Chapter 13

Protozoa

- Protozoa are **single-celled microscopic eukaryotic** organisms that are noted for their ability to move independently.
- Protozoa are **members of the kingdom protista, along with algae (plant-like), and slime molds, and water molds (Fungi-like)**.
- Protozoa are sometimes referred to as **animal-like protists**.
- Biologist have identified about **65,000 species** of protozoa, almost half which are extinct species from fossils.
- **Protozoology** is the scientific study of protozoa.
- **Goldfuss (1817)** coined the phylum name protozoa.
- Protozoa exhibit **protoplasmic level of organization**.
- The **complexity** of protozoa sets them apart from the relatively simple structures of bacteria and viruses.
- Protozoa **live in many different environments**; they can **drift** in the ocean, **creep** across vegetation in fresh water rivers and ponds, **crawl** in deep soil, and even **reproduce in the bodies of other organisms**.
- **Majority of protozoa** are **solitary** but some like *Volvox* & *Proterospongia* are **colonial**.
- Most protozoa are **heterotrophic** *i.e.*, obtain their nutrients by ingesting small molecules or cells.
- These particles are usually broken down in **food vacuoles** which is a membrane-bound chambers that contain digestive enzymes.
- Many species are **free-living**, while others are **parasites**.
- **Free-living species** live in any habitat where **water or moisture is available** at some time during the year.
- **Parasitic or commensal protozoa** usually **have complex life cycles** that take place in the cells, tissues and bloodstream of their host. Several species cause serious human diseases, including **malaria**, **amoebic dysentery** and **giardiasis**.
- Common **parasitic protozoa** are *Entamoeba*, *Trypanosoma, Giardia*, *Trichomonas*, *Leishmania*, *Plasmodium* etc.
- Many **free-living species** have a localized region of **pigment** called an **eyespot**. Eyespots **detect changes in the quantity and quality of light**.
- Common **free living protozoans** are *Amoeba, Euglena, Volvox* and *Paramecium*.
- Many species make up **zooplankton**, a population of organisms that constitutes one of the primary sources of energy in aquatic ecosystems. They are the beginning of the food chain.
- All protozoa can reproduce **asexually**, usually by **binary fission.** During binary fission, a protozoan **divides into two identical individuals**.
- Some species reproduce by **multiple fission**, a form of cell division that **results in a number of identical individuals**.
- While all species can reproduce asexually, a few also reproduce **sexually**, through **conjugation**.
- During conjugation, individuals from **opposite mating strains pair** and **exchange genetic material (DNA)**. Conjugation in protozoa is **more complex than in bacteria**.
- Many species have **physiological mechanisms** for monitoring conditions in their environment.
- Certain protozoan species also **sense physical and chemical changes** or obstacles in their environment.
- Most protozoa are separated from their environment only **by their cell membrane**.
- They can **survive in extreme (harsh) conditions due to their ability to form cysts**. A **cyst is a dormant form** characterized by a hard external covering in which metabolic activity has ceased.

- Many species form cysts **in response to changes in the environment**, such as nutrient deficiency, drought, decreased oxygen concentration, or pH or temperature changes.
- When favourable environmental condition return, a **protozoan emerges from the cysts and resumes metabolic activity**.
- **Osmoregulation** takes place in protozoa **with the help of contractile vaccole** (present in the free living forms but **absent in parasites**).
- **Locomotor organelles** in protozoa are– finger like **pseudopodia** or whip like **flagella** or hair like **cilia** or absent.
- **Gaseous exchange** and **excretion** occurs **by diffusion through body surface**.
- The **first prokaryote** evolved more than **3.5 billion years ago** and about **1.5 billion years ago the first eukaryotic organisms evolved**. Protozoa are the **descendants of these early eukaryotes**.
- The **first eukaryotes** probably **evolved through endosymbiosis**, a process in which one prokaryote lives inside another and gradually both host and guest become dependent on one another.
- A convenient way to classify protozoans is based on the **way they move** *i.e.*, **locomotion : the four phyla** of protozoans are :
  - Phylum **sarcomastigophora**, move by **flagella** and **pseudopodia**.
  - Phylum **ciliophora** (ciliophorans) or ciliates, move by **hairlike cilia**.
  - Phylum **cnidospora**, a **spore producing** protozoa.
  - Phylum **sporozoa** (sporozoans) **do not move** by themselves at all.
- Sarcomastigophora is **divided into 3 classes - mastigophora**, **sarcodina** and **opalinata**.

