**INVERTEBRATE ZOOLOGY**

INTRODUCTION: The invertebrates are animals without backbone and they constitute about 90% of known animals. There are about 30 phyla. The members of each phylum are constructed on common anatomical features, similar functions and have common ancestry.

**CHARACTERISTICS OF INVERTEBRATES**

* They originated in the sea but most of them have successfully invaded the land or its freshwater habitats.
* They exhibit varied shapes- irregular ever-changing body shape, plant-like appearance and ribbon shaped, vermiform, and star-shaped.
* They exhibit a great variation in size from microscopic protozoan to large-sized cephalopods.
* They exhibit all types of symmetries- bilateral, radial, bi-radial, etc.
* They display all grades of organization- protoplasmic grade, cellular grade, cell-tissue grade, tissue-organ grade and organ-system grade.
* Invertebrates except protozoan are diploblastic or triploblastic.
* The body covering of invertebrates is simple. Plasma membrane in Protozoa and protective pellicle in some. Most have an outer protective epidermis which is made of single layer of cells while others have further added a non-cellular cuticle secreted by underlying epidermis.
* They have multiple movement devices- some are sessile while others move from place to place using pseudopodia, flagella, cilia, contractile myonemes, setae, parapodia, suckers, jointed legs etc.
* The members of several invertebrate phyla are characterized by segmentation in their bodies. Flatworms show pseudo-segmentation while Annelida and Arthropods exhibit true segmentation.
* They are generally soft-bodied animals without a rigid internal skeleton for the attachment of muscles.
* They are grouped based on the presence of coelom as acoelomate, pseudo-coelomate or coelomate.
* The alimentary canal is either absent or partially formed or complete and when present, it is dorsal to the nerve cord, running from the anterior to the posterior.
* Digestion is both intracellular and extracellular in invertebrate depending on their phyla.
* Invertebrates exhibit diversified respiratory systems- body surface, gills, branchiae, tube feet, trachea, and respiratory trees.
* They have diversified excretory mechanisms- diffusion through cell membranes, flame cells, nephridia, malpighian tubules, green glands.
* Invertebrate nervous system is characterized by solid nerves; they are not hollow from within.
* They exhibit varied modes of reproduction- asexual, sexual, hermaphrodites.

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**Classification of Invertebrates**

Invertebrates are broadly classified into two viz PROTOZOA and METAZOA.

Generally, the invertebrates are divided into four groups, based on their cellular composition and organization, namely Protozoa and Metazoa ( Mesozoa, Parazoa and Eumetazoa).

**1. Protozoa**

• They are for the most part of their lives unicellular, i.e. made up of one cell

• They are also described as being acellular i.e. not divided into cells (non-cellular).

• Their vital functions are carried out by organelles.

In addition, division of labour in protozoa occurs at organelle level which is sub-cellular structures for different functions. No organs or tissues are present. In protozoa, the small acellular body performs all vital functions, and no single function predominates over the others. Reproduction is asexually by binary fission, budding; and cysts and sexually by conjugation or by syngamy (union of male and female gametes to form a zygote as in *Plasmodium*-malaria parasite). Generally a single nucleus occurs in protozoa; however, some have more than one nucleus. It is believed that multi-cellular animals evolved from nucleated and colonial protozoa.

**2. Metazoa** are large holozoic multicellular animals in which limitations of size are removed and their cells are potentially capable of performing all essential vital activities, but the cells are dependent on each other and all of them are not similar because specialization has taken place. This has opened up vast possibilities for an increased complexity of the body form and structure. Cell specialization in turn has led to the development of tissues in which groups of similar cells are organized into layers. These later form organs and systems. Metazoans are multicellular animals which are distinguished not only by their larger size, but by a high degree of differentiation and specialization of their parts.

**Types of Invertebrates**

The invertebrate phyla are divided two: the lower and higher invertebrates. The lower invertebrates are simple in body organization and generally smaller in size e.g. Protozoa, Porifera, Cnidaria, Platyhelminthes, Nematoda while the higher invertebrates are generally large in size and have a complex body organization e.g. Mollusca, Annelida, Arthropoda, Echinodermata. Lower metazoan invertebrates are un-segmented, radially or bilaterally symmetrical, diploblastic or triploblastic, and acoelomate or pseudo-coelomate. The phyla Porifera, Coelentrata, Platyhelminthes and Nematoda are lower metazoan invertebrates while Mollusca, Annelida, Arthropoda, Echinodermata are higher metazoan invertebrates.

