UG CBCS Semester-1

Paramecium

Paramecium lives in fresh-water ponds and streams, and is very easily obtained. Cultures prepared for *Amoeba* will in most cases sooner or later contain a host of *Paramecium.*

General morphology: If a drop of water containing *Paramecium* is placed on a slide, the animals may be seen with the naked eye moving rapidly from place to place. Under the microscope they appear cigar-shaped. A closer view reveals a depression extending from the end directed forward in swimming, obliquely backward and toward the right, ending just posterior to the middle of the animal. This is the *oral groove.* The *cytostome* is situated near the end of the oral groove. It opens into a funnel-shaped depression called the *cytopharynx* or *gullet,* which passes obliquely downward and posteriorly into the *endosarc.* The oral groove gives_ the animal an unsymmetrical appearance. Since *Paramecium* swims with the slender but blunt end foremost, we are able to distinguish this as the *anterior end.* The opposite end, which is thicker but more pointed, represents the *posterior end,* while the side containing the oral groove may be designated as *oral* or *ventral,* the opposite side *aboral* or *dorsal.* The motile organs are fine thread-like *cilia* regularly arranged over the surface. Two layers of cytoplasm are visible, as in *Amoeba,* an outer comparatively thin clear area, the *ectosarc* and a central granular mass, the *endosarc.* Besides these a distinct *pellicle* or *periplast* is present outside of the ectosarc. Lying in the ectoplasm are a great number of minute sacs, the *trichocysts,* which discharge long threads to the exterior when properly stimulated. One large *contractile vacuole* is situated near either end of the body close to the dorsal surface, while a variable number *of food vacuoles* may usually be seen. The *nuclei* are two in number, a large *macro nucleus* and a smaller micronucleus, these are suspended in the ectoplasm near the mouth opening. The anal spot can be observed only when solid particles are discharged. It is situated just behind the posterior end of the oral groove.

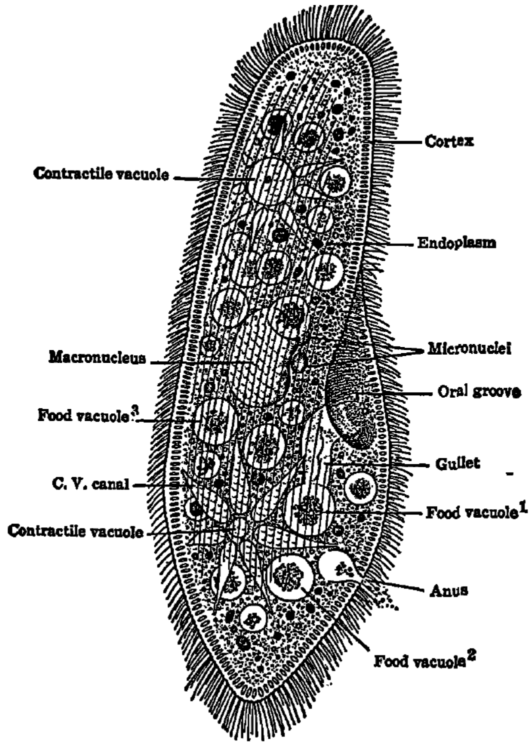

FIG. 46. — *Paramœcium aurelia* viewed from the side. This has two micronuclei. (From Newman after Pfurtscheller wall chart.)

Cytology: The *endoplasm* of *Paramecium* occupies the central part of the body. It is supposed to be alveolar in structure. Most of the larger granules contained within it are shown by microchemical reactions to be reserve food particles; they flow from place to place, indicating that the protoplasm is of a fluid nature. The *ectoplasm* does not contain any of the large granules characteristic of the endoplasm, since its density prevents their entrance. In this respect the two kinds of cytoplasm resemble the ectoplasm and endoplasm of *Amaba.* If a drop or two of 35 per cent alcohol is added to a drop of water containing *Paramecia,* the pellicle will be raised in some specimens in the form of a blister. Under the higher powers of the microscope the pellicle is then seen to be made up of a great number of hexagonal areas produced by *striations* on the surface. These striations are really very fine grooves which cross one another obliquely.