MASTIGOPHORA

- Mastigophora is divided into **phytoflagellata** and **zooflagellata**.
- The **2,500 species** that make up the **phylum zoomastigina** are characterized by the presence of one or more **flagella**, long, hairlike structures that are **made up of microtubules**.
- Zooflagellates are protozoans that move by means of **flagella**.
- Some zooflagellates are **free-living**, **freshwater or marine organisms**.
- Many can live inside other organisms in **symbiotic relationship** (a relationship in which two different organisms live closely together; it can be either beneficial or harmful to the organism).
- The symbiotic relationship may be : **mutualistic relationship** - both organisms benefit, **parasitic relationship** - causes harm to the host.
- *Euglena* is called **phytoflagellate** as it **possesses both chloroplasts as well as flagella**.
- *Euglena* is a **connecting link between animals & plants**.
- **Nutrition** in *Euglena* is **myxotrophic**, when light is available it is photosynthetic, in darkness it is saprophytic absorbing food from surrounding water.
- *Euglena* (**commonly called plant animalcule**) **contains chlorophyll**, yet it resembles animals, because it possesses a contractile vacuole near cytopharynx.
- **Reaserve food** is stored in the form of **paramylum or paramylon** in *Euglena*.
- Asexual reproduction in *Euglena* occurs by **longitudinal binary fission**, **no sexual reproduction observed**.
- Some zooflagellates are **parasitic organisms** that cause disease in humans.
- The zooflagellate *Trypanosoma* causes african trypanosomiasis, "**african sleeping sickness**", in humans. It produces toxins that destroy red blood cells, causing the host to become weak. This disease if left untreated eventually attacks the host's **nervous system, causing death**.
- This disease effects all large mammals, including humans in some parts of Africa. The disease is **spread by the bite of the tsetse fly**.
- Another species called ***Trypanosoma cruzi***, causes **Chagas' disease**. It is transmitted by an insect called the **"kissing bug"**, patients suffer from fever, and heart damage.
- The *Trichonympha* lives in the **guts of termites**, and help the termite **digest cellulose** in wood. This is a mutualistic relationship, they both benefit from the relationship.
- **Euspundia**, characterized by lesions upon skin and mucous membrane of nose, mouth, pharynx, (hence called naso-oral leishmaniasis) is caused by *Leishmania brasiliensis*.
- *Leishmania donovani* causes **kala-azar** (**also called dumdum fever**). Infection chiefly occurs in spleen

Protozoa

Divided into 4 subphylums on the basis of locomotory organelles

Sarcomastigophora

Divided into 3 classes

Mastigophora (Flagellates)

- Locomotory organ is thread like flagella (as food capturing organelles) Eg. *Euglena, Trypanosoma* etc.
- Contractile vacuole is present for osmoregulation
- Types of **flagella**
  - **Phytomastigna**; with chloroplast, plant like Eg. *Euglena*, *Chlamydomonas* etc.
  - **Zoomastigna**; without chloroplast, animal like Eg. *Trypanosoma, Leishmania, Giardia* etc.

