Chapter 5

Malaria and Plasmodium

MALARIAL PARASITE

Plasmodium vivax

Plasmodium is a sporozoan digenetic intracellular pathogenic protozoan parasite found in liver and RBCs of man and in the stomach and salivary glands of female anopheles mosquito. It takes its position in the kingdom protista are as follows:

Systematic Position

Kingdom - Protista

Phylum - Protozoa

Class - Sporozoa

Genus - Plasmodium

Species - vivax

Different species of Plasmodium are known but only four of them are pathogenic to man. The four species are P.vivax, P. malariae, falciparum and P.ovale.

Structure of parasite

Plasmodium is a dimorphic parasite, found in two stages trophozoite and sporozoite. A fully grown parasite is an amoeboid and uninucleate called the trophozoite. Its body is covered with a plasma membrane.

Cytoplasm is vacuolated which shows no differentiation between ecto and endoplasm.

A distinct nucleus with nucleolus is found in the cytoplasm. The cytoplasm contains dark palade's granules. The endoplasmic reticulum formed of smooth or rough vesicles. Mitochondria are very few in number with peripheral cristae. Golgi bodies and vacuoles of different sizes are also found. The nucleolus is placed eccentrically in the nucleus. The cytoplasm also contains food vacuoles having hemozoin.

Sporozoites are small (10-15 mm long), sickle shaped, uninucleate and motile forms of parasite. Each sporozoite consists of pellicle, CYtoplasm and nucleus. They are capable of wigging movements.

Life Cycle

Life cycle of Plasmodium is digenetic i.e. they complete their life cycle in two hosts.

I. Primary or definitive host:

Female Anopheles and other blood-sucking insects, in which they complete their sexual cycle. As the female Anopheles mosquitoes feed on blood, only they can serve as vector hosts of malarial parasites. The parasite does not harm the mosquitoes.

II. Secondary or intermediate host:

Man and other vertebrates, in which they complete their asexual cycle.

The three phases are:

i. **Schizogony:** Multiple fission in liver cells and RBCs of man.
ii. **Gamogony:** Phase of sexual reproduction occurs in mosquito.
iii. **Sporogony:** Formation of sporozoites in the stomach of mosquitoes.

Life cycle in Man (Asexual Cycle)

When an infected female Anopheles mosquito bites a healthy man to suck his blood for her meal, she injects salivary fluid containing sporozoites into the wound through its needle-like mouth parts. The saliva of mosquitoes prevents the clotting of blood. This is called **Inoculation**.

Within half of an hour the sickle shaped sporozoites completely disappear from the circulation and enter in the **parenchymatous** cells of the liver to start the life cycle.

1. Schizogony

Liver Schizogony: The **sporozoites** in the liver cells(usually single sporozoite in single liver cells) grow and become amoeboid and spherical in shape called **schizont**. The schizont divides to form many spindle shaped **merozoites.** The merozoites (cryptomerozoites) are asexual haploid forms. The multiplication of schozonts into merzoites is a method of asexual reproduction called **schizogony**.

The host liver cells rupture so merozoites are liberated in the sinusoids (spaces in the liver filled with blood) of liver. This asexual multiplication is called **Pre-erythrocytic Schizogony** and the resultant merozoites are called **cryptozoites.** It is completed in about 7 to 10 days. The interval between inoculation and initiation of the erythrocytic cycle is called the pre-**patent period**.

The cryptozoites feed on the cytoplasm of the hepatocytes and again enter into the new liver cells where they grow and become **schizont**. It divides to form a second generation of merozoites known as meta cryptozoites. This second phase of asexual multi plicati on is called **exo-erythrocyticschizogony**.The metacryptozoites divide to form meta crypto merozoites.

Erythrocytic cycle

The meta cryptozoites may again attack the new liver cells or enter into the RBCs. It takes nearly 10- 12 days from the date of infection to the formation of meta cryptozoites, which constitute the incubation period. In the RBCs, parasites become vacuolated and begin to grow. The organism is known as trophozoite.