The distribution of the motile organs, the *cilia*, corresponds to the arrangement of the striations on the cuticle, since one cilium projects from the center of each hexagonal area. These thread-like structures occur on all parts of the body, those at the posterior end being slightly longer than elsewhere.

Fig. 47. — Schematic representation of the beating of a row of cilia. (After Verworn.)

A cilium may be compared to a very fine pseudopodium which has become a permanent structure. It is an outgrowth of the cell protoplasm, coming from a basal body called a microsome which appears to arise from the nucleus. A fusion of cilia has occurred within the mouth cavity, producing the *undulating membrane* (Fig. 53). This is attached to the dorsal wall of the mouth, and guides the food particles that are swept within its reach. Just beneath the cilia, embedded in the cortical layer of the ectoplasm, is a uniform layer of spindle-shaped structures 1/1000 mm. in length, lying with their long axes perpendicular to the surface. These are *trichocysts.* They appear to be cavities in the ectoplasm filled with a semi-liquid homogeneous substance which is very refractive. They arise in the neighborhood of the nucleus. A small amount of osmic or acetic acid, when added to a drop of water containing *Paramecia,* causes in some cases the discharge of the trichocysts to the exterior through very small canals. This explosion is due to the pressure derived from the contraction of the cortical layer of the ectoplasm. After the explosion, the trichocysts appear as long threads which have been extended to about eight times their former length. Trichocysts are supposed to function as weapons of offense and defense. It is said that their contents are discharged with considerable force and that they contain a poison strong enough to paralyze any single-celled animal. Evidence that the trichocysts are weapons of defense is furnished when *Paramecium* encounters another ciliate *Didinium.* If the seizing organ of this protozoon becomes fastened in the *Paramecium,* a great number of trichocysts near the place of the injury are discharged. These produce a substance which becomes jelly-like on entering the water; this tends to force the two animals apart, and, if the *Paramecium* is a large one, it frequently succeeds in making its escape.

Two *contractile vacuoles* are present, occupying definite positions, one near either end, of the body. They lie between the ectoplasm and the endoplasm, close to the dorsal surface, and communicate with a large portion of the body by means of a system of *radiating canals,* six to ten in number. The vacuoles grow in size by the addition of liquid which is excreted by the protoplasm into the canals and is then poured into them. When the full size is reached, the walls contract and the contents are discharged to the exterior probably through a pore. The two vacuoles do not contract at the same time, but alternately, the interval between successive contractions being ten to twenty seconds. The expulsion of the fluid contents of the contractile vacuoles may be seen in the following way. *Paramecia* should be mounted in water into which has been rubbed up a stick of India or Chinese ink. They then appear white against a black background. Part of the water should be withdrawn. from beneath the cover glass, thus slightly compressing them. If now a specimen in profile is found and watched, the discharge produces

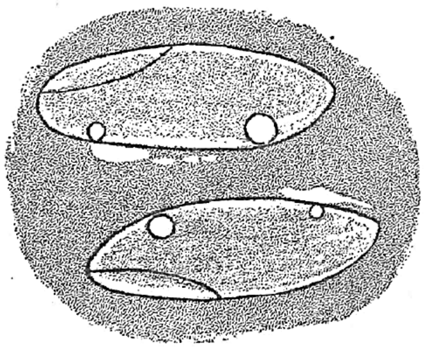

FIG. 49. — *Paramœcium:* discharge of contractile vacuoles. The organisms are represented swimming in a solution of India ink. (After Jennings.)

a bright spot outside in the opaque liquid; this lasts from one to two seconds, and is then driven off. by the cilia.