**PHYLUM PROTOZOA**

Protozoa that would be examined under this course are classified into three Subphyla: Sarcomastigophora; Apicomplexa; Ciliophora.

**SARCOMASTIGOPHORA-** This Subphylum is further subdivided into two Superclasses based on their modes of locomotion as Mastigophora and Sarcodina.

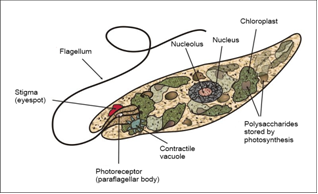
MASTIGOPHORA: They possess one or more whip-like flagella for locomotion e.g. *Euglena, Trypanosoma.*

SARCODINA: These are typically amoeboid organisms using pseudopodia for both locomotion and feeding e.g. *Amoeba*.

**APICOMPLEXA-** Subphylum Apicomplexa is formerly known as Sporozoa. All apicomplexans are endoparasites and their hosts include many animal phyla. Members of this group possess at some stage in their life cycle, a structure called the apical complex serving as the organ of attachment to host cells. Locomotor organelles are less obvious in this group than in other protozoa. The life cycle usually include both asexual and sexual reproduction e.g. *Plasmodium* (malaria parasite).

**CILIOPHORA-** These protozoa are motile by means of cilia which cover their entire body surface and beat in a coordinated rhythmical manner. They have two kinds of nuclei (macro- and micronuclei) in each individual. The macronucleus is apparently responsible for metabolic and developmental functions and for maintaining all the visible traits. Micronucleus participates in sexual reproduction and gives rise to macronucleus after exchange of micro nuclear material between individuals. Micronuclei divide mitotically, and macronuclei divide amitotically e.g. *Paramecium*.

***Euglena viridis*:** It is a solitary free-living freshwater flagellate. It occurs in freshwater- ponds, pools, ditches and slowly moving streams and brackish water rich in organic matter. Some species develop large populations as red or green “blooms” in lakes or ponds. It is elongated and spindle-shaped in appearance. The anterior end is blunt; the middle part is wider while the posterior end is pointed. From the anterior end arises a whip-like flagellum which is seen moving when the *Euglena* is proceeding forward. The body is covered by pellicle or periplast which lies beneath the plasma membrane. Its cytoplasm is differentiated into an outer layer of ECTOPLASM and inner layer of ENDOPLASM. The ectoplasm is thin, clear or non-granular, while the endoplasm is more fluid-like and granular. The endoplasm contains the nucleus, chromatophores, paramylum bodies, Golgi bodies, endoplasmic reticulum, mitochondria and the ribosome.

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**LOCOMOTION:** There are two types of movement in *Euglena* (i) flagella movement and (ii) euglenoid movement. Using its flagellum, it swims freely in water, takes a spiral course and rotates on its axis. In euglenoid movement, the flexible pellicle enables it to perform peristaltic activity which brings about worm-like wriggling movement while the animal creeps on the bottom of the pond or stream.

**NUTRITION:** It exhibits MIXOTROPHIC mode of nutrition. It feeds holophytically by means of the chlorophyll in its chromatophores but if it is kept in the dark the organism feeds saprophitically by absorbing nutrients through its body surface.

**RESPIRATION & EXCRETION:** No excretory or respiratory organs. These are performed by diffusion through the body surface.

**OSMOREGULATION:** *Euglena* has a semi-permeable membrane and lives in water, so water continuously enters its body by endosmosis. Excess water is removed by the contractile vacuole.

**REPRODUCTION:** It reproduces asexually by binary fission and multiple fission. Binary fission occurs in favourable conditions. The nucleus divides into two by mitosis and later followed by the division of the cytoplasm which starts at the anterior region. Multiple fission occurs in unfavourable conditions. Large numbers of *Euglenae* come together, lose their flagella and become rounded. They secrete gelatinous covering within which they remain embedded. This condition is called PALMELLA STAGE. Individuals of palmella stage carry on metabolic activities and reproduce by binary fission. In favourable conditions, the *Euglenae* regenerate their flagella and start normal active life.

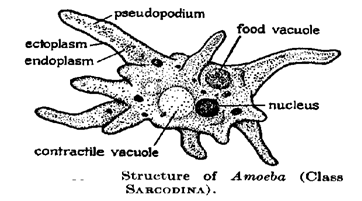
Encystment is another form of reproduction. This also takes place as a protective measure to get over unfavourable conditions. A thick cyst wall is secreted around the animal which is now inactive and lost its flagellum. It remains in this condition until favourable conditions return. During this period, it can undergo binary fission once or more times.