Incubation period

The RBC gets ruptured to release merozoites. At this stage malaria fever is felt. The interval between the entry of the sporozoite into human blood and first appearance of the symptoms is called the incubation period.

Signet Ring Stage

Inside the trophozoite, a large vacuole is developed which pushes the nucleus towards one side. It gives a signet ring-like appearance to the trophozoite. This stage is known as the **signet ring stage.**

Amoeboid stage

Trophozoite enlarges and Soon the vacuole disappears. The trophozoite becomes amoeba shaped, this is called the amoeboid stage. The pseudopodia of this stage help in ingesting the cytoplasm of the corpuscles. The cytoplasm is digested and assimilated by the trophozoite. The hemoglobin of the host cell remains undigested and in turn is decomposed into **globin** and yellowish brown pigment called **hematin.** Globin is digested for nutrition while hematin accumulates in trophozoite's cytoplasm. The host RBC gets somewhat irregular in shape. A

number of yellow eosinophilic granules of unknown nature called **schuffner's granules** are formed. The trophozoite matures in about 36 hours. It is a rounded structure bounded by a double layered plasma membrane. They undergo mitotic divisions to form multinucleated organisms known as **schizont**. The nuclei gather cytoplasm around themselves and form merozoites. The trophozoite at this stage is known as **erythrocytic schizont** which gives rise to merozoites.

Rosette stage

The product of fission i.e. merozoites come to lie near the membrane. The leftover cytoplasm containing the haematin granules, metabolic wastes or toxins etc.remains in the center called rosette stage.

Merozoites and their release

The merozoites are small thick structures. Soon the weakened corpuscles burst. The merozoite along with the residual cytoplasm containing haematin and toxins are released into the plasma. The merozoites enter the fresh RBCs and repeat the erythrocytic schizogony. When red cell ruptures, the erythrocytic cycle is completed. The merozoites are released which proceed to invade other erythrocytes. The complete development from invasion of RBCs by merozoites to their rupture takes about 48 hours.

Sexual Cycle in Mosquito

When the mosquito bites the infected man, gametocytes enter its mouth and reached in the gut (through the blood meal).

2. Gamogony

Gamogony cycle takes place in mosquitoes. After several generations of erythrocytic schizogony, the merozoites produce 2 kinds of schizonts:

I. A non-resistant type (all digested) in. A resistant type(gametocytes) Some merozoites formed above become differentiated into macro gametocytes and microgametocytes.

A. Microgametocytes

These are smaller (9-10 u) motile and few in number. They have large centrally placed nuclei. They do not have any reserved food and hence the cytoplasm is light in color and clear.

B. Microgametocytes

These are large and many in number. Their size ranges from 10-12. They have reserved food material and the cytoplasm is dark in color. These can complete their development only within the gut of an appropriate mosquito vector.

C. Gametogenesis

The gametocytes in the alimentary canal of mosquito undergo further development to form male and female gametes. The micro gametes are very active and undergo spermatogenesis. Their nucleus divides by meiosis into 6-8 haploid daughter nuclei. These nuclei migrate towards the periphery, the cytoplasm pushes out forming long flagellum-like structures having one daughter nucleus in each. Thus 6-8 flagellums like male gametes are formed. Soon these gametes separate and the process is called exflagellation. They move actively in the stomach of a mosquito in search of a female gamete. The megagamete is non-motile and develops a cytoplasmic cone called fertilization 'one or cone of reception. The female megagametophytes undergo oogenesis. Each divides twice by meiosis, throwing out two small polar bodies and itself becoming a haploid gamete or ovim.

D. Fertilization

The male gamete enters the female gamete at the cone of reception by vigorous lashings. Soon the cytoplasm of the spermixes with that of the ovum and the nuclei of the both fuse to form a diploid zygote nucleus. Zygote forms in the stomach of mosquitoes about 9 or 10 days after the blood meal. The process of fusion of male and female gametes is called syngamy. In this case the gametes are dissimilar i.e. anisogametes hence their fusion is called anisogamy.