In *Paramecium trichium* the two contractile vacuoles are permanent structures with vesicles that collect and pour fluids into them and with a long convoluted excretory tubule ending in an excretory pore opening on the aboral surface. The duration of the systole is long compared with that of the diastole due probably to the presence of the excretory tubule. What has been said of the function of the contractile vacuole in *Amoeba* applies as well to that of *Paramecium, i.e.* it acts as an organ of excretion and respiration, and is probably hydrostatic. Most of the nitrogen secreted by *Paramecium* is in the form of urea and this substance has been detected in the contractile vacuole. However, the greater part of the excretory matter, including urea, apparently passes by dialysis directly to the exterior through the pellicle. That the primary function of the contractile vacuole is to regulate the water content of the protoplasm is indicated by the correlation between the frequency of pulsation and the rate water is taken in. For example, most long periods between pulsations, up to six minutes when actively swimming, occur when little water is ingested, and most short periods occur when the animals are at rest.

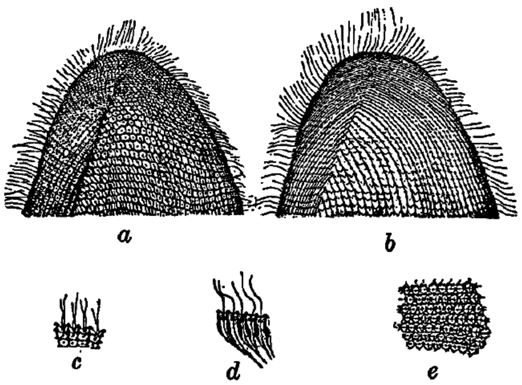

FIG. 50. — *Paramœcium caudatum.* Drawings designed to show the neuromotor apparatus. a, Anterior end showing the hexagonal sculpturing of the pellicle, the supportive preoral suture, the contractile organelles, which are wide and dark on the edges of the hexagons, the longitudinal ciliary fibrils of the neuromotor system, and the basal granules. b, Anterior end showing structures just beneath the pellicle, especially the longitudinal ciliary fibrils and curved commissural neurofibrils running transversely. c, Edge of pellicle showing basal granules in the center and papillæ at corners of the "dimples." d, Section through surface layer showing trichocysts and internal neurofibrils arising from base of basal granules. e, External structure of pellicle showing hexagon-shaped "dimples," light papillæ at the corners, basal granules, longitudinal ciliary fibrils and transverse commissural fibrils. (After Brown.)

Certal granules and associated fibrils have been described in *Paramecium* and considered to constitute a neuromotor apparatus sensory in function and of use in coordinating motion. Longitudinal ciliary fibrils, transverse commissural fibrils, and internal neurofibrils are present connected to the granules at the base of the cilia. These granules are connected near the periphery by the longitudinal ciliary fibrils and transversely by the commissural fibrils. The neurofibrils extend a short distance into the endoplasm and are perpendicular to the peripheral fibrils; they unite with each other and form a fan-like system.

Locomotion: The only movements of *Paramecium* that in any way resemble those of *Amoeba* are seen when the animal passes through a space smaller than its shorter diameter; it will then exhibit an elasticity which allows it to squirm through. In a free field *Paramecium* swims by means of its cilia. "These are usually inclined backward, and their stroke then drives the animal forward. They may at times be directed forward; their stroke then. drives the animal backward. The direction of their effective stroke may indeed be varied in many ways, as we shall see later.

