



Zagazig University



Zoology Department

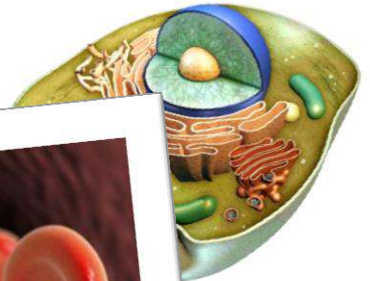
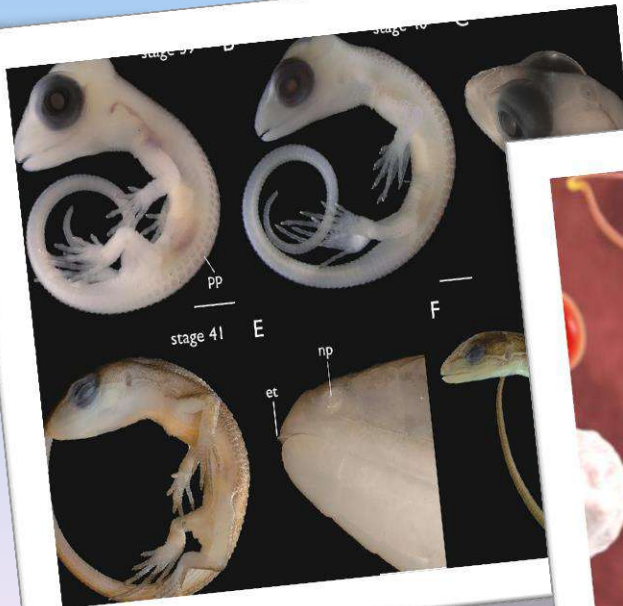


Faculty of Sciences

Introduction in Cytology, Embryology and Systematic Zoology

course code: z101

1st year, 1st semester



Course Specification

Programs on which the course is given: All biology students

Major or Minor Element of program: Major

Department offering the program: Zoology Department

Department offering the course: Zoology Department

Academic year / Level: First Year / 1st Semester

Date of specification approval: 22/9/2021

A: Basic Information

Title: Introduction in Cytology, Embryology and Systematic Zoology **Code:** Z.101

Credit Hours: 3 **Lectures:** 2 **Practical:** 1 h. **Total:** 3 h.

B: Professional Information

1. Overall Aims of Course:

- Study the cell theory, the protoplasm, cell structure and cell division.
- .Recognize the general idea about gametogenesis, fertilization and early development of animals.
- Describe the nomenclature and recent classification of animal kingdom. morphology, biology, life cycles and importance of selective examples of Protozoa, Parazoa, Diploblastica in addition to Platyhelminthes and Aschelminthes.
- Differentiate the anatomy of the different organ, system of the Egyptian Toad, Protozoa, Porifera, Coelentrata, Platyhelminthes and Aschelminthes.

Weighing of Assessments

Mid-Term Examination: -----	10%
Final-Term Examination: -----	60%
Oral Examination: -----	10%
Practical Examination: -----	20%
Semester Work: -----	%
Other types of assessment: -----	%
Total	100%

Course Coordinators

PROF.DR. MAHMOUD DESUKY

PROF.DR. KAMEL ZAKI

ASS.PROF.DR. SHEREIN ALZAHABY

DR. WAFAA GALAL



CYTOLOGY

ZOO 101

Prof.Dr. Kamel Zaki Hemmaid

Chapter 1

Definition of Cytology & Cell Biology

Cytology and cell biology are two study areas of biology that mainly deal with the structure and the function of cells. Cytology is literally 'the study of cells'. Cytology is the study of the structure and constituents of plant and animal cells. Whereas, cell biology aims in studying the structure, constituents, physiological features, function, interactions, life cycle, division, and death of cells. Also, it includes the study of simple organisms (prokaryotes) and more complex organisms (eukaryotes). Furthermore, it also includes both unicellular organisms such as protozoa and bacteria and multicellular organisms such as plants and animals including humans.

The main difference between cytology and cell biology is that the cytology is the formal term for cell biology, which is the study of the structure, function, and life history of cells and their constituents. Furthermore, cytology mainly deals with animal and plant cells while cell biology deals with all eukaryotic and prokaryotic cells. Thus, cell biology is a wider area than cytology since it studies the structure and the function of all types of cells including eukaryotic and prokaryotic cells.

Thus, cytology is a branch of biology dealing with the structure, function, multiplication, pathology, and life history of cells : CELL BIOLOGY. Cytology generally involves looking at a single cell type. **Cytology** is the study of cells as fundamental units of living things. The **cell** (Latin *cella*, means "small room" from the Greek *kytos*, "container") is the basic structural, functional, and biological unit of all known organisms.

Historical perspective of cytology:

The history of cell biology has been closely related to the development of the microscopy. Light microscopy is especially well suited for imaging cells because the size of the subcellular structures matches the

resolution limit of the conventional microscopes and also using light for imaging is largely harmless for biological samples. Though scientists had been using microscopes for centuries, they were not always sure what they were looking at. Cytology began with the English scientist Robert Hooke's (1635–1703) initial observation in 1665 of plant-cell walls in slices of cork by microscopic investigation. Hooke described the *cella* (open or hollow spaces) of plant tissues. *Cella* is a Latin word meaning 'a small room' and Latin-speaking people applied the word *Cellulae* to the six-sided cells of the honey-comb.

Robert Hooke introduced the term “cell” to describe the dead cork cells. This was followed shortly by Antonie van Leeuwenhoek's first descriptions of live cells with visibly moving parts. Leeuwenhoek (1632–1723) explored the use of light to discover the microscopic world (studied cells of algae).

Later, in the 19th century the studies by three scientists, Matthias Schleiden, Theodor Schwann, and Rudolf Virchow described the cell as a physiological unit of life that lead to cell theory, a fundamental unifying theory in biology.

As microscopes and staining techniques improved over the nineteenth and twentieth centuries, scientists were able to see more and more internal detail within cells. In the 1830s two scientists who were colleagues — The botanist Matthias Schleiden (in1838), looking at plant cells, and the zoologist Theodor Schwann (in1839), looking first at animal cells — provided the first clearly stated definition of the cell. Their definition stated that that all living creatures, both simple and complex, are made out of one or more cells, and the cell is the structural and functional unit of life

— a concept that became known as cell theory. After viewing live cells in plant and animal tissue, those scientists proposed the "Cell Theory" that all living organisms are composed of cells. The conclusions of Schleiden and Schwann are considered to represent the official formulation of 'cell theory' and their names are almost as closely linked to cell theory.

In 1892 Oscar Hertwig (German embryologist and anatomist) established cytology as a separate branch of biology. He suggested that organismic processes are reflections of cellular processes. In 1855, Rudolf Virchow contributed to the cell theory and stated that **all cells come from the division of pre-existing cells**. Virchow put forward the theory of **cell lineage** or development of cells from preexisting cells ("Omnis cellulae cellula"). Thus, the cell theory was established and stated that: "**all living things are made up of cells and that the cell is the functional and structural unit of organisms**".

A cell is the smallest unit of life. Cells are often called the "building blocks of life". The study of cells is called cell biology, cellular biology, or cytology.

After Schleiden and Swann's formulation of cell theory, the basic constituents of the cell were considered to be a wall or a simple membrane, a viscous substance called "protoplasm" (a name now replaced by Kölliker's term "cytoplasm"), and the nucleus.

It soon became evident that the protoplasm was not a homogeneous fluid. Some biologists regarded its fine structure as fibrillary, whereas others described a reticular, alveolar or granular protoplasmic architecture. This discrepancy resulted partly from artefactual and illusory images attributable to fixation and staining procedures that caused a non-homogeneous precipitation of colloidal complexes.

However, some staining of real cellular components led to the description of differentiated elements, which were subsequently identified. The introduction of the oil-immersion lens in 1870, the development of the microtome technique and the use of new fixing methods and dyes greatly improved microscopy. Towards the end of the nineteenth century, the principal organelles that are now considered to be parts of the cell were identified. The term “ergastoplasm” (endoplasmic reticulum) was introduced in 1897; mitochondria were observed by several authors and named by Carl Benda (1857–1933) in 1898, the same year in which Camillo Golgi (1843–1926) discovered the intracellular apparatus that bears his name (Golgi apparatus).

The protoplasm was not the only structure to have a heterogeneous appearance. Within the nucleus, the nucleolus and a stainable substance could be seen. Moreover, a number of structures (ribbons, bands and threads) appeared during cell division. As these structures could be heavily stained, they were called “chromatin” by Walther Flemming (1843–1905), who also introduced the term “mitosis” in 1882 and gave a superb description of its various processes . Flemming observed the longitudinal splitting of salamander chromosomes (a term introduced only in 1888 by Wilhelm Waldeyer, 1836–1921) during metaphase and established that each half-chromosome moves to the opposite pole of the mitotic nucleus. This process was also observed in plants, providing further evidence of the deep unity of the living world.

Table 1: Summary of Early Scientist contributions in Cytology

Year	Scientist	Contribution
1590	Z. Janssen F Janssen	Compound Microscope
1665	Robert Hooke	Coined the term 'Cell'
1674	Antonie Van Leeuwenhoek	Studied Sperms, Blood Corpuscles & Protozoans
1833 1838 1839	Schleiden, Robert Brown & Schwann	Formulated Cell Theory
1839	Altmann	Presence of mitochondria in the cytoplasm
1840	Purkinje	Named cell contents as "Protoplasm"
1890	Waldeyer	Discovered chromosomes in the nucleus
1890	Oscar Hertwig	Organismic processes are reflections of cellular processes
1892	Camillo Golgi	Described Golgi Apparatus in the cytoplasm
1898	Karl Benda	Described and named mitochondria in the cytoplasm
1898	Walter Sutton & Theodor Boveri	Showed the connection between cell division and heredity
1902-1904	Z. Janssen F Janssen	Compound Microscope

Cell Principle or Modern Cell Theory:

- As a result of these additions and modifications the cell theory has been termed as “**cell principle or cell doctrine**”. The cell principle is better than cell theory as it applies almost to all the living things, plants, animals and microbes and it also incorporates nearly all the modern findings about a cell. **Modern cell theory or cell principle states that :**

- 1) The body of all living beings is made up of cells and their products.
- 2) Cell is the unit of structure of body of all organisms.
- 3) A cell is made up of a small mass of protoplasm having a nucleus, many organelles and a covering cell membrane (plasmalemma).
- 4) Each cell is capable of independent existence but a cell organelle can't survive independently.
- 5) All cells have fundamental similarity in structure, chemical composition and basic metabolic reactions.
- 6) Life exists only in cells because all activities of life are performed by cells.
- 7) New cells arise from pre-existing cells through division.
- 8) All present cells of organisms have evolved from primitive cells of the remote past. They have a common ancestry.
- 9) Life transferred from one generation to the next only in the form of cells.
- 10) Genetic information are stored and expressed within the cells.
- 11) Each cell contains the whole complement of genetic information not for itself but for the whole organism (Totipotency)
- 12) All cells have a full genetic information coded in their DNA, but each cell type uses only a part of information, require for its special function or structure.
- 13) A cell has definite life span.

Living cells are of two types prokaryotic and eukaryotic. Prokaryotic cells are the smallest form of life and much smaller than eukaryotic cells.

Prokaryotic cells include Bacteria and Archaea, and lack an enclosed cell nucleus. Prokaryotic cells are distinguished from eukaryotic cells by the absence of a cell nucleus or other membrane bound organelle.

Eukaryotic cells are either unicellular or multicellular and include animal, plant, and protozoa cells which all contain organelles with various shapes and sizes.

Eukaryotic and Prokaryotic Cells

A **prokaryotic cell** has a size of only 1–10 μm and contains a nucleus equivalent (nucleoid) instead of a nucleus. This ‘nucleus-like’ densely packed molecule is located in the cytoplasm and comprises the DNA, which includes only one chromosome. In addition, a plasmid may be present (circular, extrachromosomal DNA), which plays a special role in the development of antibiotic-resistant bacteria.

Eukaryotic cells, however, are 10–100 μm in size and possess a nucleus that contains the DNA of several chromosomes.

Table 2: Differences between Prokaryotic and Eukaryotic Cells

	Prokaryotes	Eukaryotes
Size	Usually 1–2 μm	Usually 5–100 μm
Nucleus	Absent	Present, bounded by nuclear envelope
DNA	Usually a single circular molecule (=chromosome)	Multiple linear molecules (=chromosomes), but those of mitochondria and chloroplasts are circular
Internal Membranes	Rare	Complex (nuclear envelope, Golgi apparatus, endoplasmic reticulum, etc.
Cell Division	Simple fission	Mitosis or Meiosis
Cytoskeleton	Absent	Microtubules, microfilaments, intermediate filaments
First appearance	3.5×10^9 years ago	1.5×10^9 years ago

Chapter 2

CELL STRUCTURE

The Cell

Cell is the smallest unit of a living organism which is responsible for all structural, biochemical and physiological functions of the organism.

- Animals are a large group of diverse living organisms that make up to three-quarters of all species on earth. With their ability to move, to respond to stimuli, respond to environmental changes and adapt to different modes of feeding defense mechanisms and reproduction, all these mechanisms are enhanced by their constituent elements in the body. However, animals cannot manufacture their own food like plants and hence they depend on plants in one way or another.
- All living things are made up of cells that make up their body structure. Some of these living things are single-celled (**unicellular**) and other organisms are made up of more than one cell (**Multicellular**).
- A cell is the smallest (microscopic) **structural-functional unit** of life of an organism. The cells that constitute an animal are called Animal cells and those that constitute plants are known as plant cells.
- Most cells are covered by a protective membrane known as the **cell wall** which gives the cells their shape and rigidity.

Thus, Cell is the basic membrane-bound unit that contains the fundamental molecules of life and of which all living things are composed. A single cell is often a complete organism in itself, such as a bacterium or yeast. Other cells acquire specialized functions as they mature. These cells cooperate with other specialized cells and become the

building blocks of large multicellular organisms, such as humans and other animals. Although cells are much larger than atoms, they are still very small. The smallest known cells are a group of tiny bacteria called mycoplasmas; some of these single-celled organisms are spheres as small as $0.2\text{ }\mu\text{m}$ in diameter ($1\mu\text{m} = \text{about } 0.000039\text{ inch}$), with a total mass of 10^{-14} gram—equal to that of 8,000,000,000 hydrogen atoms. Cells of humans typically have a mass 400,000 times larger than the mass of a single mycoplasma bacterium, but even human cells are only about $20\text{ }\mu\text{m}$ across. It would require a sheet of about 10,000 human cells to cover the head of a pin, and each human organism is composed of more than 30,000,000,000,000 cells.

As an individual unit, the cell is capable of metabolizing its own nutrients, synthesizing many types of molecules, providing its own energy, and replicating itself in order to produce succeeding generations. It can be viewed as an enclosed vessel, within which innumerable chemical reactions take place simultaneously. These reactions are under very precise control so that they contribute to the life and procreation of the cell. In a multicellular organism, cells become specialized to perform different functions through the process of differentiation. In order to do this, each cell keeps in constant communication with its neighbours. As it receives nutrients from and expels wastes into its surroundings, it adheres to and cooperates with other cells. Cooperative assemblies of similar cells form tissues, and a cooperation between tissues in turn forms organs, which carry out the functions necessary to sustain the life of an organism.