E. Formation of Ookinete

The resulting zygote son elongates and becomes motile. It is now known as ookinete which has pointed ends. It bores through the wall of stomach of mosquito probably with the help of lytic secretion and comes to lie under the basement membrane. Its cytoplasm is lighter towards one end but darker towards the other due to accumulation of hemozoin granules.

F. Formation of Oocyst

Within 24 hours of ingestion of the blood meal, the parasite becomes spherical, secretes a cyst called oocyst or sporont. It absorbs nourishment from the stomach wall and grows in size. A number of oocysts may be seen on the stomach of an infected mosquito.

3.Sporogony

The nucleus of each oocyst undergoes multiple fission forming a large number about 10,000 of minute daughter nuclei within 2 to 3 days. The cytoplasm gets vacuolated and many irregular cytoplasmic masses are formed. The nuclei get arranged at the margins of the cytoplasmic masses and finally some cytoplasm get constricted around them so as to form many spyroblasts. The nuclei of sporoblasts again multiply and cytoplasm gets constricted around them. Thus, the resultant structures in the sporoblasts elongate to form sickle shaped **sporozoites**.

Therefore, each oocyst gets filled with numerous sporozoites. Due to the pressure of sporozoites the oocyst wall ruptures and the sporozoites are liberated into the haemocoel of the mosquito, from where they reach to the salivary glands and penetrate into them. The whole sexual cycle in mosquito is completed from 10 days to 3 weeks. Thus, the mosquito with sporozoites in its salivary glands is said to be infective. Now, it is able to infect a normal man when it bites to suck the blood and, thus the life cycle is repeated. The period between inoculation of sporozoites into blood and first appearance of symptoms is called **incubation period**. It is 14 days in P. vivar and P.ovale 12 days in P. falciparum and 28 days in P. malariae.From the description given above, it is clear that Plasmodium shows an alternation of asexual generation with sexual generation during its life cycle.

Malarial Fever:

The malarial fever is characterized by alternate fever, sweating sensation, and chilling sensation. Generally, the patients become weak. Tongue may be thickly coated. The patients also felt headache, muscular pain and sometimes nausea and vomiting.

Control measures of mosquitoes

The following general methods may be used for the control of mosquitoes:

1. **Destruction of breeding places:** Areas of swamps and stagnant water should be drained in order to rescue the number of breeding places of mosquitoes. If water sources are not

possible to drain, kerosene oil should be sprayed on the water surface. It checks the mosquitoes from deposition

2. **Destruction of larvae and pupae:** It is easier to kill them in their developmental stages, by spraying kerosene, paris green powder and DDT over the surface of water. Most of them form a thin fiIm over the surface of water. It causes suffocation for these stages and results in their death.
3. **Biological control:** Some fishes feeding on insect larvae and pupae like stickleback, trouts, minnows, Gambusia etc. may be introduced in the water reservoirs. They feed effectively on these development stages so their number reduces. Farming of ducks and clearing of floating plants are also found effective to control Mosquitoes.
4. **Destruction of adults:** Adult mosquito can be destroyed by buring sulphur, tar, etc. Using DDT and insecticides can also be an effective way to destroy adult mosquito.
5. **Personal protection:** Mosquito repellents like anti mosquito cream (odomos), anti mosquito mats and mustard oil etc. can be used to keep the mosquito away. During sleep fine mesh mosquito nets should be used. The doors and windows of houses should be screened to prevent the entry of mosquitoes.
6. **Treatment of the patient:** Quinine is the oldest drug for malaria, other anit-malarial drugs are paludrine, primaquin, chloroquinine, camoquin and comoprima.

Paramecium

Paramecium is a microscopic organism. It is visible to the naked eye as a minute elongated body. Paramecium is a typical ciliate protista. Ciliates are characterized by the presence of cilia, nuclear **dimorphism** and a unique type of sexual reproduction. The different species of Paramecium are grouped into two categories, an **aurelia group** and a **bursaria group**.