Sarcodina (= Rhizopoda)

- Commonly known as **amoebas**
- Locomotory organ is **pseudopodia**
- Body shape is changeable due to presence of pseudopodia which brought about the temporary outpushings of cytoplasm
- Types of pseudopodia are
  - **Lobopodia** (*Amoeba*)
  - **Filopodia** (*Euglypha*)
  - **Reticulopodia** (*Globigernia*)
  - **Axopodia** (*Actinophrys sol*)

Opalinata

- Intestinal parasites of amphibians (frogs and toads)
- Locomotory organs are short, **cilia like**
- Gametes are flagellated, involve in sexual reproduction Eg. *Opalina*

Sporozoa (Apicomplexa or parasitic protozoa)

- Locomotory organelles and contractile vacuole are **absent**
- All members of these groups are **endoparasites**
- Eg. *Plasmodium, Monocystis, Babesia, Eimeria, Toxoplasma* etc.

Cnidospora

- **Intracellular endoparasites**, especially of insects
- **No locomotory organelles & contractile vacuole**
- Classes, on the basis of spore formation
  - — Myxosporidea (*Myxidium*)
  - — Microsporidea (*Nosema*)

Ciliophora (Ciliates)

- Largest group of protozoa
- Locomotory organelles are **cilia or ciliary organelles** which is replaced by sucking tentacles in adult
- **Dimorphic** (2 different types of nuclei :- micro & macro)
- Class : Ciliata (Eg. *Paramecium, Balantidium*)

Flowchart : Classification of Protozoa.

and liver, secondarily in bone marrow & intestinal villi.

- *Leishmania* is a **digenetic blood flagellate** whose **intermediate host (vector) is sandfly** belonging to genus *Phlebotomus*.
- *Giardia*, commonly nicknamed as the **Grand old man of the intestine** is a diplomonadid parasitic flagellate occurring in the intestine of man and other animals.
- *Giardia* was **discovered by Leewenhoek** in his own stool in 1681.
- *Giardia* causes **diarrhoea or giardiasis** (very loose and frequent stool containing large quantity of fat), which is accompanied by flatulence, abdominal pain, loss of appetite, weight loss etc.

SARCODINES

- Biologists have classified **40,000 species of protozoa** in the phylum **sarcodina**.
- **Sarcodines** are grouped into **four types– amoebids** (eg. *Amoeba*, *Entamoeba* etc), **radiolarians** (eg. *Acanthometra* etc), **foraminiferans** (eg. *Elphidium*, *Globigerina* etc) and **heliozoans** (eg. *Actinophrys*).
- Sarcodinians are protozoans that move by **extending lobes of cytoplasm**.
- The lobes of cytoplasm that sarcodinians extend are called **pseudopods** (**pseudopodia**), which means **"false foot".**
- A pseudopodia forms when **endoplasm**, the inner portion of cytoplasm, pushes the **ectoplasm**, the outer layer, forward to create a blunt, armlike extention.
- Sarcodines **include hundreds of species of *Amoebas***, which inhabit fresh water, salt water, and soil. Some can even live on mud, rocks, and other surfaces in shallow, slow moving streams and ponds.
- Sarcodines live on other protists, which they **engulf (eat) by phagocytosis**.
- When a sarcodine feeds, it surrounds the food with its pseudopodia. A portion of the cell membrane then pinches together and surrounds the food in a food vacuole, in a process called **endocytosis**. Enzymes from the cytoplasm then enter the vacuole and digest the food. Undigested food leaves the cell in a reverse process called **exocytosis**.
- Most fresh water sarcodines have **contractile vacuoles**, an organelle that **removes excess water from the cell**.
- When conditions are unfavorable, **amoebas survive by becoming hard cysts**. The cysts can withstand drought, heat, or being eaten by other organisms.
- Not all sarcodinians are soft "naked"; **many have hard shells or test** of calcium carbonate or silica and are called **foraminiferans** and **radiolarians**.
- **Most petroleum bearing regions shows the presence of foraminiferans and radiolarians** in the fossil state.
- Most hard shell sarcodinians **live in the ocean**, and **are important food sources** for many marine animals.
- **When hard shelled sarcodinians die**, their shells sink to the bottom of the ocean making huge deposits of limestone called **chalk**.
- The most famous chalk deposits are **the Cliffs of Dover on the coast of England**.
- The **great Pyramids of Egypt** were built with stones quarried from limestone beds that are made from a large foraminiferan.
- *Amoeba* was discovered by **Russel von Rosenhoff** in 1755.
- Body of *Amoeba* is covered by **plasmalemma**, a trilaminar and selectively permeable membrane.
- Plasmalemma is **excretory** as ammonia diffuses out through it and **respiratory** as diffusion of oxygen and carbon dioxide takes place through it.
- The **type of pseudopodium** found in *Amoeba proteus* is **lobopodium**.
- Pseudopodium at its forward end gets its firm consistency by **hyaline cap** which is made of ectoplasm.
- Pseudopodia in *Amoeba* are **meant for feeding and locomotion**.
- Pseudopodia are found in *Amoeba* and leucocyte of higher animals.
- Locomotion of *Amoeba* is known as '**amoeboid movement**'.