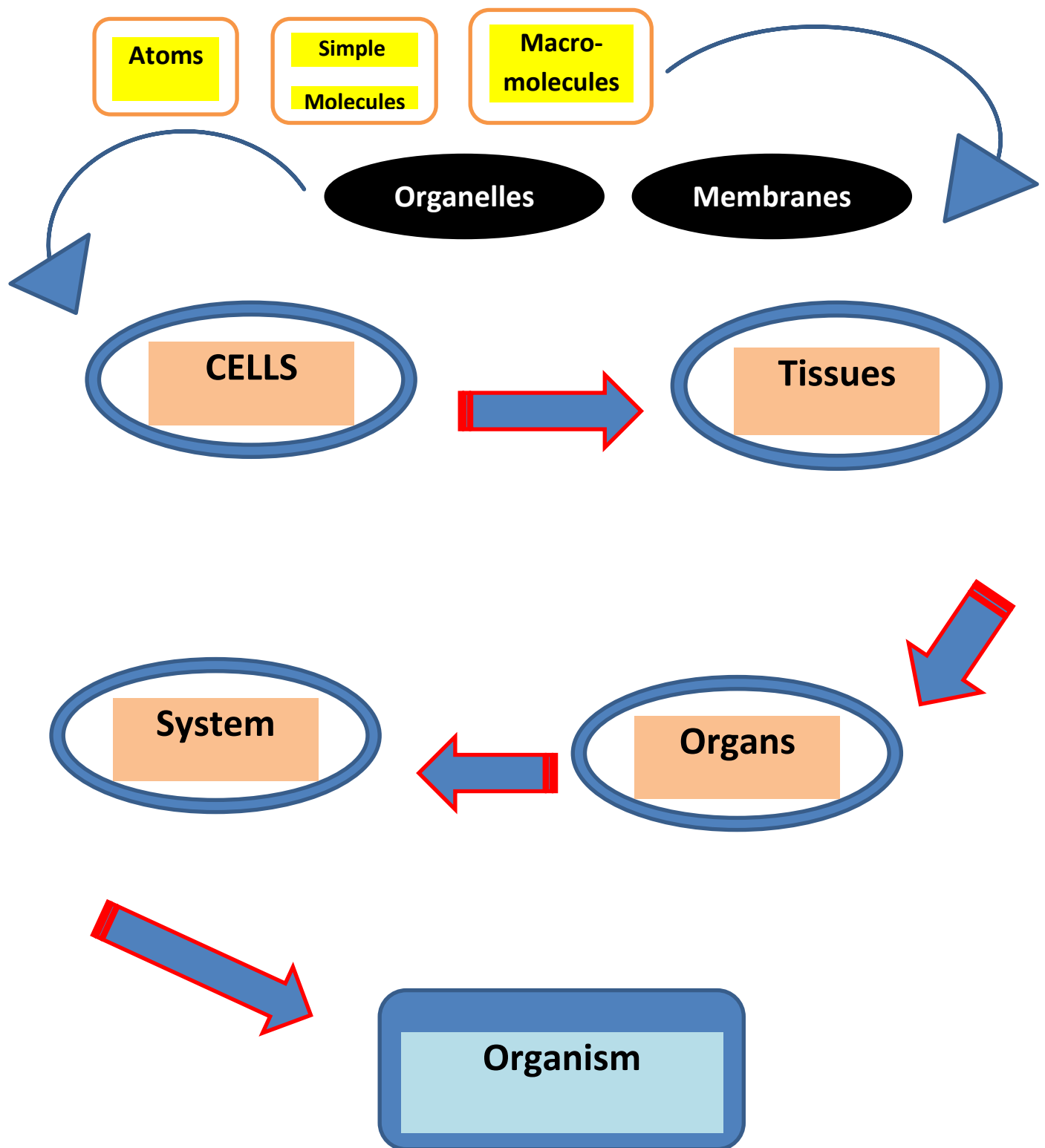


Figure 1:

Diagram showing organization from atoms to a full organism

Animal Cell

Principal structures of an animal cell

Cytoplasm surrounds the cell's specialized structures, or organelles. Ribosomes, the sites of protein synthesis, are found free in the cytoplasm or attached to the endoplasmic reticulum, through which materials are transported throughout the cell. Energy needed by the cell is released by the mitochondria. The Golgi complex, stacks of flattened sacs, processes and packages materials to be released from the cell in secretory vesicles. Digestive enzymes are contained in lysosomes. Peroxisomes contain enzymes that detoxify dangerous substances. The centrosome contains the centrioles, which play a role in cell division. The microvilli are fingerlike extensions found on certain cells. Cilia, hairlike structures that extend from the surface of many cells, can create movement of surrounding fluid. The nuclear envelope, a double membrane surrounding the nucleus, contains pores that control the movement of substances into and out of the nucleoplasm. Chromatin, a combination of DNA and proteins that coil into chromosomes, makes up much of the nucleoplasm. The dense nucleolus is the site of ribosome production.

Definition of animal cell

- An animal cell is a eukaryotic cell that lacks a cell wall, and it is enclosed by the **plasma membrane**. The cell organelles are enclosed by the plasma membrane including the cell nucleus. Unlike the animal cell lacking the cell wall, plant cells have a cell wall.
- Since animal cells lack a rigid cell wall it allows them to develop a great diversity of cell types, tissues, and organs. The nerves and muscles are made up of specialized cells that plant cells cannot evolve to form, hence giving these nerve and muscle cells have the ability to move.

Animal cell size and shape

The lack of a rigid cell wall allowed animals to develop a greater diversity of cell types, tissues, and organs. Specialized cells that formed nerves and muscles—tissues impossible for plants to evolve—gave these organisms mobility.

- Animal cells come in all kinds of shapes and sizes, with their size ranging from a few millimeters to micrometers. The largest animal cell is the ostrich egg which has a 5-inch diameter, weighing about 1.2-1.4 kg and the smallest animal cells are the neurons of about 100 microns in diameter.
- Animal cells are smaller than the plant cells and they are generally irregular in shape taking various forms of shapes, due to lack of the cell wall. Some cells are round, oval, flattened or rod-shaped, spherical, concave, rectangular. This is due to the lack of a cell wall. Note: most of the cells are microscopic hence they can only be seen under a microscope in order to study their anatomy.
- Animal cells are eukaryotic cells with a membrane-bound nucleus. Therefore, they have their genetic material in the form of DNA enclosed in the nucleus. They also have several structural organelles within the plasma membrane which perform various specific functions for proper cell function and generally to maintain the body normal mechanisms.

Animal Cell Structure

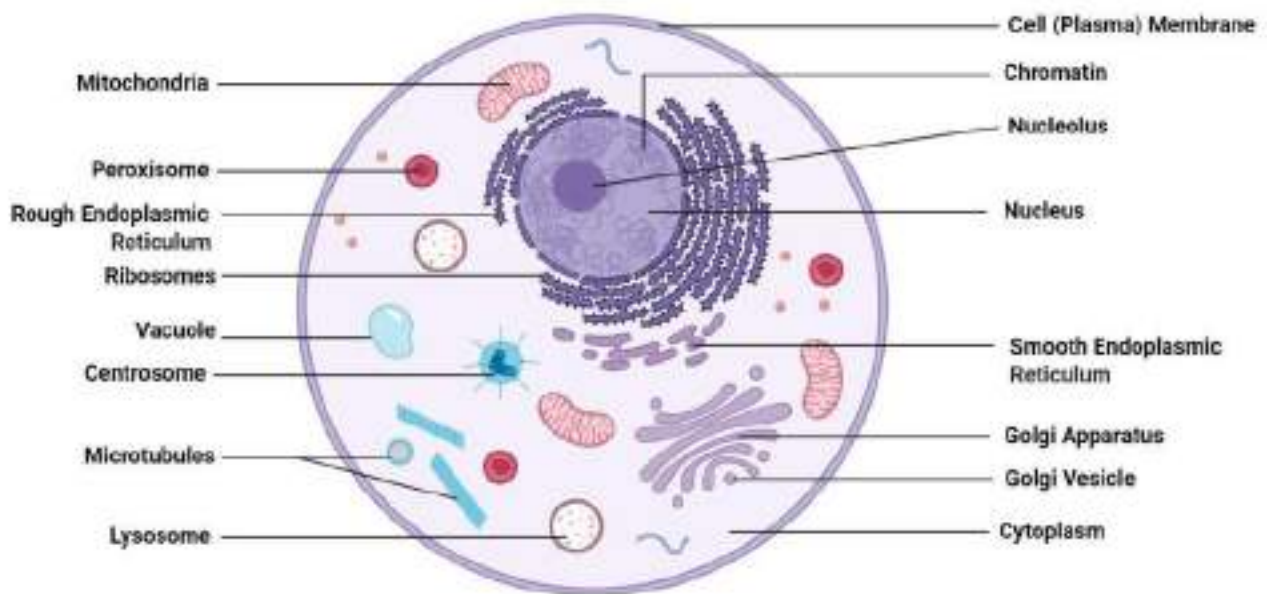


Figure: Animal Cell Structure, Image Copyright Sagar Aryal, www.microbenotes.com

Figure 2: Diagram of Animal Cell, created with biorender.com

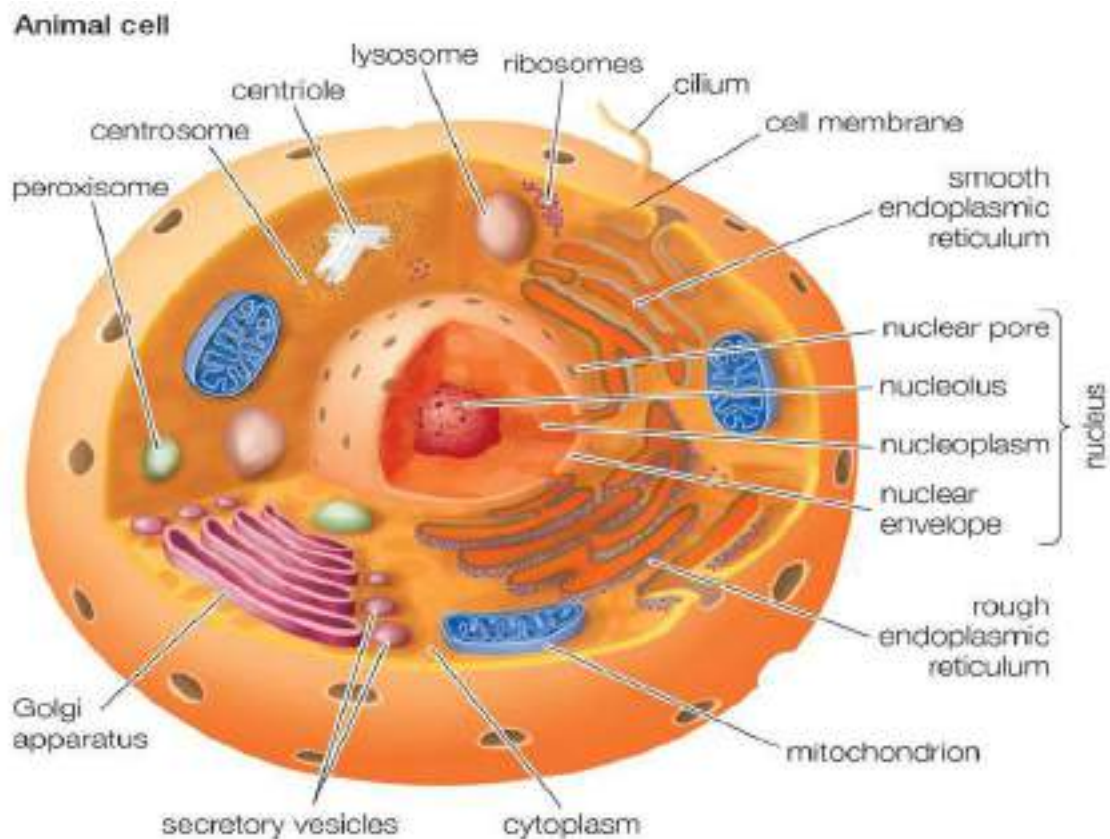


Figure 3: Three- dimensional (3-D) Diagram of Animal Cell

Chapter 3

COMPONENTS of the CELL

Cytoplasm Definition

- The cytoplasm is the semi-viscous ground substance of the cell.
- All the volume of such substance outside the nucleus and inside the **plasma membrane** is cytoplasm.
- It is sometimes described as the non-nuclear content of the protoplasm.
- All the cellular contents in prokaryotes are contained within the cell's cytoplasm.
- In eukaryote organisms, the nucleus of the cell is separated from the cytoplasm.
- The cytoplasm is the substance of life, it serves as a molecular soup and it is in the cytoplasm where all the cellular organelles are suspended and are bound together by a lipid bilayer membrane.
- The cytoplasm was discovered in the year 1835 by Robert Brown and other scientists.

Components of the Cytoplasm

The main components of the cytoplasm are:

1. **Cytosol**– a gel-like substance
2. **Organelles** – the cell's internal sub-structures, and
3. Various **cytoplasmic inclusions**.

The Cytosol

The cytosol is the part of the cytoplasm that is not occupied by any organelle. It is a gelatinous fluid, where other components of the cytoplasm

remain suspended. It mainly consists of cytoskeleton filaments, organic molecules, salt, and water.

Organelles

Organelles mean “little organs”, that are membrane-bound. They are present inside the cell and perform specific functions that are necessary for the survival of the cell. Some of the constituents of the cell that are suspended in the cytosol are cellular organelles like mitochondria, endoplasmic reticulum, Golgi apparatus, vacuoles, lysosomes, and chloroplasts in plant cells.

Cytoplasmic Inclusions

The cytoplasmic inclusions consist of different types of insoluble particles or molecules that remain suspended in the cytosol. Cytoplasmic inclusions are not surrounded by any membrane. They are basically granules of starch and glycogen, and they can store energy. A vast range of inclusions are present in different cell types. The inclusions range from calcium oxalate crystals or silicon dioxide crystals in plants to storage granules of materials like starch, glycogen, etc. Lipid droplets are a widespread example of inclusions, these are spherical droplets, they are made of lipids and proteins and are present in both prokaryotes and eukaryotes as a medium to store lipids like fatty acids and sterols.

Properties of Cytoplasm

- The cytoplasm is made of 70% – 80% water and is usually colorless.
- It contains proteins, carbohydrates, salts, sugars, amino acids, and nucleotides.
- The cytoplasm constitutes of dissolved nutrients and also dissolved waste products.

- The outer clear and glassy layer of the cytoplasm is called the ectoplasm or the cell cortex and the inner granular mass is called the endoplasm.
- The peripheral zone of cytoplasm is a thick and jelly-like substance, known as the plasmogel. The surrounding area of the nuclear zone is thin and liquefied in nature and is known as the plasmosol.
- The physical nature of the cytoplasm is variable. Sometimes, there is quick diffusion across the cell, making the cytoplasm resemble a colloidal solution. At other times, it appears to take on the properties of a gel-like or glass-like substance.
- It is said to have the properties of viscous as well as elastic materials – capable of deforming slowly under external force in addition to regaining its original shape with minimal loss of energy.
- The cytoskeleton present in the cytoplasm gives the cell its shape.
- Cytoplasm helps the movement of the cellular materials around the cell through a process called cytoplasmic streaming.
- Since the cytoplasm constitutes numerous salts, it is a very good conductor of electricity.
- It shows differential staining properties, the areas stained with the basic dyes are the basophilic areas of the cytoplasm and is termed as ergatoplasm for this material.

Functions of Cytoplasm

1. The cytoplasm is the site for most of the enzymatic reactions and metabolic activity of the cell.
2. The cytoplasm is the place where the cell expands and the growth of the cell takes place.
3. The cytoplasm provides a medium for the organelles to remain suspended.

4. The cytoplasm acts as a buffer and protects the genetic material of the cell and also the cellular organelles from damage caused due to movement and collision with other cells.
5. Cellular respiration begins in the cytoplasm with **glycolysis**. This reaction provides the intermediates that are used by the mitochondria to generate ATP.
6. The translation of mRNA into proteins on ribosomes also occurs mostly in the cytoplasm.
7. The cytoplasm also contains the monomers that go on to generate the cytoskeleton. The cytoskeleton, in addition to being important for the normal activities of the cell, is crucial for cells that have a specialized shape.
8. The cytoplasm also plays a role in creating order within the cell with specific locations for different organelles. For instance, the nucleus is usually seen towards the center of the cell, with a centrosome nearby.
9. **Cytoplasmic Inheritance:** The cytoplasm plays hosts to two organelles that contain their own genomes – the chloroplast and mitochondria. These organelles are inherited directly from the mother through the oocyte and therefore constitute genes that are inherited outside the nucleus. These organelles replicate independently of the nucleus and respond to the needs of the cell.

Thus, the cytoplasm is a gel-like material that contains all the cell organelles, enclosed within the cell membrane. These organelles include; Mitochondria, ribosomes, Endoplasmic reticulum, Golgi apparatus, lysosomes intermediate filaments, microfilaments microtubules, vesicles.

Chapter 4

PLASMA MEMBRANE

(Cell Membrane or Plasmalemma)

Definition of Plasma membrane (Cell membrane)

The cell membrane (plasma membrane) is a thin semi-permeable membrane that surrounds the cytoplasm of a cell. It serves as the delimitation between the intra- and extracellular spaces. It is composed of a phospholipid bilayer, with the hydrophilic parts of the phospholipids being directed towards the intra- and extra-cellular space.

Structure of Plasma membrane (Cell membrane)

- Thin semi-permeable membrane
- It contains a percentage of lipids making a semi-permeable barrier between the cell and its physical environment.
- It has some protein components a
- It is very consistent around the cell
- All living cells have a plasma membrane.