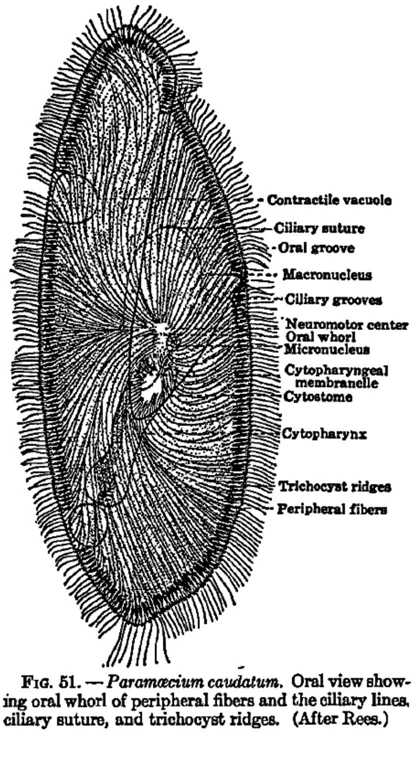

FIG. 51. — *Paramœcium caudatum.* Oral view showing oral whorl of peripheral fibers and the ciliary lines, ciliary suture, and trichocyst ridges. (After Rees.)

In addition to its forward or backward movement *Paramecium* rotates on its long axis. This rotation is over to the left, both when the animal is swimming forward and when it is swimming backward. The revolution on the long axis is not due to the oblique position of the oral groove, as might be supposed, for if the animal is cut in two, the posterior half, which has no oral groove, continues to revolve. "The cilia in the oral groove beat more effectively than those elsewhere. The result is to tum the anterior end continually away from the oral side, just as happens in a boat that is rowed on one side more strongly than on the other. As a result, the animal would swim in circles, turning continually toward the aboral side, but for the fact that it rotates on its long axis. Through the rotation the forward movement and the swerving to one side are combined to produce a spiral course. The swerving when the oral side is to the left, is to the right; when the oral side is above, the body swerves downward; when the oral side is to the right, the body swerves to the left, etc. Hence the swerving in any given direction is compensated by an equal swerving in the opposite direction; the resultant is a spiral path having a straight axis".

Rotation is thus effective in enabling an unsymmetrical animal to swim in a straight course through a medium which allows deviations to right or left, and up or down. It is well known that a human being cannot keep a straight course when lost in the woods, although he has a chance to err only to the right or left.

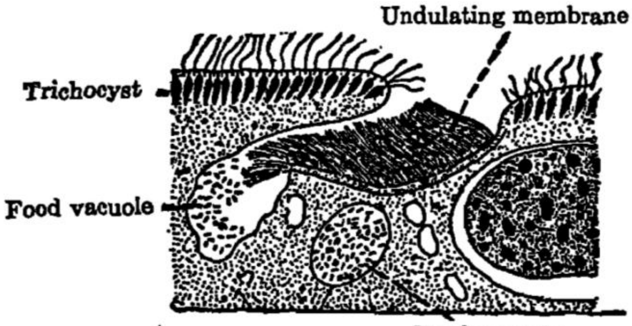

Fig. 53. — *Paramœcium:* formation of food vacuole. Section through cytopharynx showing the manner in which bacteria are swept into the food vacuole in process of formation. (After Maier.)

Nutrition: The *food* of *Paramecium* consists principally of bacteria and minute protozoa. The animal does not wait for the food to come within its reach, but by continually swimming from place to place is able to enter regions where favorable food conditions prevail. The cilia also bringing in food particles since a sort of vortex is formed by their arrangement about the oral groove which directs a steady stream of water toward the mouth.

Figure 53 illustrates the formation of a *food vacuole.* Food particles that are swept into the mouth are carried down into the cytopharynx by the undulating membrane; they are then moved onward by, the cilia lining the cytopharynx and are finally gathered together at the end of the passageway into a vacuole which gradually ·forms in the endoplasm. When this vacuole has reached a certain size, it is pinched off from the extremity of the cytopharynx by a contraction of the surrounding protoplasm, and the formation of another vacuole is begun. A food vacuole is a droplet of water with food particles suspended within it. As soon as one is separated from the cytopharynx, it is swept away by the rotary streaming movement of the endoplasm known as *cyclosis.* This carries the food vacuole around a definite course which begins just above and behind the cytopharynx, passes backward to the posterior end, then forward near the dorsal surface to the anterior end, and finally downward and along the ventral surface toward the mouth. During this journey digestion takes place. Unlike *Amoeba* a special *anal spot* or cytopyge is present in *Paramecium* through which indigestible solids are discharged to the outside. This opens on the ventral surface just behind the mouth. It can be seen only when material is cast out. It is not yet **known** whether the anal spot is a permanent orifice whose **lips are** so tightly closed as to be invisible to us or whether a fresh opening is made at each discharge. The processes of digestion, absorption, dissimilation, excretion, respiration, and growth are so similar to those described for *Amoeba* that they need not be considered further at this place