Table : Theories of amoeboid movement

Theory	Scientists
Surface tension	Berthold (1886)
Rolling movement	Jennings (1904)
Walking movement	Dellinger (1906)
Sol-gel	Hyman (1917)
Folding and unfolding	Goldacre and Lorch (1959)
Contraction-hydraulic	Rinaldi and Jahn (1963)

- Amoeboid movement is a form of **cytoplasmic streaming**, the internal flowing of a cell's cytoplasm.
- *Amoebas* move by extending part of their cell membrane into a lobe, or pseudopodia, that can attach to a surface. Then, cytoplasm streams into the pseudopodia and pulls the organism forward. This movement is called **amoeboid movement**.
- Sol-gel theory of amoeboid movement was first given by **Hyman** supported by **Pantin** and **Mast**.
- *Amoeba* has **no skeleton**.
- Contractile vacuole in *Amoeba* is concerned with **osmoregulation**, *i.e.*, removal of excess of water.
- If an *Amoeba* is **placed in distilled water**, its **contractile vacuole works faster**.
- If an *Amoeba* is **placed in salt water**, its contractile vacuole will disappear.
- If marine *Amoeba* is **shifted to fresh water**, **it swells and may burst**.
- **Contractile vacuole** of *Amoeba* is **analogous (similar in function) to uriniferous tubules of frog**.
- An *Amoeba* transferred from a container X to another container Y developed a new contractile vacuole, but the vacuole disappeared again when the *Amoeba* was transferred back to the container X. The containers X and Y respectively contain marine and freshwater.
- **Mode of nutrition** in *Amoeba* is **holozoic** *i.e.*, *Amoeba* is **heterotrophic**.
- *Amoeba* **ingest food by import, circumfluence, circumvallation or invagination**.
- Digestion in *Amoeba* is **intracellular**.
- **Food vacuole** of *Amoeba* is **analogous to the alimentary canal** of an animal or gastrovascular cavity of *Hydra*.
- The contents of food vacuole in *Amoeba* first becomes acidic then alkaline.
- The behaviour of *Amoeba* involves the manner in which responds to the environmental conditions (called **taxes**).
- **Different taxes with respect to kind of stimuli** are – **thermotaxis** (temperature), **phototaxis** (light), **thigmotaxis** (touch), **chemotaxis** (chemicals), **galvanotaxis** (electric current), **geotaxis** (gravity) and **rheotaxis** (water current).
- *Amoeba proteus* **does not reproduce sexually**.
- **Binary fission** in *Amoeba* takes place when food is abundant and temperature is suitable. It is completed in **30 minutes.**
- **Multiple fission** or **sporulation** takes place during unfavourable condition after encystment. There are three layers of cysts.
- Lack of oxygen and food **induces encystment**, products of **multiple fission** are called **'amoebulae'**.
- *Amoeba* regenerates **from nucleated bits**.
- **Lamble** (1859) discovered *E. histolytica*. **Friedrick Losch, a Russion zoologist**, discovered its pathogenic nature in 1875.
- *E. histolytica* is a **pathogenic intestinal parasite occurring in the colon of man** and causes '**amoebic dysentery** or **amoebiasis**.
- It **lives in the large intestines**, where it secretes enzymes that attack the intestinal lining and causing deep ulcers.
- Affected individuals feel **intense pain**, and complications arise when the amoebas are carried by the **blood to the liver and other organs**.
- *E. histolytica* **has only one host** and so **monogenetic** and completes its life cycle in humans.
- *E. histolytica* **occurs in two forms**: **magna** (trophozoite) which is **pathogenic** and found in the mucosa and sub-mucosa of intestine forming ulcers, and **minuta** which is **nonpathogenic** form and found in the lumen of intestine.
- Its adult is called **trophozoite** and is **monopodial**.
- Trophozoite of *Entamoeba* **reproduces by binary fission**.
- Minuta form encysts. A mature cyst is called **quadrinucleate cyst**. It has four nuclei and two **chromatoid bodies**.
- The reserve food material in cyst of *E. histolytica* is **glycogen**.
- **Quadrinucleate cyst** is the **infective stage**.
- **Contractile vacuoles are not present** in *E. histolytica* **since it inhabits an isotonic environment of intestine**.
- The **tetranucleate cysts** of *E. histolyitca* **constitute the transmittive or infective stage**. It damages the intestinal wall by enzyme **histolysin**.
- *Entamoeba coli* inhabits human colon. It is a commensal parasite and does not produce any disease.
- *Entamoeba histolytica* causes **amoebic dysentery or amoebiasis**.