Functions of Plasma membrane (Cell membrane)

1) The cell membrane is a multifaceted membrane that envelopes a cell's cytoplasm protecting its contents.

2) It protects the interior of the cell by allowing certain substances into the cell while keeping other substances out.

3) It protects the integrity of the cell along with supporting the cell and helping to maintain the cell's shape.

- 4) It also serves as a base of attachment for the cytoskeleton in some organisms.
- 5) It also regulates the molecules that pass into and out of the cell, through the plasma membrane. Therefore it controls homeostasis.
- 6) Its proteins are actively involved in transporting materials across the membrane
- 7) Proteins and lipids are the major components of the cell membrane. The proteins and lipids allow cell communication, and carbohydrates (sugars and sugar chains), which decorate both the proteins and lipids and help cells recognize each other.
- 8) Phospholipids are important components of cell membranes. They spontaneously arrange to form a lipid bilayer that is semi-permeable such that only certain substances can diffuse through the membrane to the cell's interior.
- 9) It regulates cell growth through the balance of endocytosis and exocytosis. In endocytosis, lipids and proteins are removed from the cell membrane as substances are internalized. In exocytosis, vesicles containing lipids and proteins fuse with the cell membrane increasing cell size.
- 10) The cell membrane's functionality is determined by its **membrane proteins**, which include: ion channels, cell adhesion molecules, aquaporins, membrane pumps, carrier proteins, and receptor proteins.

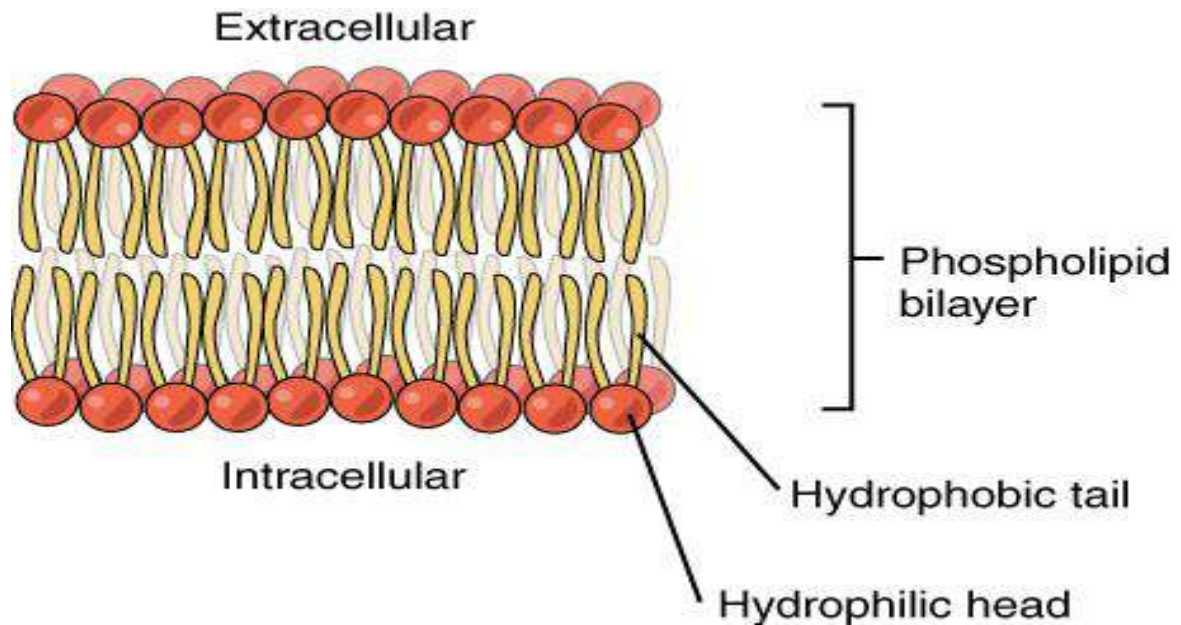


Figure 4: Diagram of the lipid bilayer of cell membrane.

Image: Phospholipid Bilayer. By philschatz, License: [CC BY 4.0](#)

Fluid Mosaic Model of Cell Membrane

The currently accepted model for the structure of the plasma membrane, called the **fluid mosaic model**, was first proposed in 1972. This model has evolved over time, but it still provides a good basic description of the structure and behavior of membranes in many cells.

According to the fluid mosaic model, the plasma membrane is a mosaic of components—primarily, phospholipids, cholesterol, and proteins—that move freely and fluidly in the plane of the membrane. In other words, a diagram of the membrane (like the one below) is just a snapshot of a dynamic process in which phospholipids and proteins are continually sliding past one another.

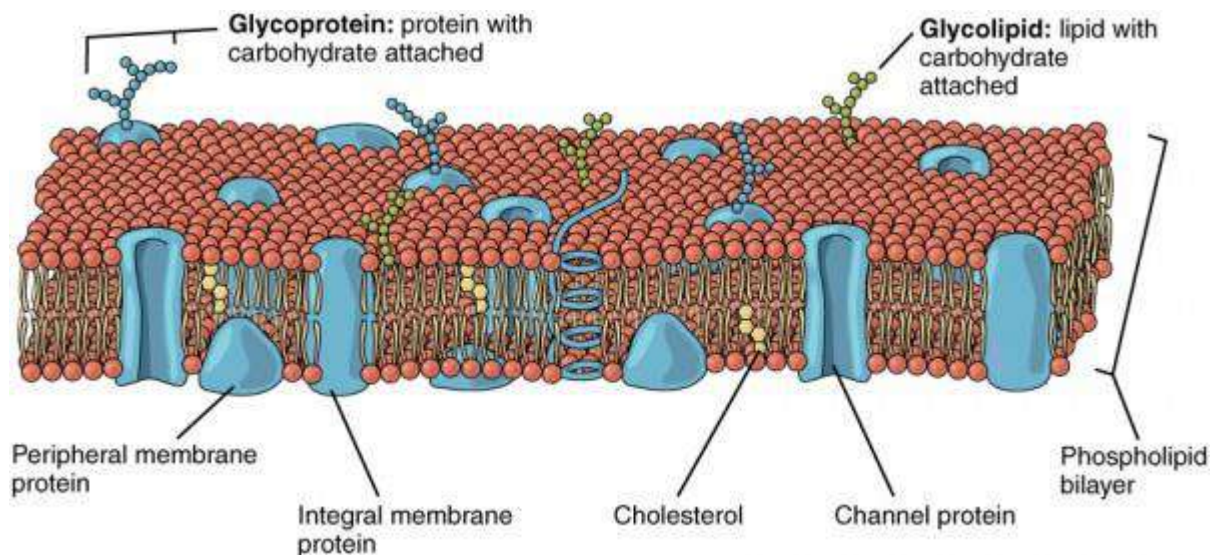


Figure 5: Diagram of the fluid mosaic model of the cell membrane

The peripheral **glycocalyx** consists of sugar chains (polysaccharides) that are covalently bonded to membrane proteins (glycoproteins) and membrane lipids (glycolipids). The glycocalyx is individual and cell type-specific, this means for example, that it determines the blood group characteristics of the erythrocytes.

Facilitated by its fluidity, the cell membrane is stable and flexible at the same time. Its fluidity can change depending on temperature and lipid composition. The membrane is **semi-permeable** (also referred to as selective permeability), which means it is permeable to small-molecular substances like water, which are able to diffuse **osmotically**. Higher-molecular substances such as proteins require specific transport systems in order to pass through the cell membrane.

Microvilli

These are surface protrusions from the free face of the cell membrane. It is found in the intestinal lining, on egg cell surfaces, and on white blood cells.

Structure of Microvilli

- These are surface protrusions formed from accessory proteins of the actin filaments. The accessory proteins bundle together to form microvilli on the surface of the cell membrane

Functions of Microvilli

- In the small intestines, they increase the surface area for the absorption of digested food and water. Some microvilli may be found in the ear for detection of sound and they transmit the sound waves to the brain through an electric signal.
- They also help to anchor the sperm to the egg for easy fertilization.
- In white blood cells, they also act as anchors allowing the white blood cells freely moving in the circulatory system to attach to possible pathogens.

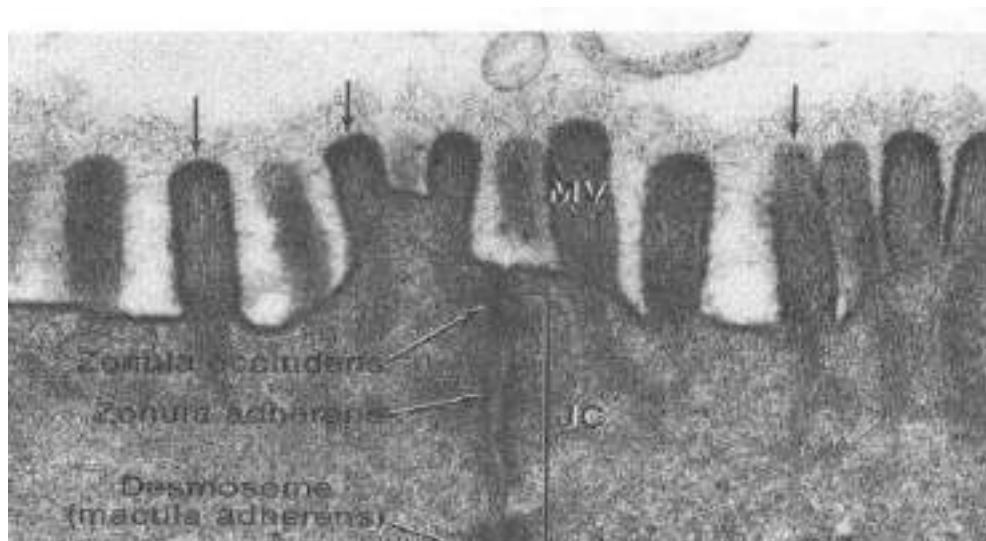


Figure 6: Microvilli (MV) at the apical surface of two neighboring epithelial cells joined by a junctional complex (JC)

Chapter 5

CYTOPLASMIC ORGANELLES (ORGANOIDS)

Some cell organelles are also surrounded by protective membranes. The nucleus, endoplasmic reticulum, vacuoles, lysosomes, and Golgi apparatus are examples of membrane-bound organelles. The membranes of the different organelles vary in molecular composition and are well suited for the functions they perform. Organelle membranes are important to several vital cell functions including protein synthesis, lipid production, and cellular respiration.

1- Endoplasmic Reticulum (ER)

Structure of Endoplasmic Reticulum (ER)

- This is a continuous folded membranous organelle found in the cytoplasm made up of a thin network of flattened interconnected compartments (sacs) that connects from the cytoplasm to the cell nucleus.
- Within its membranes, there are membranous spaces called the **cisternal spaces** and the membrane folding are called **cisternae or lamellae**.
- There are two types of ER based on their structure and the function they perform including **Rough Endoplasmic reticulum** and the **Smooth endoplasmic reticulum**.

Functions of Endoplasmic Reticulum (ER)

- Manufacturing, processing and transporting proteins for cell utilization both in and out of the cell. This is because it is directly connected to the nuclear membrane providing a passage between the nucleus and the cytoplasm.

- The ER has more than half the membranous cell content, hence it has a large surface area where chemical reactions take place. They also contain the enzymes for almost all the cell lipid synthesis hence they are the site for lipid synthesis.

The variation in physical and functional characteristics differentiates the ER into two types i.e., Rough endoplasmic reticulum and Smooth endoplasmic reticulum.

Types of Endoplasmic Reticulum

1. Rough Endoplasmic Reticulum (Rough ER) –

Rough ER is called “rough” because their surface is covered with ribosomes, giving it a rough appearance. The function of the ribosomes on rough ER is to synthesize proteins and they have a signaling sequence, directing them to the endoplasmic reticulum for processing. Rough ER transports the proteins and lipids through the cell into the cristae. They are then sent into the Golgi bodies or inserted into the cell membrane.

2. Smooth Endoplasmic Reticulum (Smooth ER)

The smooth endoplasmic reticulum is primarily composed of three-dimensional polygonal networks of tubules called cisternae. They are about 50 nm in diameter in mammals. The smooth ER is also a dynamic structure, with new tubules budding off from the sides of existing structures.

Smooth ER is not associated with ribosomes and their function is different from that of the rough endoplasmic reticulum, despite lying adjacent to the rough endoplasmic reticulum. Its function is to synthesize lipids (cholesterol and phospholipids) that are utilized for producing new cellular membranes. They are also involved in the synthesis of steroid hormones from cholesterol for certain cell types (ovaries, testes, and the adrenal gland). It also contributes to the detoxification of the liver after the intake of drugs

and toxic chemicals. In liver cells the smooth ER produces enzymes that help to detoxify certain compounds.

There is also a specialized type of smooth ER known as the **sarcoplasmic reticulum**. Its function is to regulate the concentration of Calcium ions in the muscle cell cytoplasm. In muscles the smooth ER assists in the contraction of muscle cells. Probably the most universal role of the smooth endoplasmic reticulum is the storage and sudden release of calcium ions. Calcium ions are pumped from the cytosol into the lumen of the smooth endoplasmic reticulum to more than 100 times the concentration found in the cytosol.

- Smooth ER also serves as a transitional area for vesicles that transport ER products to various destinations.
- In brain cells it synthesizes male and female hormones.

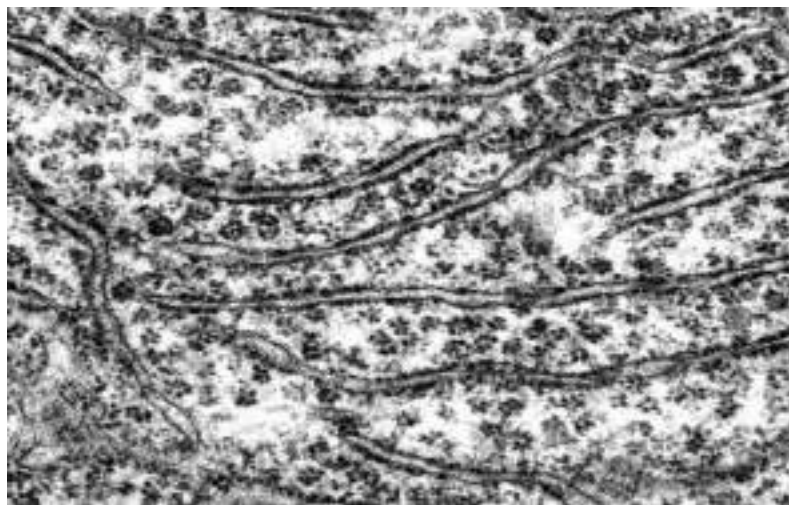


Figure 7: Rough endoplasmic reticulum with ribosomes on the outer lamellar surface

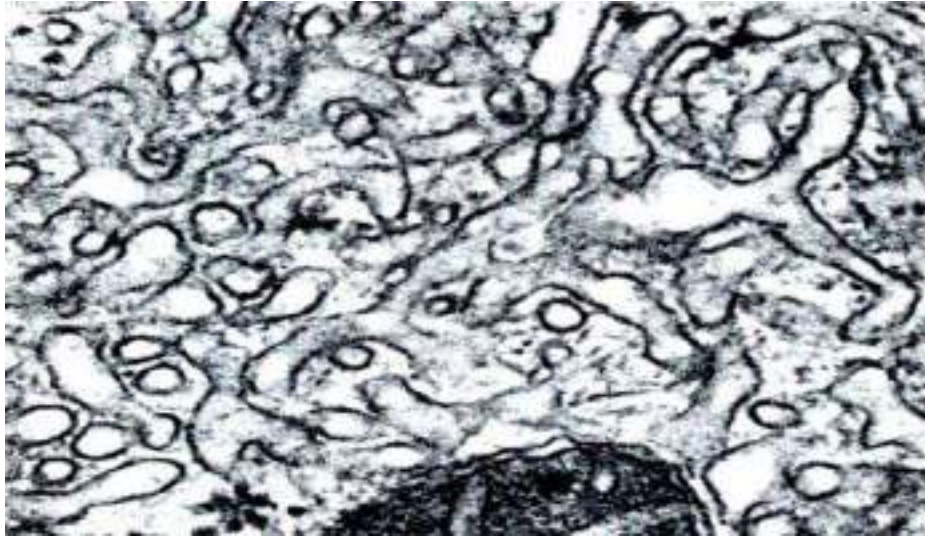


Figure 8: Cisternae of smooth endoplasmic reticulum
showing labyrinthine architecture