I. P. auxelia are elongated, spindle shaped, body length more than width and cytoproct is lateral. Paramecium caudatum, P. aurelia and P. multi micronucleatum are common members of this group.

II. P. bursaria are short and broad, the posterior end is somewhat broad and the cytoproct is subterminal. The common members of this group are P. bursaria, P. trichium, P. woodruffi etc.

Paramecium caudatum is described here in detail.

Systematic Position

Kingdom - Protista

Phylum - Protozoa

Sub-Phylum-Ciliophora

Class - Ciliata

Genus - Paramecium

Species - caudatum

Habit and Habitat

Paramecium is freshwater, unicellular ciliate which inhabits in ponds, ditches water, rivers, rice fields etc; abundantly found in stagnant water, where organic matter is in plenty. It moves here and there with the help of cilia, which also functions as food capture. There are about 10 known species of Paramecium, differing in shape, size number of micronuclei etc.

Structure

Body of the Paramecium is streamlined. The anterior end is blunt and semicircular while the posterior end is thick and pointed. The ventral surface is flattened and the dorsal side is concave. The body of the animal is **asymmetrical** in form showing a well defined oral and aboral

surface.

Shape: The shape of Paramecium is lengthy and is just like that of the sole of the shoe. So it is named as **"slipper animalcule."**

Size: The size of Paramecium is variable, ranging from 0.06 mm to 0.3 mm long.

P. caudatum - 0.15 to 0.3 mm long.

P. aurelia - 0.12 to 0.25 mm long.

P. trichium - 0.06 mm long.

External Structures

The external structure of Paramecium is complex and it consists of the following parts: Pellicle, oral groove, cilia and cytopyge.

1. Pellicle

The Paramecium is externally bounded by a thin, firm, elastic and a colourless membrane known as pellicle. Because of the pellicle, it always maintains its body shape. The pellicle is made of gelatin. The pellicle shows **hexagonal depressions** on its surface. 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**.

2. Oral groove

At the anterior end of the ventral side shows a large depression called the oral groove or buccal groove. Posteriorly it opens into the cytopharynx through the cytostome. The oral groove leads into a short and conical funnel-shaped depression called **vestibule**. The vestibule leads directly into the fixed, oval shaped opening called **cytosome (mouth)**. The cytostome extends into a tubular wide passage known as cytopharynx which terminates into the endoplasm forming a food vacuole. The oral groove, vestibule, cytosome and cytopharynx together are known as the feeding apparatus of *Paramecium*.

3. Cytopyge

It is situated on the ventral surface of the oral groove. It is also called as permanent cell anal spot. Through this spot undigested food is egested out

4. Cilia

The entire body surface is covered by numerous, small, hair like fine threads called cilia. The cilia are of equal size and arranged in regular longitudinal rows. Under the pellicle each cilium is connected to a spherical basal granule and it is embedded in the ectoplasm. The úlium arises from basal granules. The cilia are organelles of locomotion and food collection. They also act as sensory receptors and detect the stimuli of the external environment.

Internal Structures

The cytoplasm is differentiated into a narrow, external region called ectoplasm and a larger internal region called **endoplasm**.

A. Ectoplasm: It is a permanent part of a body and forms a thin clear and dense outer layer. It contains the trichocyst, cilia and is bounded externally by a pellicle.

Trichocyst:

It is situated in the ectoplasm and forms the perpendicular arrangement with the body surface. It is tiny and spindle shaped. It opens to the exterior through a minute pore on the pellicle surface. They are filled with a refractive, dense fluid having a swelling substance. The outer end is a conical head or spike. They arise from kinetosomes of cilia, then migrate and locate themselves at equal distance in the endoplasm. When the animal is irritated the trichocysts are discharged as long sticky threads. A discharged trichocyst has an opaque spike-like an inverted nail and long striated shaft. The shaft is not seen in the undischarged state and is probably formed during discharge. The trichocyst helps in defense as well as in offence . According to modern views it also helps in sticking.