**BEHAVIOUR:** *Euglena* responds to a variety of stimuli and is very sensitive to light. It swims towards an ordinary light and avoid strong light. It gives avoiding reaction to mechanical, thermal and chemical stimuli on a trial and error pattern.

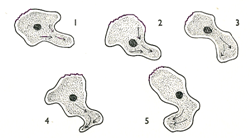
*Euglena* shows characters of plants such as chloroplasts with chlorophyll and holophytic nutrition but it is regarded as an animal due to the following facts.

* Absence of cellulose cell-wall overlying the plasma membrane.
* Its pellicle is made of proteins and not cellulose as in plants.
* Presence of centrioles forming the blepharoplasts or kinetosomes.
* Presence of paraflagellar body, the photosensitive structures.
* Reserve food is paramylum which is not a true starch.
* Presence of contractile vacuoles, which are not found in plants.
* Nutrition is saprozoic as in animals.
* Presence of longitudinal binary fission, which is not found in plants.
* Presence of flagellum and ability to move around.
* Presence of eyespot.

***Amoeba proteus*:** It is widely distributed; found commonly in bottom mud in freshwater ponds, pools, ditches, lakes and slow streams and damp soils. It occurs in abundance in the water which contains bacteria and organic substances such as leaves, twigs and other aquatic vegetation in abundance. It is a unicellular, microscopic organism with an irregular and constantly changing shape due to the formation of finger-like processes, the PSEUDOPODIA or LOBOPODIA. It has no cell-wall but a thin delicate outer membrane, the PLASMALEMMA; beneath which is a non-granular layer, the ECTOPLASM which encloses the granular ENDOPLASM. The endoplasm contains the nucleus, contractile vacuole, food vacuole, water globules and other endoplasmic organelles.



**LOCOMOTION:** Movement is by the pseudopodia which are formed as a result of the flowing of the cytoplasm. This is done by the thickening of the ectoplasm to form a clear hyaline cap, into which the fluidy endoplasm flows. As the endoplasm reaches the forward tip, it fountains out and is converted into ectoplasm, forming a stiff outer tube that lengthens as the forward flow continues. Posteriorly the ectoplasm is converted into fluid endoplasm, replenishing the flow.



1 At one point on the amoeba, the ectoplasm extends and the endoplasm flows in, forming a pseudopodium.

2 The pseudopodium continues to extend and the endoplasm continues to flow so that the whole amoeba is moving to the right.

3 A new pseudopodium starts to form and …

4 …the endoplasm flows into this.

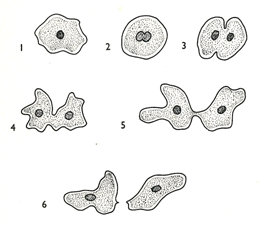
5 As a result, the amoeba has changed its direction of movement

**NUTRITION:** Mode of nutrition is holozoic. There is no mouth and nutrition involves ingestion, digestion, assimilation, dissimulation and egestion and it is by the aid of the pseudopodia. Holozoic nutrition implies phagocytosis, in which an infolding or invagination of the cell membrane surrounds a food particle. As the invagination extends farther into the cell, it is pinched off at the surface. The food particle thus is contained in an intracellular, membrane-bound vesicle, a food vacuole or phagosome. Lysosomes, small vesicles containing digestive enzymes, fuse with the food vacuole and pour their contents into it, where digestion begins and it is intracellular. As digested products are absorbed across the vacuolar membrane by diffusion, the food vacuole becomes smaller. Any undigested material may be released to the outside by exocytosis, the vacuole again fusing with the cell surface membrane. Egestion of undigested particles occurs at no fixed point; they pass out at any point on the surface through no special opening.

*Amoeba* engulfing a prey

**RESPIRATION & EXCRETION:** They are both done by diffusion through the semi-permeable plasmalemma. Contractile vacuole also helps in excretion. This feature is absent in marine and parasitic forms.

**REPRODUCTION:** *Amoeba proteus* reproduces asexually by binary fission, encystment.



1. Amoeba stops moving and rounds off

2. The nucleus begins to divide.

3. The nucleus has divided and the cytoplasm starts to constrict.

4 & 5. The constriction continues to divide the cytoplasm.

6. The daughter amoebae separate.

This is a form of asexual reproduction called binary fission.