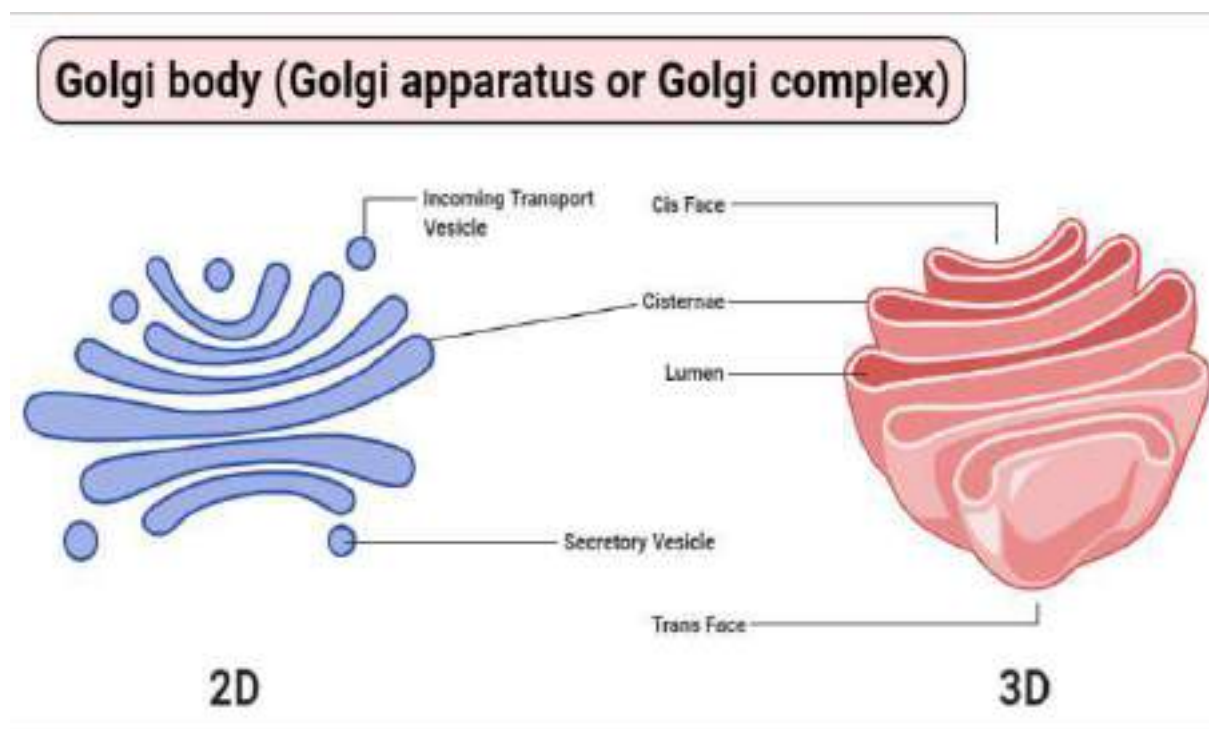
2- Golgi apparatus (Golgi bodies/Golgi complex)

Structure of Golgi apparatus (Golgi bodies)

A Golgi body, also known as a Golgi apparatus, is a cell organelle that helps process and package proteins and lipid molecules, especially proteins destined to be exported from the cell. It was named after its discoverer, Camillo Golgi in 1898. It is a membrane-bound cell organelle found in the cytoplasm of a eukaryotic cell, next to the endoplasmic reticulum and near the nucleus.

- Golgi bodies are supported together by cytoplasmic microtubules and held by a protein matrix
- It is made up of flattened stacked pouches known as cisternae or saccules.
- These cisternae formed stacks that may be 4- 10 in number for animal cell Golgi bodies. In some single-celled organisms they may be 60 cisternae.
- They have three primary compartments known as **cis** (Cisternae nearest the Endoplasmic Reticulum), **medial** (central layers of

cisternae) **and the trans** (cisternae farthest from the endoplasmic reticulum).



Created with BioRender.com

Figure 9: Two- dimension and 3-dimension representation of Golgi apparatus

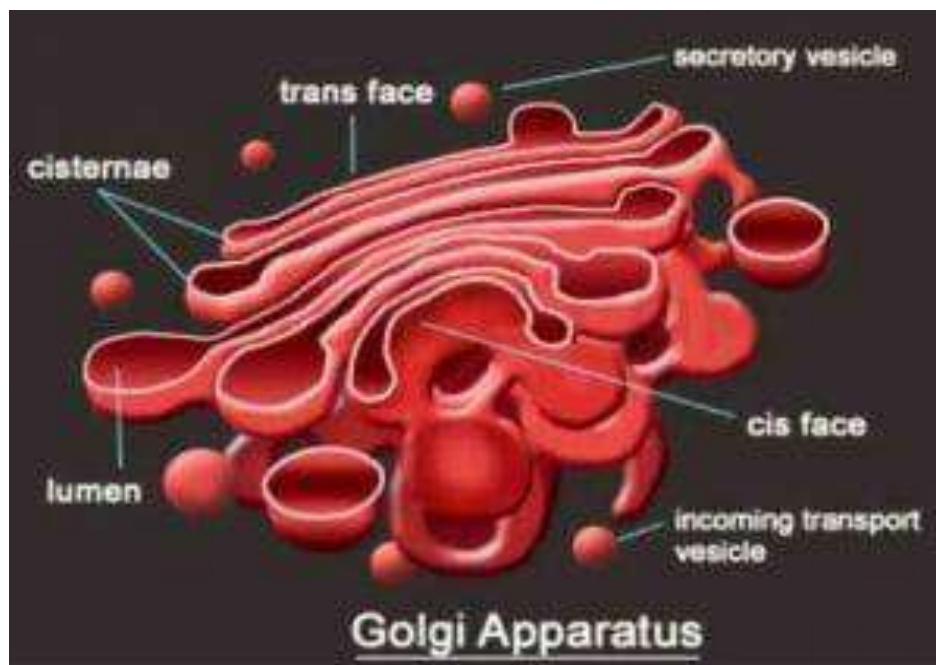


Figure 10: Faces of Golgi apparatus

Functions of Golgi apparatus (Golgi bodies)

- Their primary function is to transport, modify and pack proteins and lipids into the Golgi vesicles to deliver them to their target sites. Cis and trans Golgi network make up the outer layer of cisternae at the cis and trans face and they are responsible for sorting proteins and lipids received at the cis face and released by the trans face, by the Golgi bodies.
- The cis face collects the proteins and lipids, of fused vesicles in clusters. The fused vesicles move along the microtubules through a specialized compartment known as the **vesicular-tubular cluster**. This compartment is found between the endoplasmic reticulum and the Golgi apparatus.
- The vesicle clusters fuse with the cis Golgi network, delivering the proteins and lipids into the cis face cisternae and as they move from the cis face to the trans face, they get **modified** to functional units. These functional units get delivered to intracellular and extracellular components of the cell.
- Modification mechanisms include:
 - Cleaving of oligosaccharides chains
 - Attachment of sugar moieties of different side chains
 - Adding fatty acids and/or phosphate groups by phosphorylation, and/or removing monosaccharides e.g. the removal of the mannose moieties takes place in the cis and the medial cisternae while adding of galactose takes place in the trans cisternae.
- Sorting of the modified proteins and lipids occurs in the trans-Golgi network and packed into the trans vesicles, which then delivers them to the lysosomes or sometimes to the cell membrane for exocytosis.
- Thus, Golgi apparatus is the distribution and shipping department for the cell's chemical products. It modifies proteins and fats built in the

endoplasmic reticulum and prepares them for export to the outside of the cell.

3- Ribosomes

Definition of Ribosomes

- They are small organelles majorly made up of 60% RNA cytoplasmic-granules and 40% proteins.
- All living cells contain ribosomes, which may be freely scattered in the cytoplasm and some are connected to the outer faces of the endoplasmic reticulum lamellae.
 - Free and the bound ribosomes are very much alike in structure and are associated with protein synthesis.
- Ribosomes are a part of the protein-generating factory in the cell. It comprises of two sections, known as subunits. The tinier subunit is the place the mRNA binds, whereas the bigger subunit is the place the amino acids are included. This structure acts as a docking station for the transfer RNA that contains the amino acid that will then become part of the growing polypeptide chain.
 - Around 37 to 62% of RNA is comprised of RNA and the rest is proteins.

Ribosomes are made of proteins and ribonucleic acid (abbreviated as RNA), in almost equal amounts. Both subunits comprise of both ribonucleic acid and protein components and are linked to each other by interactions between the proteins in one subunit and the rRNAs in the other subunit. The ribonucleic acid is obtained from the nucleolus.

Structure of Ribosomes

The structures of ribosomes include:

- Prokaryotes have 70S ribosomes respectively subunits comprising the little subunit of 30S and the bigger subunit of 50S. Eukaryotes have 80S ribosomes respectively comprising of little (40S) and substantial (60S) subunits.

Ribosomes are usually made up of three or four rRNA molecules and anywhere from about 40 to 80 different ribosomal proteins. Each ribosome is composed of two subunits, a larger one and a smaller one, each of which has a characteristic shape.

- Ribosomes are made up of ribosomal proteins and ribosomal RNA (rRNA). In a eukaryotic cell, ribosomes constitute half ribosomal RNA and half ribosomal proteins.
- Each ribosome is made up of two subunits i. e large subunit and small subunit with their own distinct shapes. These subunits are designated as the 40s and 60s in the animal cell.

Functions of Ribosomes

- Ribosomes that occur as free particles are attached to the endoplasmic reticulum membrane occurring in large numbers accounting for about a quarter of the cell organelles. A single replicated cell has about 10 million ribosomes.
- The ribosomal subunits are the site for genetic coding into proteins. On the ribosomes, the mRNA helps determine the coding for Transfer RNA (tRNA) which also determines the protein amino acid sequences.

The other functions include:

1. Procedure of creation of proteins, the deoxyribonucleic acid makes mRNA by the step of DNA transcription.
2. Hereditary information from the mRNA is converted into proteins amid DNA translation.

3. The arrangements of protein assembly amid protein synthesis are indicated in the mRNA.
4. The mRNA is arranged in the nucleus and is moved to the cytoplasm for an additional operation of protein synthesis.
5. Proteins which are arranged by the ribosomes currently in the cytoplasm are utilized inside the cytoplasm by itself. The proteins created by the bound ribosomes are moved outside the cell.

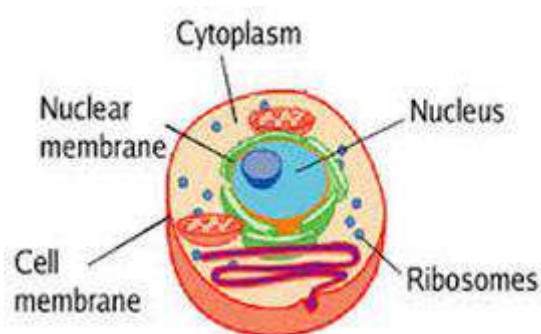


Figure 11: Ribosomes are scattered free in the cytoplasm or attached to the surface of RER

4- Mitochondria

Definition of Mitochondria

- These are membrane-bound organelles located in the cytoplasm of all eukaryotic cells
- The number of mitochondria found in each cell varies widely depending on the function of the cell it performs.
- For example, erythrocytes do not have mitochondria while the liver and muscle cells have thousands of mitochondria.

Structure of Mitochondria

- They are rod-shaped or oval or spherically shaped, with a size of 0.5 to 10 μm .
- Mitochondria have two special membranes – outer smooth one and inner convoluted or folded membrane. Due to the presence of the two membranes two chambers are produced outer and inner chambers.
- They have a mitochondrial gel-matrix (ground substance) inside the central mass. The matrix has mitochondrial DNA rods and ribosome-like (in size) granules.
- The membranes bend into folds known as **cristae**.

Functions of Mitochondria

- In the animal cell, they are the main power generators, converting oxygen and nutrients into energy.
- Their primary function is to generate energy for the cell i.e., they are the power generators, producing energy in form of Adenosine Triphosphate (ATP), by converting nutrients and oxygen into energy enabling the cell to perform its function and to also release excess energy from the cell.
- Mitochondria also store calcium which assists in cell signaling activity, generating cellular and mechanical heat and mediating cellular growth and death.
- The outer membrane is permeable, allowing the transport of small molecules and a special channel to transport large molecules.
- The inner mitochondrial membrane is less permeable thus allowing very small molecules into the mitochondrial gel-matrix in the central mass. The gel matrix is composed of the mitochondria DNA and enzymes for the Tricarboxylic Acid (TCA) cycle or the Krebs's Cycle.
- The TCA cycle uses up the nutrients, converting them into by-products that the mitochondria use for producing energy. These processes take place in the inner membrane.

- Some if not all proteins and molecules that make up the mitochondria come from the cell nucleus. The mitochondrial nucleus genome has 37 genes of which 13 of these genes produce most of the components of the Electron Transport Chain (ETC). ETC is the main source of ATP production in the body ETC. However, the mitochondrial DNA is very vulnerable to mutations because they don't possess a large DNA repair mechanism, a common element found in other nuclear DNAs.

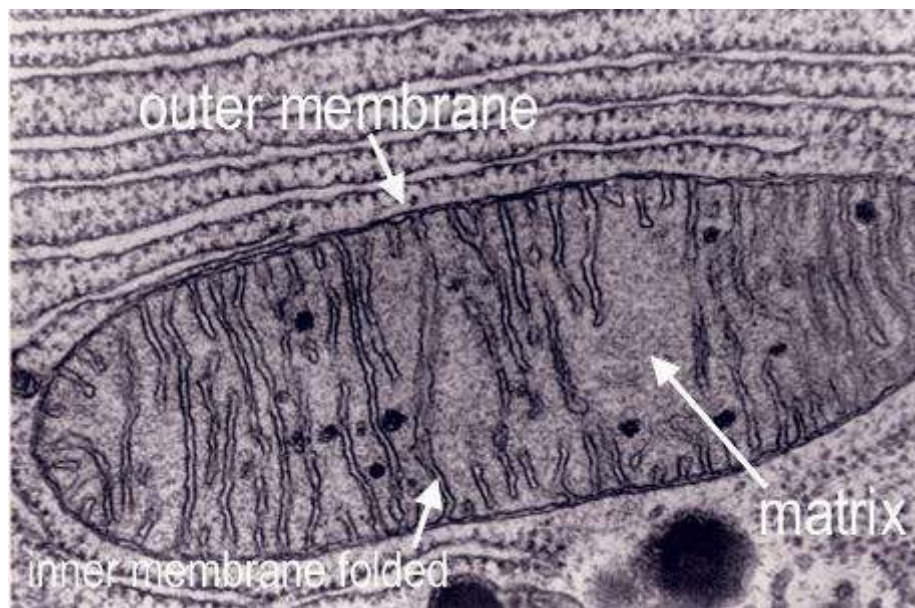


Figure 12: Ultrastructure of mitochondrion surrounded with lamellae of RER

5- Centrioles

This is distinctly found in the animal cell, which has the ability to replicate or division. It is made up of 9 triplet microtubule bundles ($9 \times 3 = 27$ microtubules) held together by proteins forming a cylinder.

. As triplets, they remain very strong together hence they have been observed to be in structures like cilia and flagella.

- They are found in the centrosome, creating and holding microtubules within the cell.
- The triplet microtubules are surrounded by a pericentriolar matrix containing molecules that build up the microtubules.

- Each microtubule within the triplet microtubule complex is made up of tubulin subunits that join together forming long hollow tubes that look like straw (microtubules).

Functions of Centrioles

The primary function of centrioles is to assist in organizing the cell division process.

- The centriole microtubules allow the transportation of substances that are linked together with a glycoprotein to any cell location. The glycoprotein linkage acts as a signaling unit to move specific proteins.
- The centrioles anchor the microtubules that extend from it and contain the factors needed to create more tubules.
- Mitosis is achieved by replication of each centriole which makes duplicates of each centriole (4 centrioles). The newly formed centrioles divide into two centrosomes, each centriole at an angle to the second centriole. The microtubules between the centrosomes, push the pairs of centrioles apart, to the opposite ends of the cell. When the centrioles are in place, the microtubules extend to the cell cytoplasm, to seek for the chromosome. The microtubules then bind to the chromosome at the centromere. The microtubules are then unassembled moving the chromosomes apart.