- *Entamoeba gingivalis* is a **parasite of human teeth**, found in the abscesses of gum and in pus pockets of **pyorrhoea** bleeding gums.
- Cyst is not formed in *E. gingivalis* and infection occurs by direct contact like kissing.

CILIATES

- The **8,000 species** that make up the phylum ciliophora swim by means of **cilia**, which are **short**, **hairlike cytoplasmic projections** that line the cell membrane.
- The cilia is **used for movement by beating like oars** (= a long shaft of wood for propelling a boat by rowing) **to propel the protists**.
- Some kinds of ciliates have **specialized cilia shaped like teeth**, paddles, or feet.
- Ciliates have the **most elaborate organelles** of any protozoa.
- Most ciliates **live in freshwater**. A common freshwater ciliate is the *Paramecium*.
- Protozoan both eats and swims **through water** with it's cilia.
- When eating, the cilia sweeps food particles, such as microscopic algae and bacteria, into the **oral groove**. In the oral groove, the **mouth pore** opens into a **gullet**, which pinches off around them to form a **food vacuoles**.
- The food vacuoles move inside the cytoplasm where nutrients are extracted, it ejects the waste through an opening called the **anal pore**.
- All protozoans have **contractile vacuoles**. These are an important adaptation for living in water. Contractile vacuoles **collect excess water (osmosis)** and **pump it outside the cell body**.
- *Paramecium* is a **holotrichous ciliate protozoan**.
- **Hill** (1752) discovered *Paramecium*.
- *Paramecium* is commonly called as **'Slipper animalcule'**.
- *Paramecium* have a protective covering over their cell membrane, it is a clear, elastic layer of protein, called a **pellicle**.
- **Trichocysts** are peculiar bottle-shaped organelles present in the ectoplasm of *Paramecium*.
- Trichocysts are the **organelles of offence and defence**.
- *Paramecium* is **heterokaryotic** (dimorphic nuclei).
- **Micronuclei**, one (*P. caudatum*), two (*P. aurelia*) and several (*P. multimicronucleatum*) are **only concerned with reproduction.**
- Oral apparatus or food apparatus consists of **cytopharynx** and **cytostome** (mouth), **cytopyge** or **cytoproct** (anus).
- Nutrition or food intake in *Paramecium* is **holozoic**.
- *Paramecium* is a **filter feeder**.
- *Paramecium* **has two contractile vacuoles which control osmoregulation**.
- Most favourite food of *Paramecium* is *Tetrahymena*, another ciliate protozoa used in biological research.
- **Digestion is intracellular** in *Paramecium*.
- **Respiration and excretion** of *Paramecium* are **through general body surface**.
- *Paramecium* shows **negative response** and moves against water current.
- *Paramecium* also have two distinct kinds of nuclei (**multinucleate**) – **macronucleus** and **micronucleus**.
- The large **macronucleus** (containing multiple copies of DNA) controls **ongoing metabolic functions** of the cell (the brain) and asexual reproduction.
- The smaller **micronucleus** is involved in **genetic exchange during sexual reproduction** by conjugation - the joining of two opposite mating strains and exchanging genetic material.
- *Paramecium* reproduces asexually by **transverse binary fission** and **nuclear reorganisation**.
- In binary fission, macronucleus divides amitotically and micronucleus mitotically.
- Binary fission occurs during favourable condition. It is faster multiplication, completes about in half an hour (upto three divisions per day).
- *Paramecium* undergoes several kinds of nuclear reorganization such as **conjugation**, **autogamy**, **cytogamy**, **endomixis** and **hemixis**. In all these processes the macronucleus breaks into many parts and disintegrates.
- In *Paramecium* nuclear reorganization takes place for rejuvenation.
- Conjugation occurs between two mating types of same species of *Paramecium*. It is a modified form of cross fertilization.
- **Conjugation** of *Paramecium* **involves exchange of micronuclei**.
- Each *Paramecium* (**exconjugant**) at the end of the conjugation produces four daughter paramecia.
- Autogamy is a **process of self-fertilization**. It occurs in a single animal of *P. aurelia*.