There is no evidence of sexual reproduction in this species of Amoeba

**OSMOREGULATION:** This is done by the contractile vacuole.

**BEHAVIOUR:** It responds to various kinds of stimuli either positively or negatively though it has no special structures for the reception of stimuli.

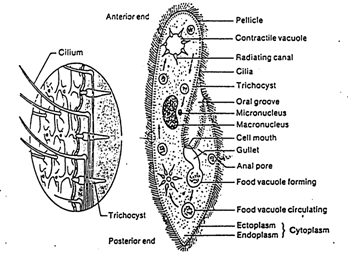
BIOLOGICAL SIGNIFICANCE OF *AMOEBA*

* It depicts organization of protoplasmic mass or a single cell into a complete organism.
* Binary fission provides a clear-cut understanding of mitotic division of a cell.
* Its responses or taxes represent the early beginning of sensitivity in animals.
* The larger number of chromosomes present in the nucleus suggests the occurrence of isolated genes, which in higher animals are located in chromosomes.
* It provides a faint idea regarding the anatomical structures of higher animals. For example, the food cup is comparable to buccal cavity; food vacuole to gut; pseudopodia to legs; contractile vacuole to urinary bladder etc.
* It helps in understanding the relationship and interactions between the nucleus and the cytoplasm.

***Paramecium caudatum*:** *Paramecium* is found in freshwater ponds, pools, ditches, streams, rivers, lakes, reservoirs etc. and especially in waters rich in decaying organic matters. It is a microscopic, slipper-shaped or spindle-shaped, asymmetrical organism. The body is elongated, blunt and rounded at the anterior end and pointed at the posterior end. The body is covered by a thin, double layered, elastic and firm pellicle made of gelatin. The pellicle holds the animal in shape but it’s elastic enough to permit contractions. About 2,500 tiny hair-like projections, called cilia, extend from the pellicle; the cilia move back and forth like oars to help the *Paramecium* move about.

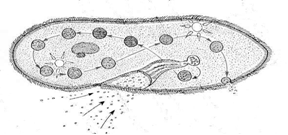
The inner membrane of the pellicle continues with the cytoplasm and the outer membrane with the cilia. The cytoplasm is divided into ECTOPLASM and the larger mass of granular ENDOPLASM. The endoplasm contains the nuclei and other organelles. A cytostome at the end of the oral groove leads into a tubular cytopharynx, or gullet. A *Paramecium* has two contractile vacuoles located close to the surface near the ends of the cell. They function in regulating the water content within the cell and may also be considered as excretory structures since the expelled water contains metabolic wastes.

*Paramecium* has two kinds of nuclei: a large ellipsoidal nucleus called macronucleus and at least one small nucleus called micronucleus. Both types of nuclei contain the full complement of genes that bear the hereditary information of the organism. The organism cannot survive without the macronucleus; it cannot reproduce without the micronucleus. The micronucleus is the center of all metabolic activities of the organism. The micronucleus is a storage site for the genetic material of the organism. It gives rise to the macronucleus and is responsible for the genetic reorganization that occurs during conjugation (cross-fertilization). The macronucleus is involved in protein synthesis and other cellular activities, while the micronucleus functions in sexual reproduction.



**LOCOMOTION:** It moves by metaboly or body contortions and by cilia. The body is elastic, allowing it to bend and to squeeze through narrow places. Its cilia can beat either forward or backward, so that the organism can swim in either direction. The cilia beat obliquely, causing the organism to rotate on its long axis. In the oral groove the cilia are longer and beat vigorously than others so that the anterior end swerves aborally. As a result of these factors, the organism moves forward in a spiral path. When it contacts a barrier or a disturbing chemical stimulus, it reverses its cilia, backs up a short distance, and swerves the anterior end as it pivots on its posterior end.

**NUTRITION:** It is holozoic and it feeds on bacteria and minute protozoa which are swept into the oral groove by the cilia. The cilia beat rhythmically to direct bacteria and other food particles into their mouths or cytostomes, from which they are carried into cytopharynx (gullet) by the undulating membrane of the modified cilia. From the cytopharynx food is collected into a food vacuole that is constricted into the endoplasm. Digestion takes place within each food vacuole. Food vacuoles circulate in a definite course through the cytoplasm while the food is being digested by enzymes from the endoplasm. Undigested parts of the food are ejected through the potential anus or cytoproct or cytopyge.