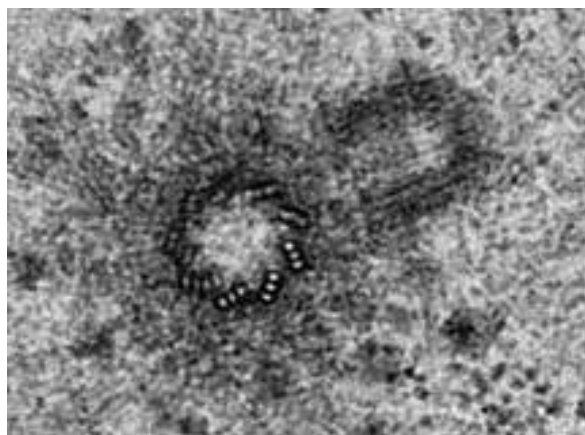


Figure 13: Ultrastructure of centrioles L.S. and T.S.

6- Lysosomes

Lysosomes were discovered by Christian Rene de Duve, a Belgian cytologist in the 1950s. It was known as cell vesicles or microbodies. Lysosomes break down cellular waste products and debris from outside the cell into simple compounds, which are transferred to the cytoplasm as new cell-building materials. Lysosomes are sometimes called “cell stomachs” because they contain enzymes that digest cellular components. They are particularly plentiful in cells that digest and destroy other cells, such as macrophages.

Structure of Lysosomes

Lysosomes are roughly spherical and usually 250–500 nm in diameter.

- They are round subcellular organelle found in almost all eukaryotic cells
- Lysosomes are very acidic organelles containing the digestive enzymes and therefore each of the lysosomes is surrounded by a membrane to protect it from the outer environment.

Functions of Lysosomes

- This is the site for digestion of cell nutrients, excretion, and cell renewal.
- Lysosomes break down macromolecules components from the outside of the cell into simpler elements that are transported into the cytoplasm via a **proton pump** to build new cell materials.
- These macromolecule components include old cells and parts, cell waste products, microorganisms, and cell debris.
- The digestive enzymes found in the lysosomes are called hydrolytic enzymes or acid hydrolases, breaking down large molecules into smaller molecules that can be utilized by the cell.
- These enzymes also break down large molecules e. g proteins, carbohydrates, lipids, into small molecules e.g. amino acids and simple sugars, fatty acids, respectively.

- **Note:** The enzymes are active only on the inside of the acidic lysosome and their acidity protects the cell from degrading itself when there is lysosomal leakage because the cell pH is neutral to slightly alkaline.

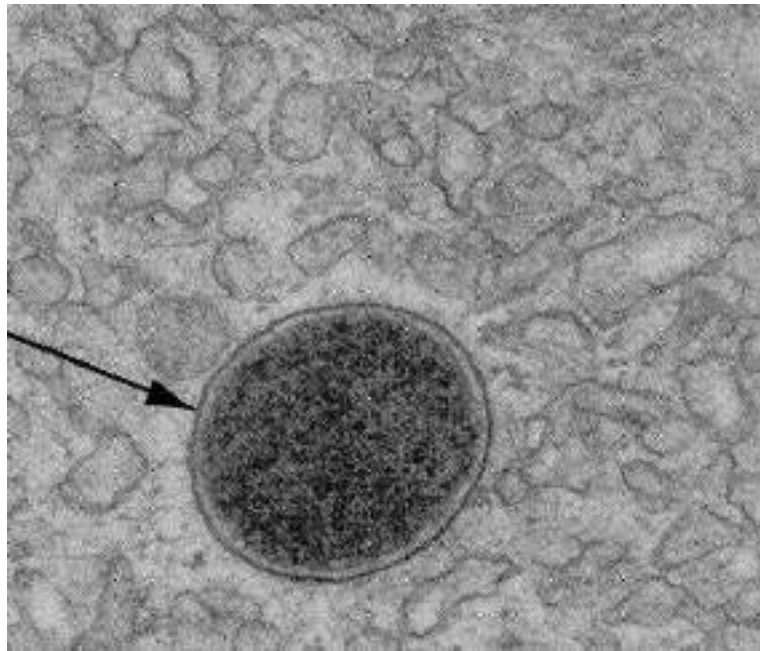
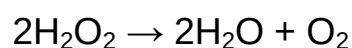


Figure 14: Ultrastructure of a primary lysosome

7- Peroxisomes

Structure of Peroxisomes

They are tiny spherical bodies, bound by a single membrane and they are the most common micro-bodies in the cell cytoplasm. Peroxisomes are so named because they are frequently responsible for the conversion of the highly reactive molecule hydrogen peroxide (H₂O₂), which is formed as a by-product of the reactions in the mitochondrion, into water:



Functions of Peroxisomes

- Peroxisomes functions include:
- Lipid metabolism

- Chemical detoxification by moving hydrogen atoms from various oxygen molecules to produce hydrogen peroxide (H_2O_2), hence neutralizing body poison such as alcohol.
- Its mechanism in Reactive Oxygen species is highly essential.

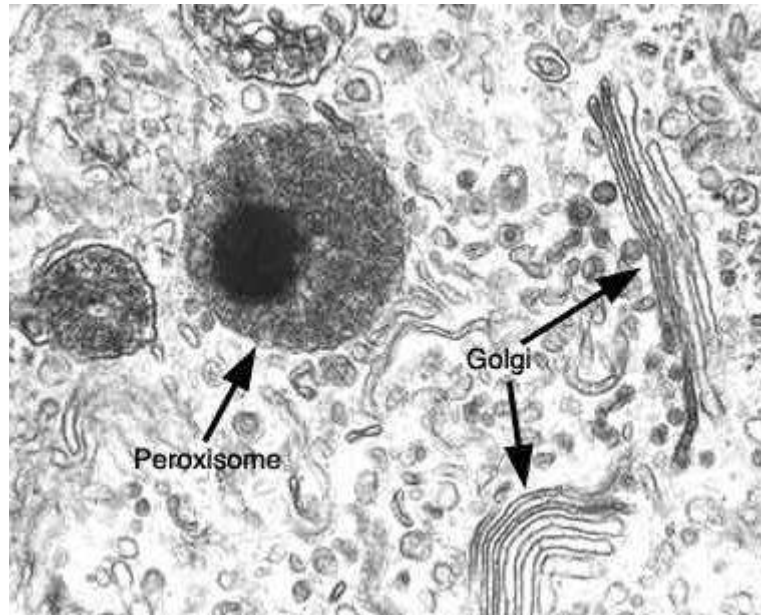


Figure 15: Ultrastructure of a primary lysosome

8- Cytoskeleton

Structure of Cytoskeleton

- This is a fibrous network that's formed from and by different proteins of long chains of amino acids.
- These proteins are found in the cell cytoplasm of the eukaryotic cells.
- They are also made up of 3 types of tiny filaments: Actin filaments (Microfilaments), Microtubules, Intermediate filaments.

Functions of Cytoskeleton

- The cytoskeleton functions to create a network organizing the cell components and to also maintain the cell shape.
- It also provided a uniform movement of the cell and its organelles, by the filament system network found in the cell's cytoplasm.
- It also organizes some of the cell components maintaining the cell shape
- It plays a major role in the movement of the cell and some cell organelles in the cytoplasm.
- The tiny filaments include:
 - **Microfilaments (Actin filaments):** These are solid rods made of globular proteins called actin. These filaments are primarily structural in function and are an important component of the cytoskeleton. They form a meshwork of fibers running parallel to each other and they play a primary role in giving the cell its shape; they change consistently, helping the cell to move and to also mediate certain cell activities such as adherence ability to substrates and cleavage mechanisms during mitotic cell division
 - **Microtubules-** these are long filaments that assist in mitosis moving daughter chromosomes to new forming daughter cells.
 - **Intermediate filaments**– they are more stable filaments in comparison to the actin and microtubules. They form the true skeleton of the cell, and the hold the nucleus in its rightful position within the cell.
- It also allows the cell's elasticity factor enabling it to endure physical tension.
- Other proteins that may be added as part of the cytoskeleton of the cell include septin ((assembles the filaments) and spectrin (help maintain the structure of the cell by pulling together the cell membrane with the intracellular surface of the cell).

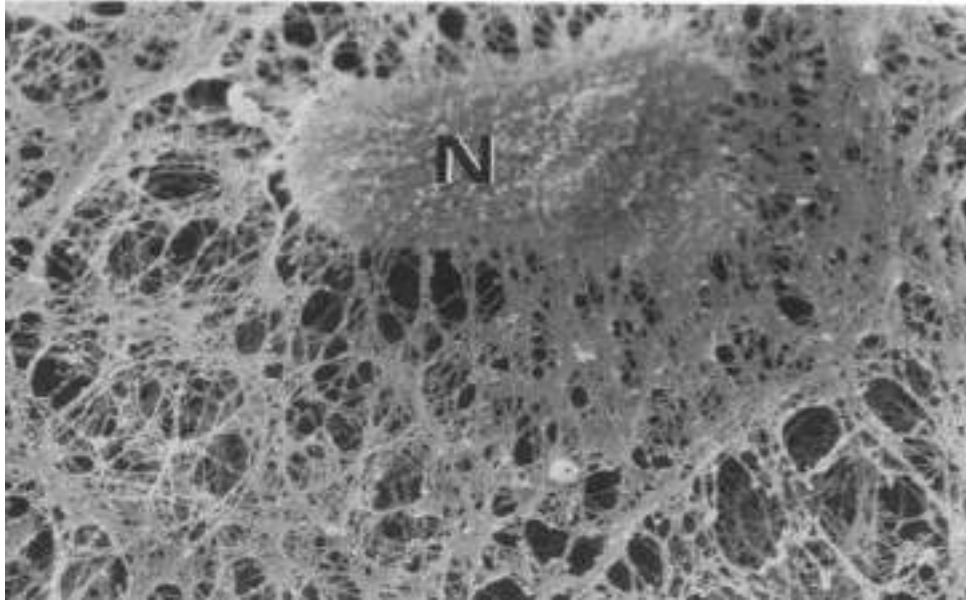


Figure 16: Cytoskeleton of the cell

9- Microtubules

Structure of Microtubules

- These are long straight, hollow cylinders found throughout the cytoplasm of all eukaryotic cells (prokaryotes don't have them) and carry out a variety of functions, ranging from transport to structural support.
- They are constructed from 13-15 sub-filaments (protofilament) of a special globular protein called **tubulin**, found only in eukaryotic cells.

Functions of Microtubules

- Transportation of some organelles like the mitochondria and the vesicles i.e. transporting vesicles from the neuron cell body to the axon tips, and back to the cell body
- Structural support, they give characteristic support to the Golgi bodies, holding them within the gel-matrix of the cytoplasm.

- They provide the rigid and organized component of the cytoskeleton of the cell, enabling a cell to take up a particular shape.
- They are the main elements that make up the locomotive projections of a cell (cilia and flagella)
- They also play a role in forming the spindle fibers of the chromosome of the cell during mitotic cell division.

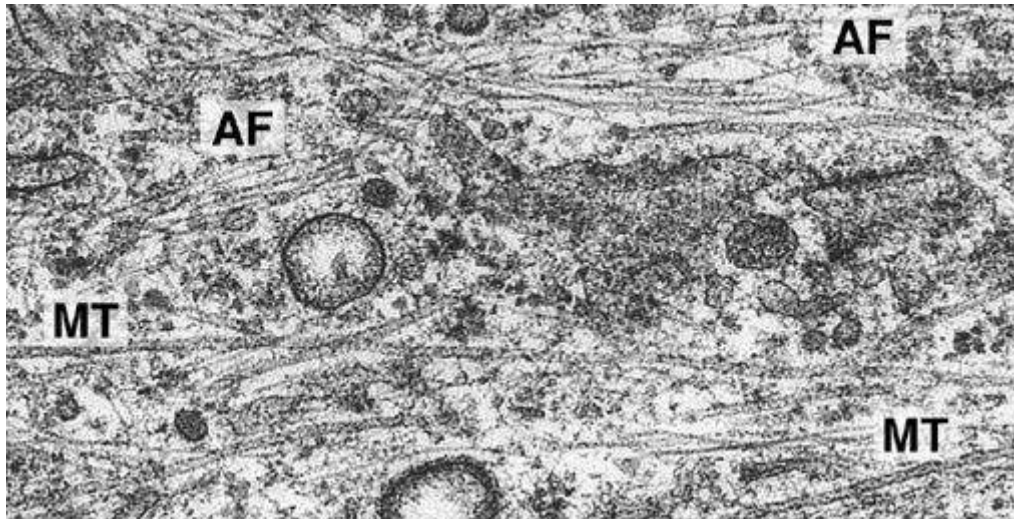


Figure 17: Ultrastructure of microtubules (MT) and actin filaments (AF)

10- Vacuoles

These are fluid-filled cell organelles enclosed by a membrane.

Structure of Vacuoles

- They are membrane-bound sacs found within the cell cytoplasm.
- The vacuole sac has a single membrane surrounding it known as a tonoplast and this membrane resembles the plasma membrane.

Functions of Vacuoles

- The primary function of vacuoles is to store food, water, carbohydrates in the form of sugars and waste materials.
- Tonoplast is a regulator controlling the inflow and outflow of small across a protein pump

- acts as the guard for what kinds of matter are allowed passage to and from vacuoles
- They also remove toxic substances and waste materials from the cell as a protection strategy.
- They also remove poorly folded proteins from the cell.
- Vacuoles also can be able to change their functionality to provide necessary roles that suit the cell, by being able to change shape and size.

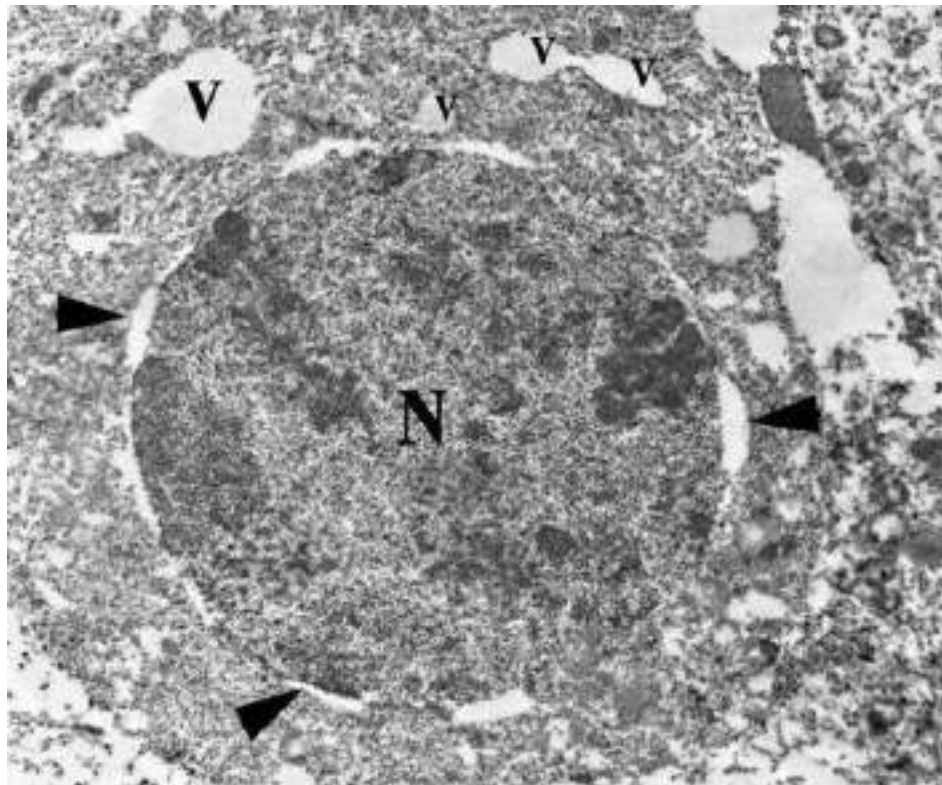


Figure 18: Ultrastructure of cytoplasmic vacuoles

Chapter 6

The Nucleus

The nucleus is the most prominent cell organelle. It contains the **genome**, the cell's database, which is encoded in molecules of the nucleic acid, DNA. The nucleus is bounded by a nuclear envelope composed of two membranes separated by an intermembrane space. The inner membrane of the nuclear envelope is lined by a meshwork of proteins called the nuclear lamina which provides rigidity to the nucleus. A two-way traffic of proteins and nucleic acids between the nucleus and the cytoplasm passes through holes in the nuclear envelope called nuclear pores.

Definition of Nucleus

- This is a spherical structured organelle found majorly at the center of a cell surrounded by a double-layered nuclear membrane separating it from the cytoplasm.
- It is held together to the cytoplasm with the help of the filaments and microtubules.
- It holds other cells organelles including the nucleolus, nucleosomes, and chromatins.
- A cell has one nucleus which divides producing multinucleated cells e.g. the skeletal muscle cell fibers.
- Some cells lose their nuclei after maturations e.g. the red blood cells.

