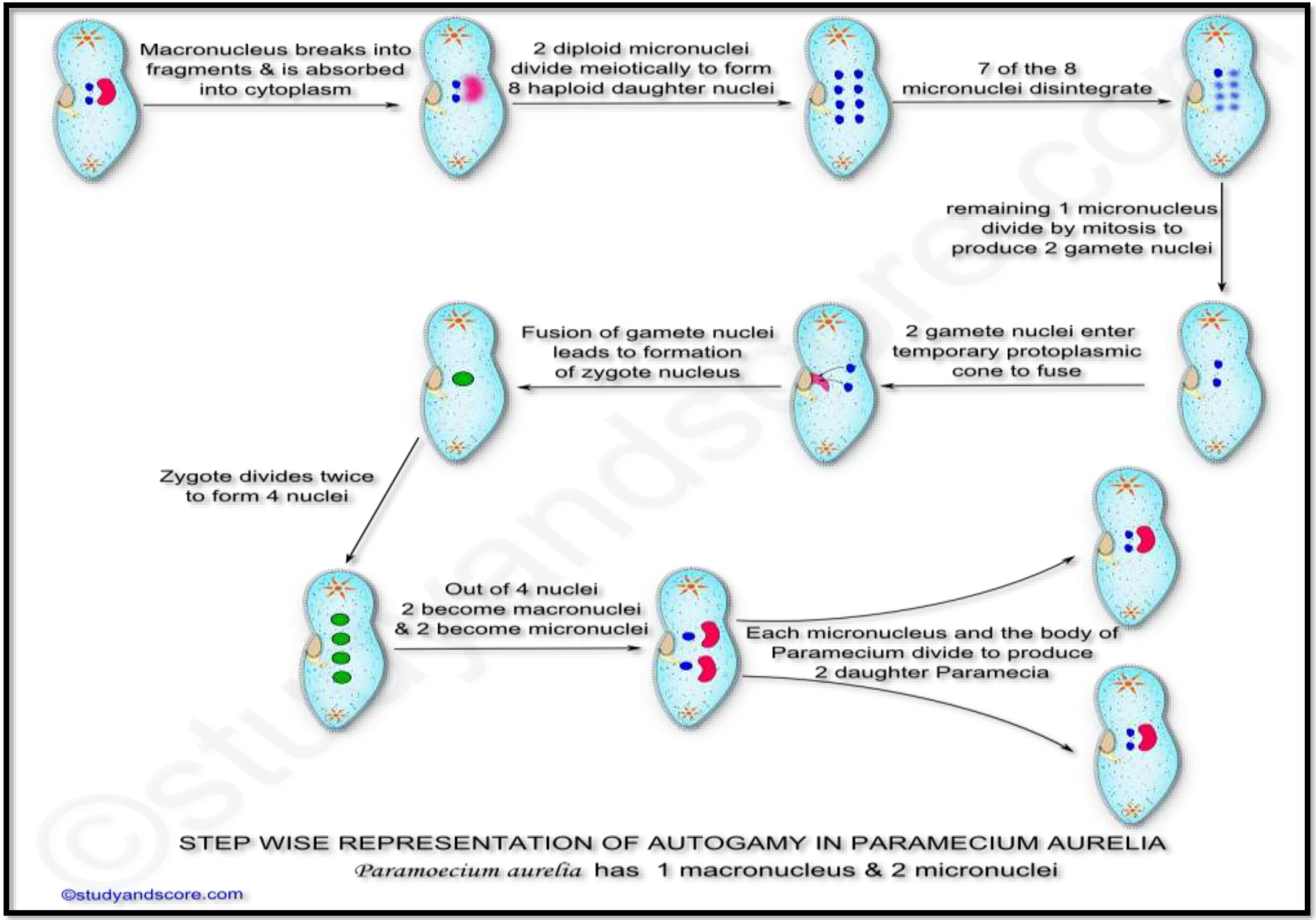
STEP WISE REPRESENTATION OF CONJUGATION PROCESS IN PARAMECIUM

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

AUTOGAMY

- W. F Diller in 1936 described Autogamy in *Paramecium aurelia*. Macronucleus grows in size and breaks open into fragments which are absorbed by the endoplasm
- 2micro+1macro
- 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.