- Autogamy **results in the production of two daughter paramecia from each**.
- **Cytogamy** occurs in *P. caudatum*. The two cytogamonts do not exchange their male pronuclei.
- **Endomixis** occurs in *P. aurelia*. It is asexual reproduction and one individual produces four daughter paramecia.
- *Paramecium* has **Kappa**, **Lambda**, **Mu** and **Pi particles in cytoplasm**. They differentiate paramecia between sensitive and killer forms.
- Although genetic material is exchanged during conjugation, **no new cells are produced**.
- Following conjugation, each *Paramecium* divides, producing **four genetically identical paramecia**.
- Exchange of genes can enable organisms to adapt better to changing environments, **the four offspring are genetically different from either original paramecium**.
- *Balantidium coli* is a ciliate protozoan parasite in **colon and caecum of man**.
- *Balantidium* cause '**Balantidial dysentery** or **Balantidiasis**'.

SPOROZOA

- The name sporozoan comes from the fact that when they are immature, **they are surrounded by thick, sporelike walls**.
- All species in the phylum sporozoa have adult forms with **no means of movement**.
- Most sporozoans are **spore-forming parasitic** (harmful) **protozoans**.
- Adult sporozoans have no structures for movement. Immature sporozoans, called **sporozoites**, can be **transmitted through fluids from one host to another**.
- Sporozoans cause many human diseases, including **malaria**. The protozoan that causes malaria is named *Plasmodium*, and is transmitted by female mosquitoes (*Anopheles*).
- **Malaria means 'bad air'**. It is a communicable disease.
- There are about 60 species of *Plasmodium*. Only four species causes malaria in man. They are : *Plasmodium vivax* (the most common species), *P. ovale, P. malaria* and *P. falciparum*.
- Malaria is a very serious disease **characterized by severe chills**, **fever**, **sweating**, **fatigue**, and **great thirst**.

Table : Types of malaria

Disease	Causative agent
Tertian malaria	*Plasmodium vivax*
Benign tertian malaria	*Plasmodium vivax*
Vivax malaria	*Plasmodium vivax*
Mild tertian malaria	*Plasmodium ovale*
Ovale malaria	*Plasmodium ovale*
Subtertian malaria	*Plasmodium falciparum*
Estivo-autumnal malaria	*Plasmodium falciparum*
Malignant tertian malaria	*Plasmodium falciparum*
Cerebral malaria	*Plasmodium falciparum*
Black water fever	*Plasmodium falciparum*
Quartan malaria	*Plasmodium malariae*
Quotidian malaria	Mixed infections