Structure of Nucleus

- The double-layered membrane is a continuous channel of membranous from the endoplasmic reticulum network.
- The membrane has pores which allow entry of large molecule
- Nucleoli (Singular; nucleolus) are tiny/small bodies found in the nucleus

- The nucleus and its component organelles are suspended in the **nucleoplasm** (House of the chromosomal DNA and genetic materials)

Functions of Nucleus

- The primary role of the nucleus is to control and regulate cell activities of growth and maintain cell metabolisms.
- It also carries the genes that have hereditary information of the cell.
- The chromosomal DNA and genetic materials, which are made up of genetic coded ultimately make up their proteins' amino acid sequences for use by the cell.
- Therefore, the nucleus is the information center.
- It is the site for Transcription (formation of mRNA from DNA) and the mRNA is transported to the nuclear envelope.

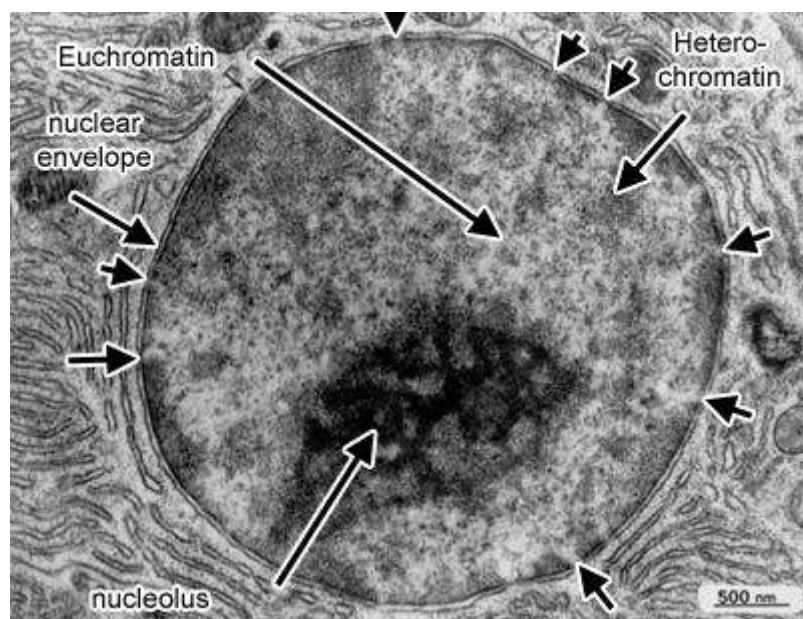


Figure 19: Ultrastructure of the nucleus

References

- Bolsover, S.R.; Hyams, J.S.; Shephard, E. A.; White, H.A. and Wiedemann, C.G. (2004): Cell Biology: a short course. 2nd ed., John Wiley & Sons, Inc., Hoboken, New Jersey. Pp:535.
- Raven, P.H.; Johanson, G. B.; Mason, K.A.; Loses, J.B. and Singer, S.R. (2011) : "Biology", 9th ed. McGraw-Hill, New York. Pp: 1406.
- Robinson, R. (2002): Biology. Macmillan Reference USA. Pp: 1175.

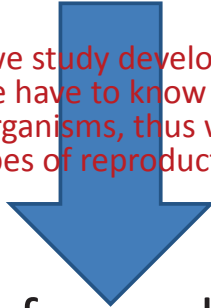
CONTENTS

Chapter	Title	Page
1	Definition of Cytology & Cell Biology	1
2	Cell Structure	9
3	Components of the Cell	15
4	Plasma membrane (Plasmalemma)	19
5	Cytoplasmic Organelles (Organoids)	24
6	The Nucleus	43

EMBRYOLOGY

It is the study of the early developmental stages of living organisms.

Before we study developmental stages, we have to know the origin of living organisms, thus we have to study types of reproduction first.



types of reproduction

A sexual reproduction

sexual reproduction

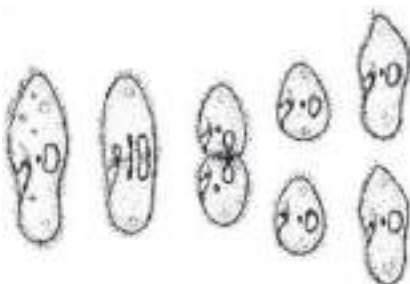
A sexual reproduction

It needs one parent, i.e. a single organism which splits, buds or fragments to give rise to two or more individuals.

Types

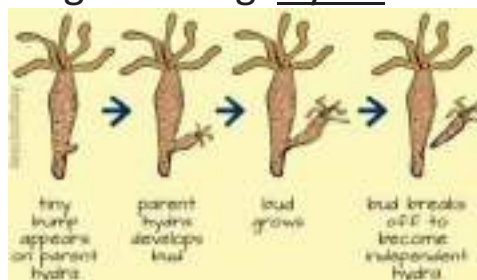
1- SPLITTING:

the organism splits to two individuals
e.g. Paramecium



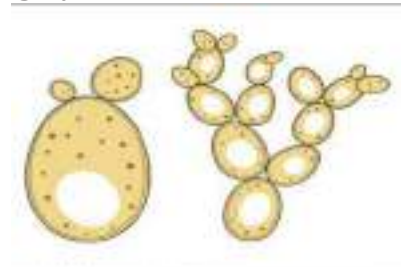
2- BUDDING:

the organism produces a small bud which grows on the mother's body then breaks down to a new organism e.g. Hydra



3- FRAGMENTATION:

the organism fragments to more than two organisms forming a colony
e.g. yeast

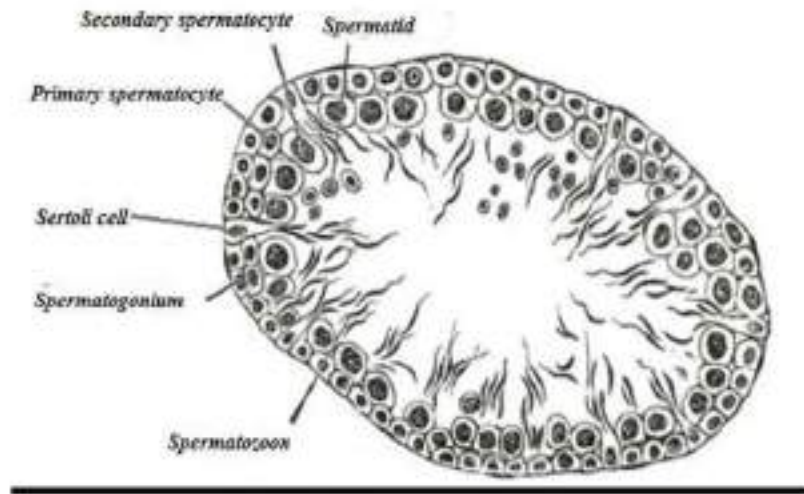


sexual reproduction

- It involves the fusion of two gametes, a male gamete (sperm) fuses with a female gamete (ovum) to form a ZYGOTE or fertilized egg.
- In this case the chromosomes (n) of sperm join with the chromosomes (n) of ovum forming the chromosomes ($2n$) of the zygote.
- Zygote undergoes embryonic developmental stages which involve the division of zygote cell to a large number of somatic cells containing diploid number of chromosomes ($2n$) that form the body of an embryo.
- Before we study these developmental stages we have to study the formation of gametes containing haploid number of chromosomes (n) by a process called GAMETOGENESIS .

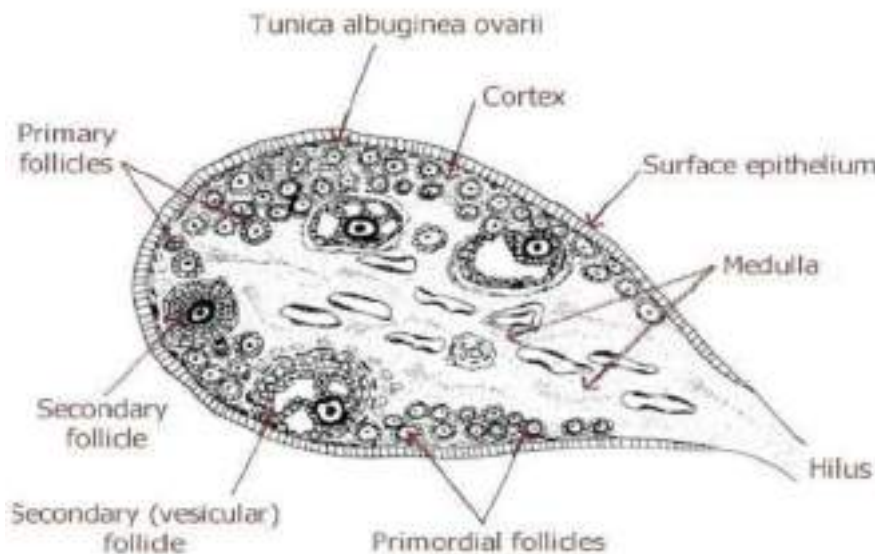
GAMETOGENESIS

- It is the production of gametes by parents which involves the reduction of number of chromosomes to haploid sets of chromosomes in the resulting gametes.
- The body of an organism contains many organs which all are formed of somatic cells ($2n$) even the gonads (testis) in male and (ovary) in female, the cells lining these organs are diploid in chromosomes.
- The origin of the haploid germ cells is those diploid cells lining the testis and the ovary (the primordial germ cells) which undergo a number of changes in two processes called spermatogenesis (production of sperm) and oogenesis (production of ovum) through three phases in each process.



T.S. in testis of Rat

- Testis are formed of a large number of seminiferous tubules in which countless number of sperms is formed.
- Walls of seminiferous tubules are lined with the germinal epithelium $2n$ formed of cubical primordial germ cells from which sperms $1n$ are produced.



T.S. in the ovary of cat

The ovary of female is lined with the germinal epithelium consisting of primordial germ cells $2n$ which undergo oogenesis to produce mature ovum $1n$ finally

SPERMATOGENESIS

- The formation of male gametes or sperms in the testis

- Involves three phases:-

a) Multiplication phases:

Repeated mitotic divisions in the primordial germ cells lining the testis to produce large number of spermatogonia ($2n$)

b) Growth phase:

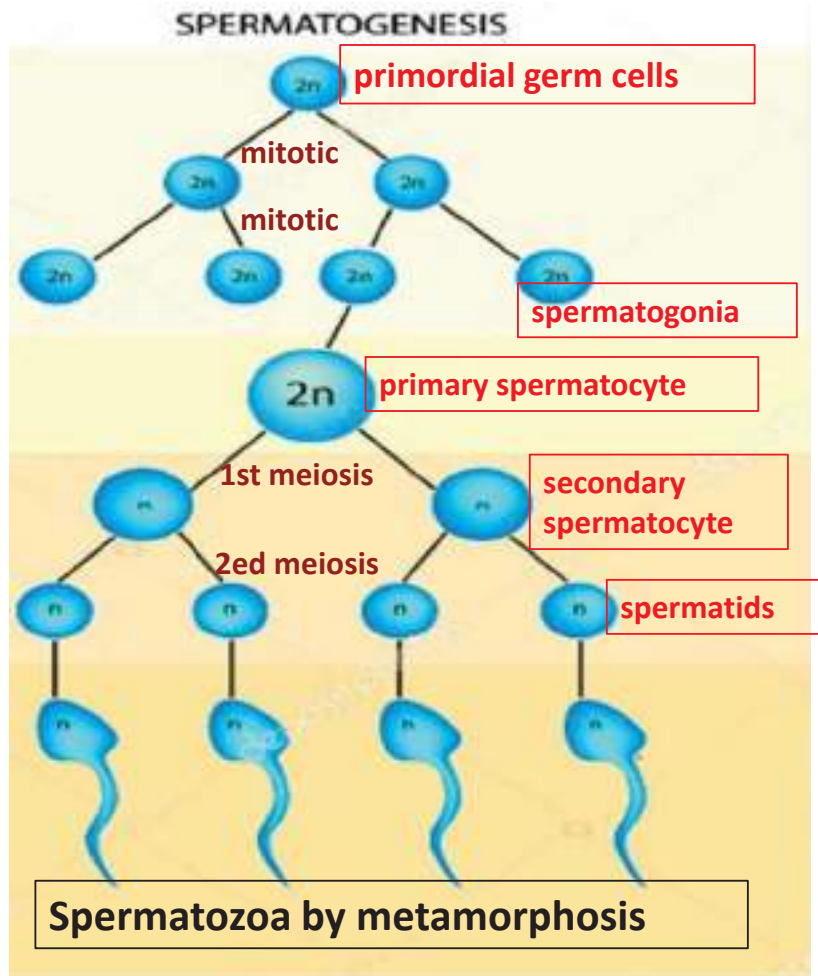
Spermatogonia grow and become larger in size it becomes primary spermatocyte and still $2n$.

c) Maturation phase:

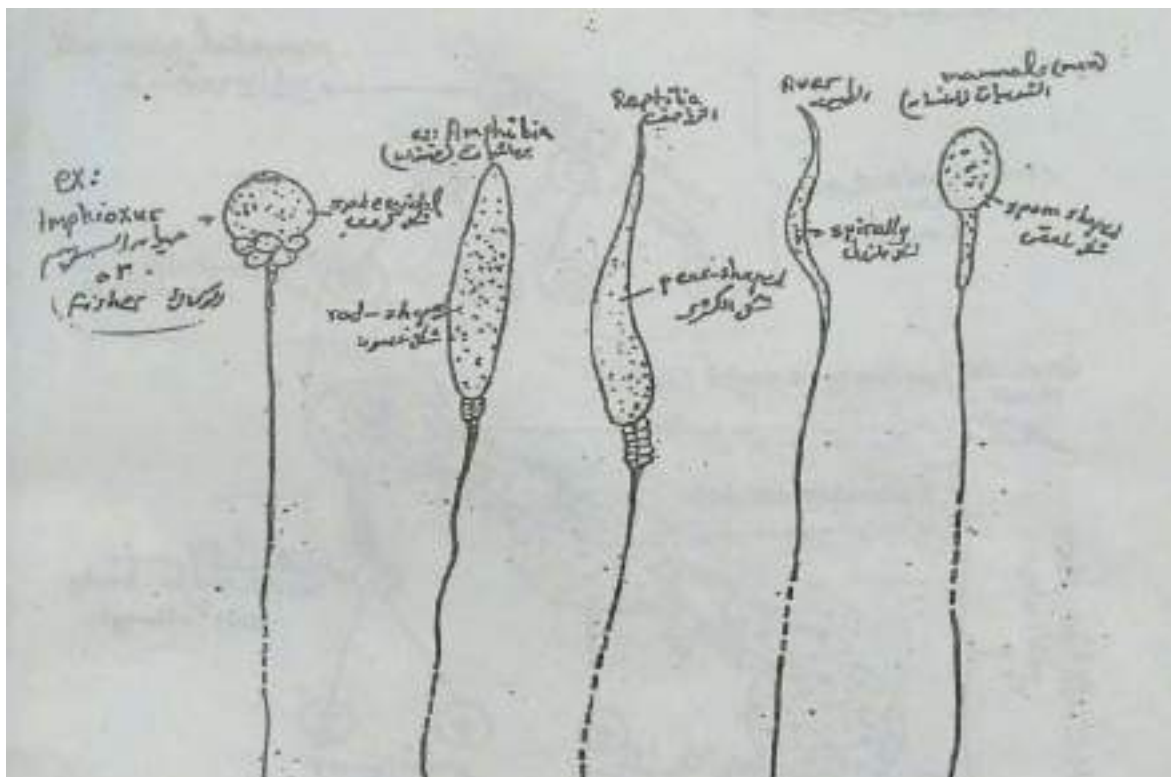
Each spermatocyte undergoes meiosis in two successive nuclear divisions, the first produces two equal secondary spermatocytes each is haploid in chromosomes (n), the second immediately follows and each spermatocyte divides into two equal and identical spermatids also haploid, thus each primary spermatocyte produces four spermatids.

- The spermatid undergoes certain morphological changes called metamorphosis to form the active motile spermatozoa.

- 1- Multiplication phase
- 2- Growth phase
- 3- Maturation phase



Types of sperms:



OÖGENESIS

- The formation of female gametes or ova in the ovaries.

- Involves three phases:-

a) Multiplication phases:

Repeated mitotic divisions in the primordial germ cells lining the ovary to produce large number of oogonia ($2n$), they accumulate in nests of cells lining the periphery of ovary.

b) Growth phase:

oogonia grow and become larger in size as it collects all the organic matter from surrounding medium, it becomes primary oocyte and still $2n$.