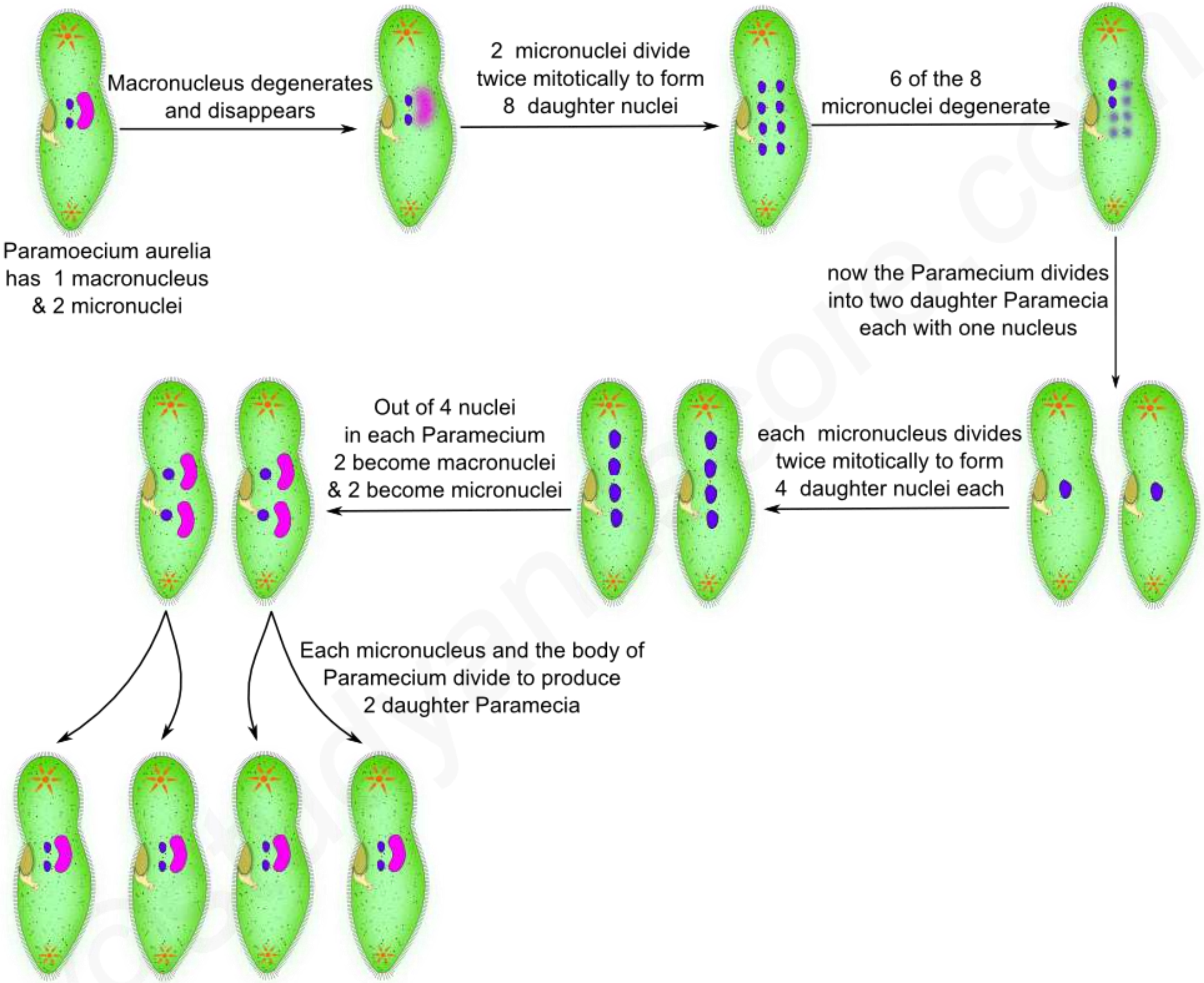


Macronucleus breaks into fragments & is absorbed into cytoplasm
2 diploid micronuclei divide meiotically to form 8 haploid daughter nuclei
7 of the 8 micronuclei disintegrate
remaining 1 micronucleus divide by mitosis to produce 2 gamete nuclei
2 gamete nuclei enter temporary protoplasmic cone to fuse
Fusion of gamete nuclei leads to formation of zygote nucleus
Zygote divides twice to form 4 nuclei
Out of 4 nuclei 2 become macronuclei & 2 become micronuclei
Each micronucleus and the body of Paramecium divide to produce 2 daughter Paramecia
STEP WISE REPRESENTATION OF AUTOGAMY IN PARAMECIUM AURELIA
Paramoecium aurelia has 1 macronucleus & 2 micronuclei
©studyandscore.com

- 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.

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.



STEP WISE REPRESENTATION OF ENDOMIXIS IN PARAMECIUM

- 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.

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.

HEMIMIXIS

(i) Kappa Particles:

In 1938, T.M. Sonneborn reported that some races (known as killers or killer strain) of Paramecium produce a poisonous substance, called paramecin which is lethal to other individuals called sensitives. The paramecin is water soluble, diffusible and depends for its production upon some particles located in the cytoplasm of the Paramecium (killer strain).

These particles are called kappa particles. The kappa particles have DNA and RNA. A killer Paramecium may contain hundreds of kappa particles. The detailed study of these particles has revealed that a dominant gene (K) in the nucleus of Paramecium is necessary for kappa particles to exist, multiply and produce paramecin.

(ii) mμ, Particles:

R.W. Siegel (1952) reported another type of killer particles in the cytoplasm of some Paramecium. A Paramecium with mp particles is called mate killer because when it conjugates with a Paramecium without any mμ particles called mate sensitive, then it kills the latter. The mp particles are also composed of DNA, RNA, etc.

These particles exist only in those paramecia whose micronucleus contains at least one dominant gene of either of two pairs of unlinked chromosomal genes (M_1 and M_2).

(iii) Pi Particles:

These particles are supposed to be the mutant form of kappa particles but they do not produce any type of poisonous substance.

(iv) Lambda Particles:

These particles are reported in killer paramecia and said to produce some substance responsible for causing lysis or disintegration of sensitive paramecia, i.e., which do not possess it.