- One way to reduce human deaths (2.7 million annually) from malaria is to control mosquito populations. **Without the mosquito host**, the *Plasmodium* protozoan cannot complete their life cycle.
- *Plasmodium* was **discovered by Charles Laveran in 1880**.
- **Lancisi** first **suspected a relationship between mosquito and malaria**.
- **Ronald Ross** (1897) **discovered** (**confirmed**) **relationship between malaria and mosquito**.
- In 1897 Ross discovered oocytes of *Plasmodium* in the stomach of mosquito at Secunderabad in India. He got Nobel Prize in 1902.
- **Grassi** (1898) described the life history of the parasite in female *Anopheles* mosquito.
- **Shortt** and **Garnham** (1948) are associated with the discovery of life cycle of malarial parasite.
- *Plasmodium* is an **endoparasite**, **blood parasite**, **intracellular parasite**, **pathogenic parasite** and **digenetic parasite**. (**Principle host** : man; and **secondary/intermediate/primary host** : mosquito)
- **Asexual cycle** is passed in man by a process termed **schizogony** (schizogony in liver and RBCs).
- Schizogony is a type of **multiple fission**.
- Pre-erythrocytic and exo-erythrocytic cycles occur in **liver cells** and involve **schizogony**.
- **Cryptozoites** and **metacryptozoites** are produced in respective cycles.
- Exoerythrocytic cycle is absent in *Plasmodium falciparum*.
- **Sexual cycle** is completed in **mosquito** involving **gametogony** and **sporogony**.

- Stage of *Plasmodium* infective to man is, or the stage of *Plasmodium* injected by mosquito into human blood is **sporozoite**.
- Sporozoite directly goes to parenchyma cells of liver.
- **Incubation period** is the duration between the initial sporozoite infection and the first appearence of malarial symptoms. It is about 14 days in *P. vivax*, 30 days in *P.malariae*, 14 days in *P. ovale* and 12 days in *P. falciparum*.
- **Erythrocytic cycle occurs in RBCs.**
- Signet ring stage, amoeboid stage (adult trophozoite) and schizogony **occurs in RBCs.**
- **Haemozoin** is the unused hematin, it **forms toxic malarial pigment**.
- The cytoplasm of RBCs with trophozoite contain various pigment granules: **Schuffner's dots** in *P. vivax*, **Ziemann's dots** in *P. malariae* and **Maurer's dots** in *P. falciparum*.
- Haemozoin **causes chill and body pain**. Malarial parasites can be obtained in large numbers in blood from a person when temperature rise with rigor.
- **Gametocytes** of malarial parasite are **developed from merozoites in RBCs of man**.
- There are two types of gametocytes : **megagametocyte** (female) and **microgametocyte** (male).
- **Sexual phase** in the life cycle of *Plasmodium* occurs in the gut of mosquito.
- Gametocytes reach the stomach of female *Anopheles* mosquito by sucking human blood.
- Megagametocyte produces only one gamete from each.
- Microgametocytes undergo **exflagellation,** produce 6–8 motile **microgametes** having haploid nuclei.
- The motile zygote formed by fertilization (anisogamy) of macrogamete by a microgamete is called **ookinete**.
- Ookinete penetrates the stomach wall and forms encysted zygote called **oocyst** or **sporont**.
- Oocyst undergoes sporogony which is meiosis followed by mitosis.
- Sporogony produces about 10,000 **sporozoites** from each oocyst and they migrate to the salivary gland.
- **Cerebral malaria** is drug resistant and fatal.
- *Gambusia* (mosquito fish) feeds on larvae and pupae of mosquito. This fish is **used in biological control of mosquito**.
- 20th August is **malaria day**. Ministry of Health, Government of India started **National Malaria Eradication Programme** (NMEP) in the year 1953.
- Malaria is usually cured with a drug derived from the Cinchona tree, (native to the America), called **quinine**.
- A **biolumniscent protozoa** is *Noctiluca*.

End of the Chapter