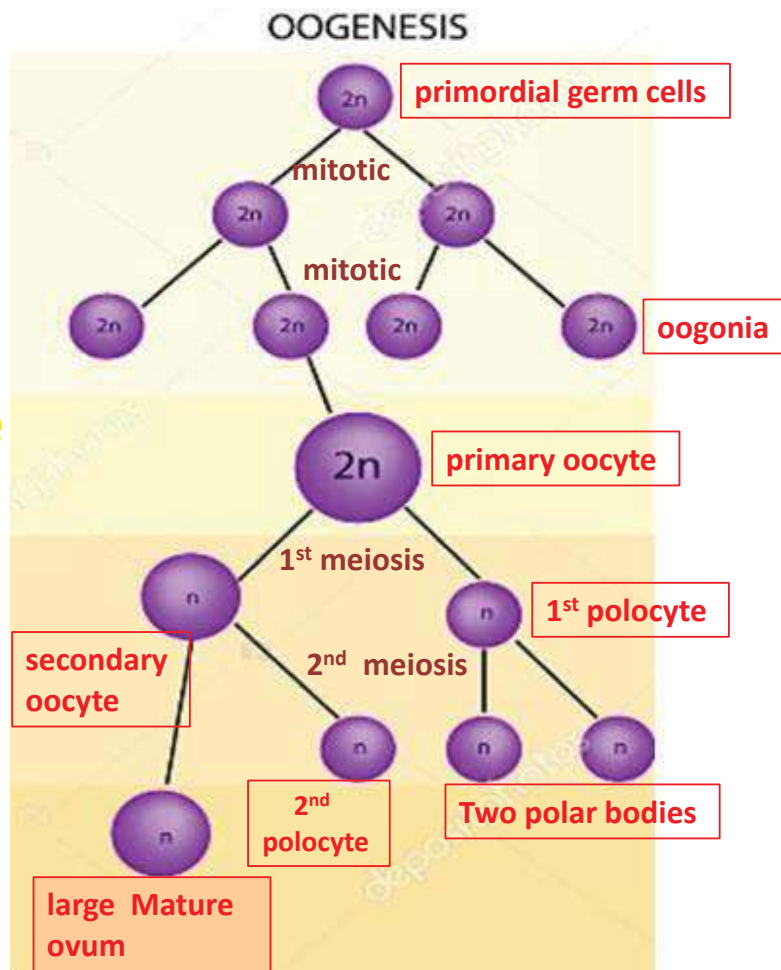
c) Maturation phase:

Each primary oocyte undergoes meiosis in two successive nuclear divisions, the first produces two unequal cells; a large secondary oocyte containing all the organic matter and a small first polocyte with a very thin layer of cytoplasm but each is haploid in chromosomes (n), the second meiosis splits the secondary oocyte into two unequal cells; the mature ovum and the second polocyte, also polocyte splits into two secondary polar bodies. each of the products are haploid, polocyte and polar bodies all disintegrate.

1-
Multiplication
phase

2- Growth phase

3-
Maturation
phase



Types of ova:

1- isolecithal:

- Small amount of yolk
- Homogeneously distributed in the cell
- In Amphioxus

2- mesolecithal:

- Moderate amount of yolk
- Concentrated in the lower part of the cell (animal pole)
- In Toad

3- centrolecithal:

- Moderate amount of yolk
- distributed around the nucleus in center of the cell
- In insects

4- telolecithal:

- Very large amount of yolk
- Occupies the whole free space of the cell so that it pushes the nucleus and cytoplasm upwards in so called germinal disk.
- In birds



FERTILIZATION

- The process in which two gametes egg and sperm unite to form the zygote.
- Types of fertilization:-

A) External fertilization:

-Both kinds of gametes are shed into the surrounding medium, sperms swim or are carried with water current to eggs, sperms and eggs are released with vast numbers to overcome the losses expected in water.

-Animals that perform external fertilization are:
most fishes, the bony fishes but not the cartilaginous fishes and many amphibians.

B) internal fertilization:

-the eggs remain in the females body until they are fertilized by sperms introduced into the females genital system by the male during copulation.

-Animals that perform internal fertilization are classified into three types:

1- OVIPAROUS :

These are egg laying animals which incubate the fertilized egg in the females body to complete development in a calcified shell in which the nourishment of embryo takes place through the yolk then it lays the egg from which the young eventually hatch.

Like all birds most insects and many aquatic invertebrates.

2- VIVIPAROUS:

Eggs are retained in females uterus and nourished by the blood stream of mother through placenta i.e. there is an organic connection between the embryo and mother.

Like mammals

3- OVIVIVIPAROUS:

Eggs are incubated and hatched in the mothers body , nourishment comes from the organic material stored in the eggs and there is no organic connection with mother and finally the youngs are released by female.

Like shark and lizard.

parthenogenesis

- A special type of reproduction in some animals which reproduce sexually and perform internal fertilization in which eggs are stimulated to develop without fertilization.
- Honey bee for example:
- The queen is fertilized once during lifetime , sperms are kept in germinal pouch, eggs are laid and sperms are released for fertilization, this will produce workers and queens.
- Males come from the growth of unfertilized eggs by the action of hormones and enzymes, eggs are haploid (16) chromosomes so males are haploid while females are diploid (32).

EMBRYONIC DEVELOPMENT

- Three main stages:
- A) cleavage: repeated mitotic divisions in the original zygote resulting in the formation of a large number of small cells known as blastomers.....(BLASTULA).
- B) gastrulation: subsequent stages in which the blastomers are arranged to form the ectoderm, mesoderm and endoderm.....(GASTRULA)
- C) organogenesis: the differentiation of different tissues and organs from the three main germ layers.....(EMBRYO)

The early development of amphioxus

The development of amphioxus represents the simplest type of chordate development.

Cleavage:

It is described as holoblastic cleavage or complete:

1-**The first cleavage**, appears as a superficial groove at the animal pole and gradually extends towards the vegetal pole. The nucleus is divided mitotically into two nuclei and then the cytoplasm divides into two halves, each half has one of the two nuclei, each half is called blastomere.

2- **The second cleavage**, is also vertical but it is at the right angles to the first division, resulting in 4 blastomeres which are all equal in size.

3-The third cleavage is horizontal the plane of division near to the animal pole and producing eight unequal blastomers, 4 micromeres towards the animal pole and 4 macromeres towards the vegetal pole.

4-The fourth cleavage, is vertical and consists mainly of two planes, divide the 8- blastotmeres into 16- blastomeres (8- micromeres 8-macromeres).

5-The fifth cleavage, is horizontal takes place by 2- plans to form 32 blastomeres : these blastomeres are arranged in eight vertical rows, each row is formed of 4 cells. The smallest of which lies near the animal pole. Then the size of the cells gradually increases towards the vegetative pole. This stage is called the morula stage.

Blastula:

A cavity is also appearing at the inside of the dividing mass. This is the beginning the blastocoel, it makes it first appearance at the 4-blastomeres stage- During the following divisions, this space increases in size as the resulting cells push themselves from the center of the mass towards outside.

After the sixth division, cleavage becomes irregular. The cells divide rapidly and arrange themselves in single epithelial layer which is composed of one cell thickness, this stage is spherical in shape and designated as the blastula stage. It is composed of single layered blastoderm and the cavity inside it ,is the blastocoel. The blastoderm is composed of micromeres near of animal pole and macromeres near the vegetative pole.

Gastrulation:

The formation of gastrula takes place as the following steps:

1-flattening of the macromeres.

2-small depression appears at the out flattened area.

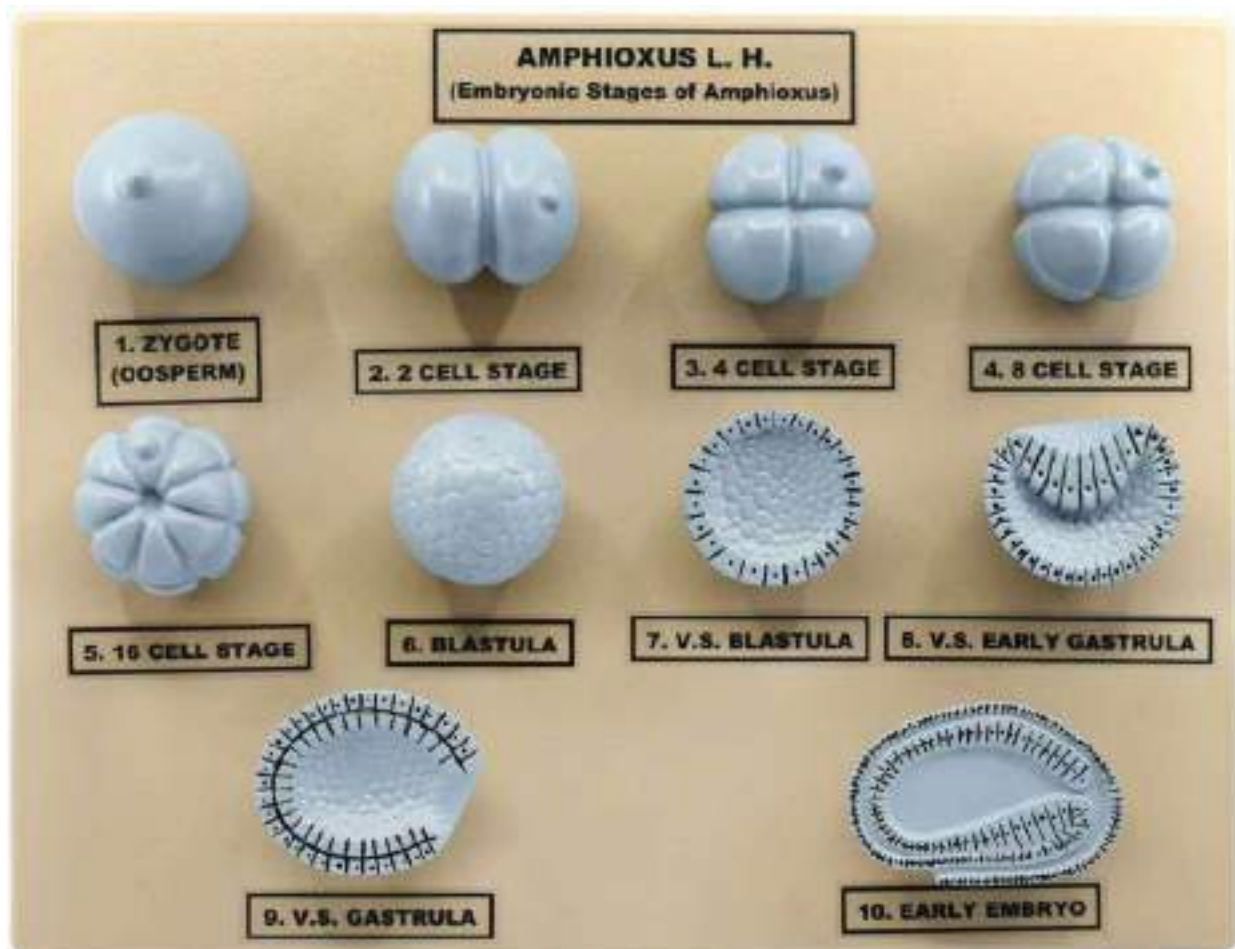
3-increasing of the depression resulting in the approach of the cells of the vegetal pole (macromeres) to the cells of animal pole (micromeres).

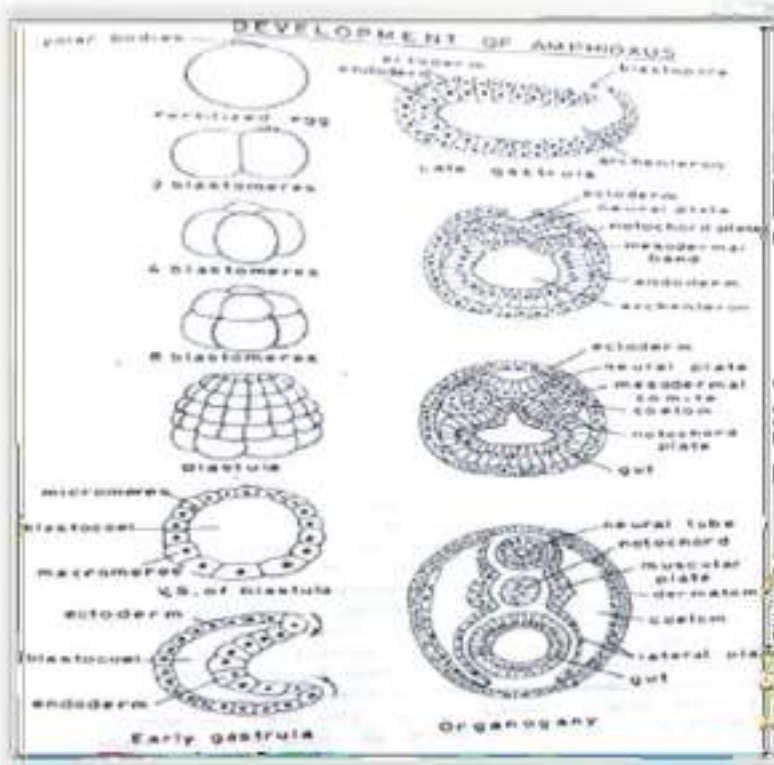
4- macromeres come in contact with the micromeres.

5-blastocoel disappears and a new cavity appears which is known as primitive gut or archenteron. This stage is known as gastrula which as a hemispherical structure with 2 layers, outer layer known as ectoderm (micromeres) and inner layer known as endoderm or mesoderm (macromeres).

It is composed of an upper lip and lower lip which enclose a blastopore between the two lips.

The cleavage continues in all parts of the gastrula but it is very rapid at the area of dorsal lip and decrease gradually as we go towards to the ventral lip. This leads to that gastrula becomes elongated in the anterior and posterior direction.





The early development of the frog

The egg of the frog is mesolecithal. It is covered by pigment which is either black or brown. Near the vegetative pole there is a small area which is free from pigment.

Cleavage

it is of holoblastic form.

1. **The first cleavage** as the same of amphioxus resulting 2 equal blastomeres.
2. **The second cleavage** like the first, is vertical and at right angle to the first, resulting 4 equal blastomeres.
3. **The third cleavage** is horizontal, parallel to the equator but nearer to the animal pole than to the vegetal pole, resulting 8 unequal blastomeres, 4 small micromeres and 4 large macromeres which near the animal and vegetal poles respectively.

4- The fourth cleavage is vertical in two planes each is oriented from the animal pole to vegetal pole, the two planes are oriented at right angles to each other and to the third cleavage plane. Thus producing 16 blastomeres, 8 micromeres and 8 macromeres.

5- The fifth cleavage takes place by two horizontal planes which are parallel to the third cleavage plane. Thus producing 32 blastomeres. The regularity of cleavage is lost after the fifth cleavage.

Blastula formation:

1- The beginning of blastocoel appears firstly in 8 blastomeres stage among the inner margins of the cells.

2- It is nearer to the animal pole and becomes gradually larger in size.

3- The 32 blastomeres stage is considered as an early blastula with large cavity and a single layer of cells.

4- The early blastula becomes late blastula with a several layered blastoderm this is achieved by a series of horizontal cleavages which are parallel to the surface of the cells.

5- The micromeres near to the animal pole are freely from yolk. The macromeres near to the vegetal pole are with great amount of yolk.

6- The animal pole cells (micromeres) move towards the equator, thus the roof of blastocoel becomes thin and its side. wall becomes thick

7- This thick layer which lies near the equator is composed of actively dividing cells and forms the germ ring, which has no sharp limit between it and the surrounding cells and it extends around the blastula.

Gastrulation:

gastrulation in the frog includes two different processors:

A. over growth (epipoly)

B. invagination

1-It begins with the appearance of a small groove in the posterior side of the blastula at the lower margin of the germ ring. The groove represents the beginning of the archenteron.

2-The upper margin is the dorsal lip of the blastopore. This lip extends right and left from place of its first appearance and moves as a down growth towards the vegetative pole

3-Finally the two lateral lips right and left meet each other on the ventral side to form the ventral lip of the blastopore.

4-Thus , the blastopore becomes a closed ring and the small pigmented cells cover the layer yolked cells of the vegetative pole, with the exception of small part of large cells which is known as the yolk plug. This process is known as over growth or epipoly.

5-The second process invagination, it takes place as an elevation of the floor of the blastocoel, which becomes reduced into a narrow slit which separate ectoderm from the endoderm.

6-The beginning of archenteron goes deeper inside the embryo and gradually becomes larger in size.

7-At later stage of the development, the slit which represents the reduced blastocoel disappears.

8-The yolk plug disappears, when the diameter of the blastopore decreases in size gradually.