B. Endoplasm: The endoplasm of Paramecium is thin, less granular in structure. The following are the different parts of it:

I. Nuclear apparatus: Paramecium is binucleate, with nuclear dimorphism.

a. Mega nucleus: It is large and kidney shaped.It controls the metabolic activities inside the body. The nuclear membrane is absent in it.

It divides **amitotically** during reproduction and is formed by small **micronuclei**.

b. Micronuclei: It is small, rounded and situated in the depression of meganucleus. It controls the reproduction in *Paramecium*. It is bounded by a nuclear membrane and always divides mitotically.

II. Contractile vacuoles: There are two contractile vacuoles present in the Paramecium. It is situated on the dorsal surface of anterior and posterior parts and is of fixed shape. It maintains the **osmoregulation.** It is of contractile nature and also helps in the. removal of carbon dioxide and excretory products to outside. The contractile vacuole is surrounded by 6 to 8 radial canals.

III. Food vacuole: Numerous non-contractile vacuoles are present in the cytoplasm of Paramecium. It moves inside the endoplasm just like that of needles of a watch. The movement of the vacuoles are known as cyclosis. Cylcosis helps in circulation of food. Thus shape and size changes according to the quality of food particles. The food vacuole is also called gastrioles.

In addition to this starch, glycogen, fat, mitochondria, ribosome, and kappa particles are also found in the cytoplasm of *Paramecium*.

Locomotion

Paramecium performs two types of locomotion. They are: creeping and Swimming locomotion.

1. **Creeping locomotion**

It occurs with the help of pellicle and cilia. It simply glides along using the cilia of its oral surface. At this time pellicle becomes elastic, the body can easily bend and squeeze through small gaps narrower than its own body diameter. This type of locomotion is performed at the time when many obstacles are found in ponds and ditches.

2. **Swimming locomotion**

This type of locomotion occurs through cilia. If an animal wants to move forward, the cilia become inclined backward and they move rapidly by repetition.

Nutrition

Mode of nutrition in Paramecium is **holozoic**. Food includes minute living organisms mainly bacteria, unicellular algae, diatoms, yeasts, etc. Ingestion takes place by specialized cilia - dorsal **quadrulus**, dorsal peninculas and ventral peninculas through water current.

Paramecium is filter feeder.

The food passes into the cytopharynx through the cytostome and finally settles down in the reservoir. Digestion takes place with the help of certain enzymes secreted by protoplasm into the vacuoles. In digestion proteins are changed into **amino acids**, carbohydrates into soluble sugars and glycogen and fats are probably also digested. The contents of food vacuoles are at first **acidic** (pH about 4) and then become alkaline. The major digestion of food occurs during the alkali phase. A food vacuole is formed at the end of cytopharynx. When the vacuoles become full; it leaves into the endoplasm independently.

Digested food distributed in the endoplasm by cyclosis. Undigested food is expelled out through permanent cell anal aperture the **cytopyge.**

Respiration

Respiration takes place by the general body surface. The pellicle is semi-permeable through which exchange of gases takes place. They obtain oxygen from the surrounding water and carbon dioxide and other wastes excreted by using outward in the reverse directions.

Excretion

Excretion also takes place by general body surface. Cytopyge is the permanent excretory organ. Contractile vacuoles are concerned with osmoregulation. Paramecium is an **ammonotelic**.

Reproduction

Reproduction is the outstanding characteristics of living beings. They reproduce again and again in their lifetime to continue their generations. Paramecium reproduces asexually as well as sexually.

Asexual Reproduction

Asexual reproduction in Paramecium takes place by transverse binary fission. It is found during **favorable conditions.** Single individual divides into two daughter individuals by transverse binary fission. It completes in following steps:

a. The macronucleus changes its shape and through as it divides by amitotically into two.
b. The micronucleus becomes spindle shaped and divides mitotically and forms two daughter micronuclei.
c. Paramecia stops feeding and the oral groove disappears. Each daughter Paramecium develops its own oral groove. One contractile vacuole goes to one half; another goes to another half.
d. The endoplasm is divided into two in the middle of the body transversely.
e. Daughter individuals are called proter (formed from anterior) and opisthe (formed form posterior).
f. The whole process completes within twenty minutes and in 24 hours it divides two or three times.