*Pamerecium* feeding 

**RESPIRATION & EXCRETION:** These take place by diffusion through the semi-permeable pellicle. In addition, the contractile vacuoles help in excretion.

**OSMOREGULATION:** Osmoregulation is by the two contractile vacuoles. The animal responds either positively or negatively depending on the stimuli.

**REPRODUCTION:** It reproduces asexually by binary fission and also undergoes several types of nuclear reorganization namely, conjugation. Ordinarily *Paramecium* multiplies by binary fission for a long time, but at intervals this may be interrupted by joining of two animals along their oral surfaces for sexual process of conjugation.

* Two *Paramecia* fuse as conjugants.
* Macronuclei degenerate and micronuclei divide.
* Micronuclei divide again.
* Three out of four nuclei in each conjugant disappear.
* The remaining nucleus divides unequally.
* The smaller pronuclei are exchanged.
* The two pronuclei in each unite to form the zygote nucleus.
* The *Paramecia* separate as exconjugants.
* Zygote nucleus divides three times to form 8 nuclei.
* Four out of the 8 nuclei become macronuclei, three disappear and one remains as micronucleus.
* Micronucleus and *Paramecium* divide twice to yield four *Paramecia* from each conjugant.

***Plasmodium vivax*:** It is a protozoan parasite of man and it lives as an intracellular parasite in the red blood corpuscles of man as mature adult called TROPHOZOITE. Four species of Plasmodium parasites cause malaria in humans: *Plasmodium falciparum, P. vivax, P. ovale,* and *P.* malariae. Each causes a different form of the disease. *P. vivax* and *P.* ovale cause the mildest forms; *P. falciparum,* the severest and most deadly form. Other *Plasmodium* species infect primates, rodents, birds, and lizards. Several of these species, particularly those that infect rodents, have been used in experimental studies and for testing malaria drugs and vaccines. The trophozoite is amoeboid, uninucleated having vacuolated and granular cytoplasm. It has a double membrane, the plasmalemma closely applied to the cytoplasm. The cytoplasm contains some organelles.

The mode of nutrition is saprozoic, occurs by osmotrophy. Organ of locomotion, contractile vacuoles etc. are not found. Respiration takes place anaerobically.

**REPRODUCTION:** This is both asexually and sexually. The life cycle of *Plasmodium* is digenetic. The parasite is transmitted to humans by the bite of female mosquito. The *Plasmodium* parasite spends its life cycle partly in humans and partly in mosquitoes. Asexual phase is completed in man by SCHIZOGONY (differentiated into EXOERYTHROCYTIC SCHIZOGONY involving pre- and post-erythrocytic schizogonic cycles, and ERYTHROCYTIC SCHIZOGONY) and sexual phase of its life cycle is completed in female mosquito by GAMETOGONY, SYNGAMY and SPOROGONY.

The parasite is carried by mosquitoes and sporozoites are injected into a human with the insect’s saliva during its bite. Sporozoites penetrate liver cells and initiate schizogony. Each sporozoite undergoes asexual reproduction (multiple fission), in which its nucleus splits to form two new cells, called merozoites. The period when the parasites are in the liver is called incubation period. Merozoites released as a result of liver schizogony enter red blood cells, where they begin a series of schizogonous cycles. When they enter red blood cells, they become amoeboid trophozoites, feeding on haemoglobin. The end product of the parasite’s digestion of heamoglobin is a dark, insoluble pigment, heamozoin. Heamozoin accumulates in the host cell, is released when the next generation of merozoites is produced, and eventually accumulates in the liver, spleen, or other organs. When a red blood cell containing merozoites bursts, it releases the parasite’s metabolic products, which have accumulated there. Release of these foreign substances into the patient’s circulation causes the chills and fever characteristic of malaria.

After some cycles of schizogony in red blood cells, infection of new cells by some of the merozoites causes production of microgametocytes and macrogametocytes rather than another generation of merozoites. This process is called GAMETOGONY. When gametocytes are ingested by a mosquito feeding on a patient’s blood, they mature into gametes in the mosquito’s stomach and fertilization occurs uniting to form a zygote (SYNGAMY). The zygote remains motionless for sometimes and later become active as OOKINETE, which penetrates the stomach wall of the mosquito and become encysted as OOCYST. The oocyst by meiosis and mitotic division produces the sporozoites and bursts to liberate them into the heamolymph of the insect where they reach the salivary glands. The sporozoites will infect a human host when bitten by mosquito and the cycle starts again.