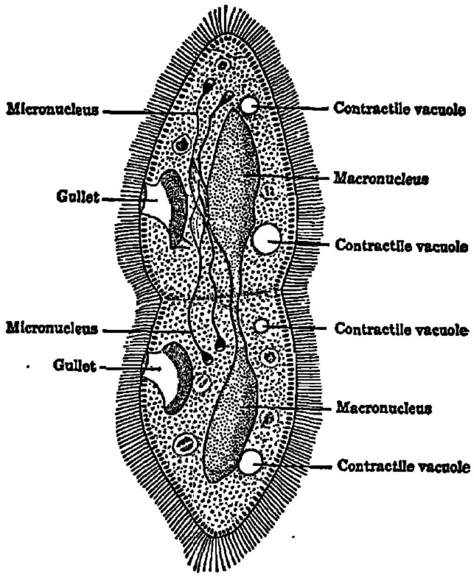

FIG. 55. — *Paramœcium aurelia:* binary fission. (From Newman after Lang.)

Reproduction: *Paramecium* reproduces only by simple *binary division.* This process is interrupted occasionally by a temporary union *(conjugation)* of two individuals and a subsequent mutual *fertilization.*

Binary fission- In binary fission the animal divides transversely. The first indication of a forthcoming division is seen in the micronucleus, which undergoes a sort of mitosis, its substance being equally divided between the two daughter nuclei; these separate and finally come to lie one near either end of the body. Figure shows two dividing micronuclei, since there are two of these in *Paramecium aurelia.* The macronucleus elongates and then divides transversely. The cytopharynx produces a bud which develops into another cytopharynx; these two structures move apart, the old cytopharynx advancing to the ventral middle line of the forepart of the body, and the new one to a similar position in the posterior half. The undulating membrane remains with the old cytopharynx while a new one arises in connection with the new cytopharynx. A new contractile vacuole arises near the anterior end of the body, another just back of the middle line. While these events are taking place, a constriction appears near the middle of the longitudinal diameter of the body; this cleavage furrow becomes deeper and deeper until only a slender thread of protoplasm holds the two halves of the body together. This connection is finally severed and the two daughter *Paramecia* are freed from each other. Each contains both macro- and micronuclei, two contractile vacuoles, and. a cytostome with cytopharynx. The entire process occupies about two hours. The time, however, varies considerably, depending upon the temperature of the water, the quality and quantity of food, and probably other factors. The daughter *Paramecia* increase rapidly in size, and at the end of twenty-four hours divide again if the temperature remains at from 15°-17° C; if the temperature is raised to 17°-20° C, two divisions may take place in one day. Encystment of *Paramecium* has been described, but if it really occurs, it apparently is a rare phenomenon.

Conjugation. - At a certain time in the life cycle of *Paramecium* conjugation occurs. The conditions that initiate this process are not yet known, but the complicated stages have been quite fully worked out. When two *Paramecia,* which are ready to conjugate, come together, they remain attached to each other because of the adhesive state of the external protoplasm. The ventral surfaces of the two animals are opposed, and a protoplasmic bridge is constructed between them. As soon as this union is affected, the nuclei pass through a series of stages which have been likened to the maturation processes of metazoan eggs. Two micronuclei are present in this species. The micronuclei *(A)* grow larger, their chromatin breaking up into granules which radiate from a division center at one end. The nucleus then lengthens, forming So spindle, and subsequently divides into two *(B).* These immediately divide again without the intervention of a resting stage. The resultant eight nuclei (C) have been compared to the sperms produced by primary spermatocytes or to eggs with their polar bodies, and the divisions are considered as the first and second maturation mitoses. Reduction occurs, at least in part, at the