Sexual Reproduction

Sexual reproduction takes place by conjugation. Conjugation is the temporary union of two individuals to exchange their nuclear materials (micronucleus) later to become separate. Paramecia which are ready to conjugate are called conjugants or gametocytes. Conjugation only takes place in those two Paramecia which are morphologically similar and physiologically different.

Process of conjugation

The making partners come near each other and unite with their ventral surfaces. They stop feeding and their feeding apparatus disappears. Both of them are adhered together by sticky substances secreted by the cilia. Pellicle dissolves and a cytoplasmic bridge formed between their buccal apparatus.

i. The macronucleus disintegrates. The micronucleus increases in size and divides into two parts.
ii. ii. The micronucleus of each Paramecium divides again by meitic division and forms four haploid nuclei.
iii. Out of the four haploid nuclei, three disappear in each conjugant.
iv. The remaining nucleus divides unequally and is distributed into two portions. One is larger known as stationary or female pronucleus and other is smaller known as migratory pronucleus.
v. Stationary pronucleus remains inside the body, while migratory (smaller) pronuclei are exchanged.
vi. The two pronuclei in each unite as a zygote nucleus. They are diploid in nature just like that of its parents.
vii. The hereditary materials of both of the Paramecium are transferred to each other. The protoplasmic bridge disintegrates and the two Paramecia become separated known as exconjugants.
viii. The zygote nucleus (synkaryon) of each ex-conjugant divides three times repeatedly and produces eight nuclei. Among them the large four are called macronuclei and small four are called micronuclei
ix. Out of the four micronuclei, three disappear and only one persists.

x. The remaining micronucleus divides into two. So, each daughter Paramecium has one micro and two macronuclei.

xi. xii. The micronuclei of the two daughter Paramecia divide into two and later the daughter Paramecium also divides mitotically into two.

xii. In this way eight Paramecia are formed after conjugation of each conjugant.

Significance of Conjugation

i. After continuous binary fissions the micronucleus of Paramecium becomes very weak. Paramecium losses the power to reproduce more. So, conjugation helps in the rejuvenation of it.

ii. The mutual transfer of hereditary materials brings the new daughter nuclei with new vigour and vitality.

iii. Due to the repeated divisions, the macronucleus also becomes very weak. So by this process it is also rejuvenated, and this helps to store energy and strength in Paramecium.

iv. The daughter Paramecia become more suited to new environment.

Autogamy

Autogamy is a modified form of self-fertilization. It was first reported in P. aurelia which is a bimicronucleate species. It occurs in single individuals. The macronucleus breaks and disintegrates, but the two micronuclei divide, once by meiotic and then by mitotic division. As a result haploid daughter nuclei are formed. Now, seven daughter micronuclei disintegrate and the remaining one dives again into male and female pronuclei. Both pronuclei move towards the oral region and fuse together to form a diploid synkaryon. The latter divides twice and the animal also divides into two daughters. Each of them receives one macronucleus distribution and two micronuclei by their division Autogamy rejuvenates Paramecium.

Cytogamy

Cytogamy is a sexual process which occurs without nuclear exchange. The process of cytogamy resembles that of conjugation in which the small Paramecia temporarily unite by

their oral surfaces. Male and female pronuclei of the same individual fuse to form synkaryon as in autogamy.

Endomixis

Endomixis is an interesting phenomenon involving a total internal nuclear reorganization within a single individual. It takes place in the absence of conjugation in which the macronucleus disintegrates as usual and the micronuclei divide twice into & daughter nuclei only by mitosis. Out of these nuclei, 6 or 7 disintegrates. Now, the animal itself divides into two daughters, each receiving a single nucleus. This nucleus divides into 4 nuclei of which two as macro and two as micronuclei.