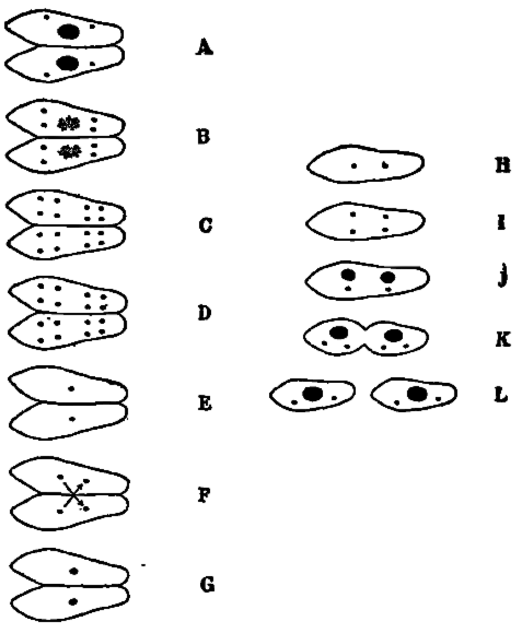

FIG. 56. — *Paramecium aurelia:* conjugation. A, union of two individuals along the peristomal region. B, degeneration of macronucleus and first division of the micronuclei. C, second division of micronuclei. D, seven of the eight micronuclei in each conjugant degenerate (indicated by circles) and disappear. E, each conjugant with a single remaining micronucleus. F, this nucleus divides into a stationary micronucleus and a migratory micronucleus — the gametic nuclei. The migratory micronuclei are exchanged by the conjugants and fuse with the respective stationary micronuclei to form the synkarya. This is fertilization. G, conjugants, with synkarya, separate (only one is followed from this point). H, first division of synkaryon to form two micronuclei. I, second reconstruction division. J, transformation of two micronuclei into macronuclei. K, division of micronuclei accompanied by cell division. L, typical nuclear condition restored. (After Woodruff.)

second maturation division. Seven of the eight nuclei degenerate *(D),* the eighth divides again. During this division there are no definite spindle fibers and no longitudinal splitting of the chromosomes, but the granules of chromatin contained in the nuclei separate into two groups, one smaller than the other. These groups of chromatic material then become recognizable as distinct nuclei. The smaller nucleus might be male nucleus, the other the female. The male nucleus migrates across the protoplasmic bridge between the two animals and unites with the female nucleus of the other conjugant forming a fusion nucleus, thus is *fertilization* effected. The conjugants separate soon after fertilization. The fusion nucleus of each conjugant, shortly after separation, divides by mitosis into two *(H),* and these two into four (1). Two of these increase in size and develop into macronuclei *(J).* The whole animal then divides by binary fission *(K),* each daughter cell securing one macronucleus and two micronuclei *(L).* An indefinite number of generations are produced by the transverse division of the two daughter cells resulting from each conjugant.

In a culture under continual observation a decline in the rate of reproduction occurs. The protoplasm at this stage undergoes a change both physically and chemically; the surface layer becomes sticky, so that when two cells meet, they fuse, and conjugation results. This frequently occurs in a large Dumber of animals in a single culture at the same time and a so-called "epidemic" of conjugation may then be observed. The conjugants are smaller than the other specimens, being only .21 mm. long, while the usual length is about .3 mm.

If the *Paramecia* are kept in a constant medium, *e.g.* hay infusion, they undergo a period of physiological depression about every three months, as shown by the decrease in their rate of division. Semi-annual periods also occur, but recovery from these does not take place if the animals are kept under constant conditions or conjugation is prevented, but the protoplasm degenerates and becomes vacuolated and the animals lose their energies and finally die.

Reference:

HEGNER R.W., Invertebrate Zoology, 1933, New York.