-Finally, change of the single layered blastula into a double layered gastrula in which the outer layer is the ectoderm, and the inner layer is the endoderm. The archenteron is hemispherical cavity having a comparatively thin roof and a very thick floor composed of large cells heavily charged of yolk.

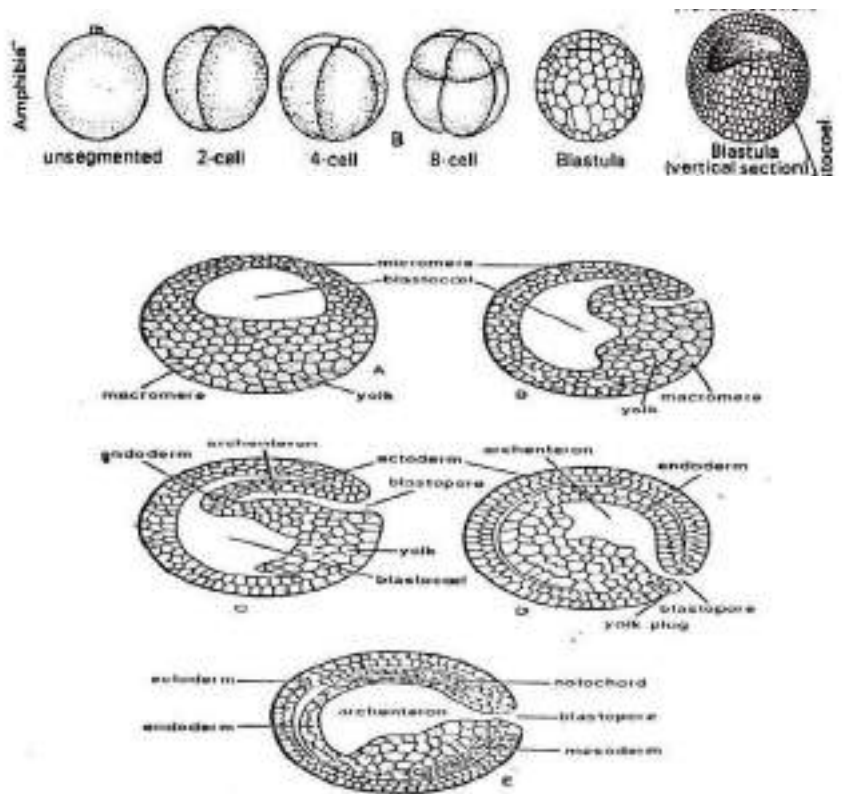
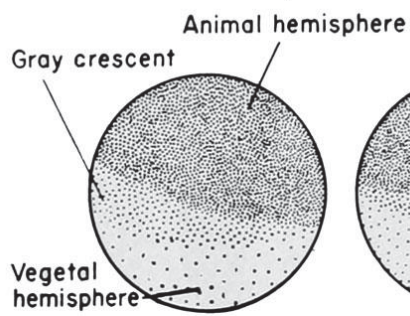
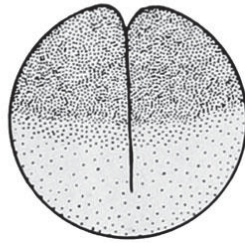


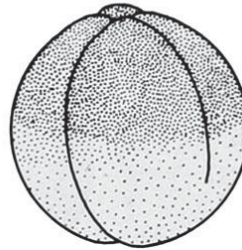
Fig. 40.7. Rana sp. Formation of germinal layers (Sagittal view).
 A. Blastula. B. Beginning of gastrulation. C-D. Gastrulation and formation of archenteron.
 E. Formation of mesoderm and notochord.



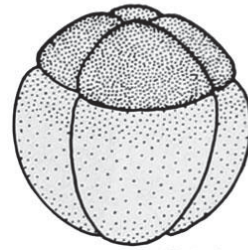
Stage 2. 1 hr. post-fertilization. Right side view.



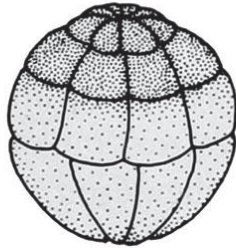
Stage 3. First cleavage at 3.5 hrs. Posterior view.



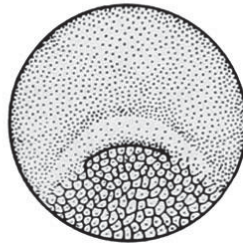
Stage 4. Second cleavage at 4.5 hrs. Right side view.



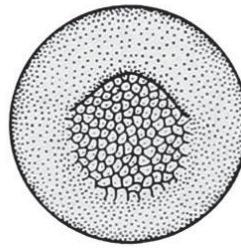
Stage 5. Third cleavage at 5.4 hrs. 8 cells.



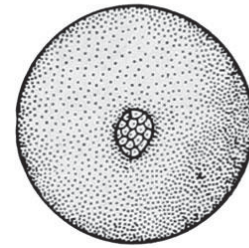
Stage 7. Fifth cleavage. 32 cells at 7 hrs.



Stage 10. Earliest involution of dorsal lip at 26 hrs. Posterior view.



Stage 11. Extension of dorsal to lateral lips at 34 hrs. Posterior view.



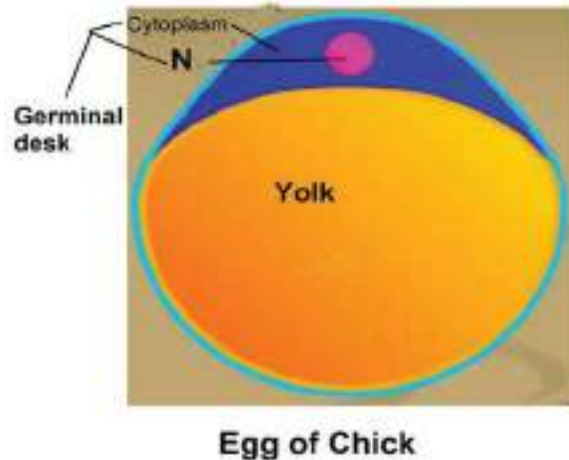
Stage 12. Complete lip involution, encircling yolk at 42 hrs.

THE EARLY DEVELOPMENT OF CHICK

Type of fertilization: internal

Type of egg: telolecithal

Type of cleavage: meroblastic discoidal



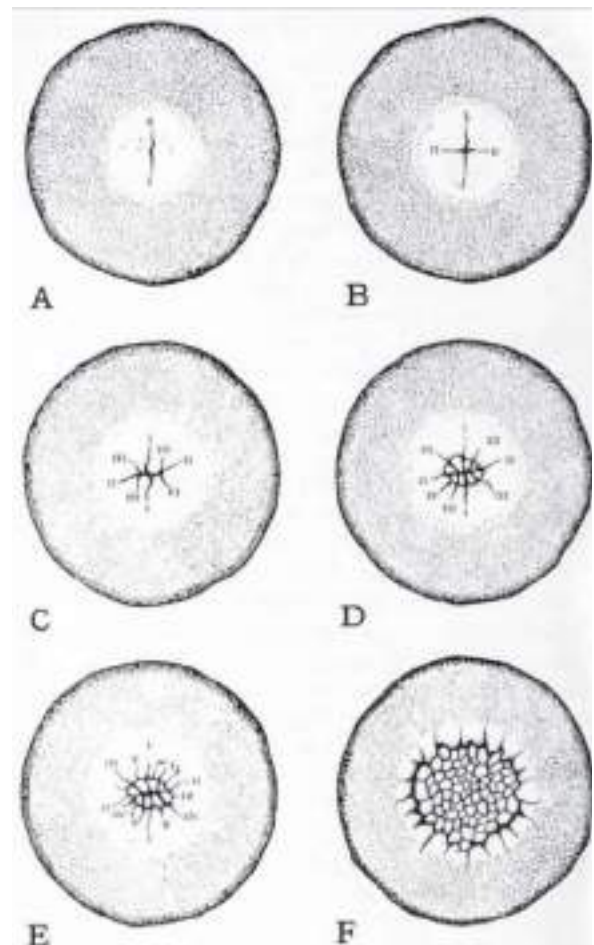
Cleavage:

1-the first: vertical groove at the middle of germinal disk gives two incomplete blastomeres.

2-the second: horizontal at right angle to the first gives four incomplete blastomeres.

3-the third: two vertical fissures parallel to the first gives 8 blastomeres.

4- the fourth: each blastomere divides into a small central and a large peripheral cell, this cleavage gives 16 blastomeres, then the regularity is lost, cells divide, increase in number forming a single-layered blastoderm which becomes multi-layered as a result of a series of divisions, yolk is still adhering to blastoderm.



Blastula formation:

Subgerminal cavity is formed when the central portion of the blastoderm detaches itself from the underlying yolk, here the blastula is formed.

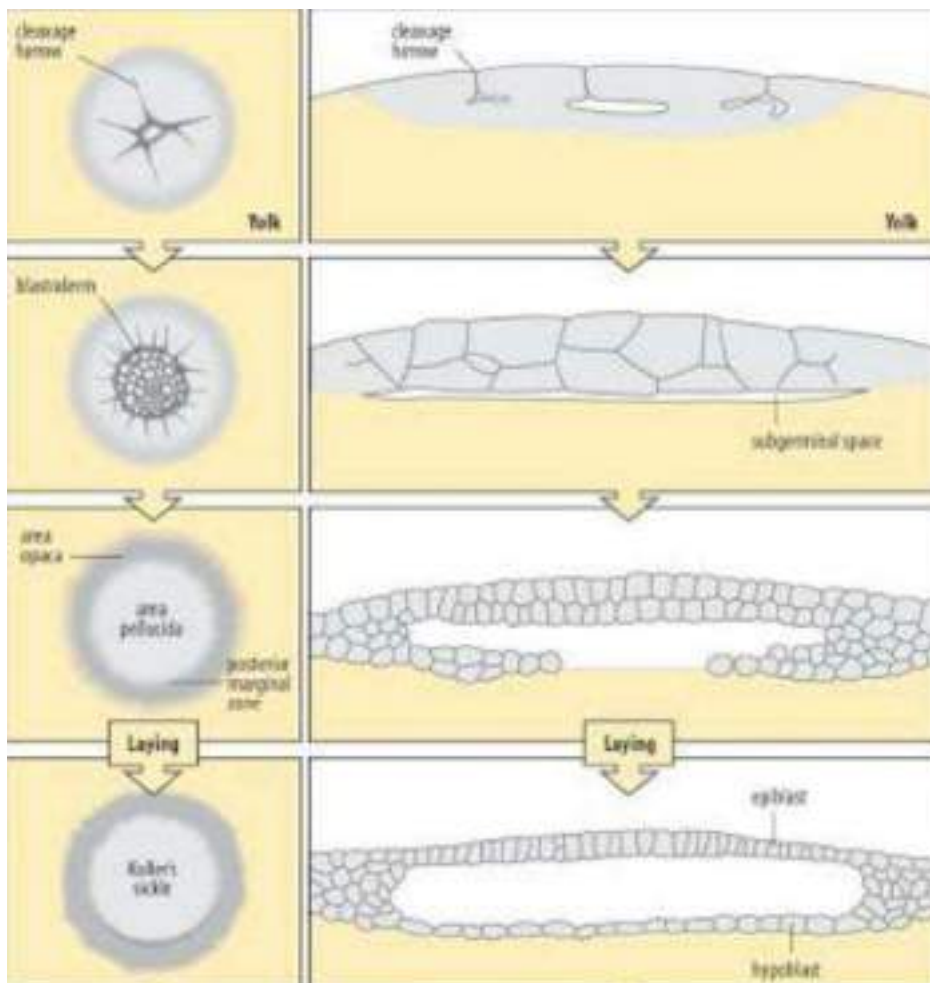
- **Description of blastula:**

Two zones , the first is the peripheral zone (area opaca) the outer zone of blastoderm which is still adhering to yolk, the second is the central (area pellucida) the inner zone which was detached from yolk.

Gastrulation: includes two phases, Early gastrulation and gastrulation proper

1) Early gastrulation:

In this stage the blastoderm is differentiated into two separate layers to form the gastrula.



Blastula

**gastrula
formation**

gastrula

- **Description of gastrula:**

An upper epiblast which will give ectoderm and mesoderm later, a lower hypoblast which will give endoderm later and a central cavity between the two layers which is the blastocoel, the old space between the hypoblast and the yolk is archentron.

- **Theories of gastrula formation:**

Three theories :

a)involution: the posterior portion of the blastoderm is involutes downwards and then extends forward forming the hypoblast.

b)delamination: cellular complex splits forming two separate layers, the epiblast and hypoblast .

c)infiltration: individual cells separate and migrate down to the surface of yolk, then they mix together forming hypoblast.

2) Gastrulation proper:

The cells of the anterior and lateral regions of the embryo move medially and posteriorly resulting in the formation of a slightly thickened band of cells in the area pelucida , these cells are called PREMITIVE STREEEK that gives rise to the mesoderm and ectoderm, while the hypoblast forms the endoderm.



Zagazig University
Faculty of Science
Department of Zoology



Principles of Systematic Zoology **(Acoelomates)**



Contents

	Page
1. INTRODUCTION TO SYSTEMATIC ZOOLOGY	
1.1. Importance of classification	1
1.2. What is Systematic?	1
1.3. Definition of terms	2
1.4. How did it start?	2
1.5. How many species are there?	2
1.6. History and different kinds of Systematics	3
1.6.1. Aristotle (384 – 322 BC.)	3
1.6.2. Ibn Rushd	3
1.6.3. Concepts of species	3
1.6.4. Linnaeus (1770 – 1778)	4
1.6.5. Kingdom system.....	6
1.6.6. Cladistic classification	8
1.6.7. Cytotaxonomy	8
1.6.8. Molecular taxonomy	9
I. KINGDOM: PROTISTA	
2. SUBKINGDOM: PROTOZOA	12
General characters of Protozoa	12
Classification of Protozoa	13
2.1. PHYLUM: SARCOMASTIGOPHORA	13
General characters	13
2.1.1. Subphylum: Mastigophora (Flagellates)	13
General characters	13
2.1.1.1. Class: <i>Phytomastigophora</i>	14
e. g. <i>Euglena</i>	14
2.1.1.2. Class:- <i>Zoomostigophora</i>	17
e.g. ₁ <i>Trypanosoma</i>	17
e.g. ₂ <i>Leishmania donovani</i>	19
2.1.2. Subphylum: Sarcodina	21
General characters	21
e.g. ₁ <i>Amoeba</i>	21
e.g. ₂ <i>Entamoeba histolytica</i>	25
e.g. ₃ <i>Entamoeba coli</i>	27
16e.g. ₄ <i>Elephidium</i> (The Foraminefera)	28
2.2. PHYLUM: CILIOPHRA	24
General characters	29
e.g. <i>Paramecium</i>	29
2.3. PHYLUM: EPICOMPLEXA (SPOROZOA)	29
General characters	34
e.g. ₂ <i>Plasmodium</i>	35
ECONOMIC IMPORTANCE OF PROTOZOA	38
II. KINGDOM: ANIMALIA	
3. Basics of Animals Classifications	
3.1. General characters of animals	41
3.2. Basics of Classification of Animal Kingdom	42

A. SUBKINGDOM: PARAZOA	
4. Phylum: Porifera (Sponges)	
4.1. General characters of Porifera	46
4.2. Morphology	46
4.3. The complexity of organisation	46
4.4. Body wall	47
4.5. Skeleton	49
4.6. Water current	49
4.7. Nutrition and respiration	49
4.8. Reproduction	50
4.10. Some economic importance of sponges	51
B. SUBKINGDOM: EUMETAZOA	
I. GRADE: RADIATA	
5- Phylum : Cnidaria	
5.1. General characters of Cnidaria	53
5.2. Classification of Cnidaria	54
5.2.1. CLASS: HYDROZOA	54
General characters	54
e.g. ₁ <i>Hydra</i>	55
e.g. ₂ <i>Obelia</i>	61
5.3. Economic importance of Cnidaria	64
II- GRADE: BILATERIA	
i. Subgrade: Acoelomata	
7. PHYLUM: PLATYHELMINTHES (FLATEWORMS)	
GRADE: BILATERIA	66
I . Subgrade: Acoelomata	67
6.PHYLUM: PLATYHELMINTHES	67
6.1. General characters	67
6.2. Classification of Platyhemlminthes	67
6.2.1. CLASS: TURBELLARIA	68
e.g. <i>Planaria</i>	68
6.2.2. CLASS: TREMATODA	69
Classification of Trematoda	69
Order Digenea	70
e.g. ₁ <i>Faciola</i> (liver fluck)	70
e.g. ₂ <i>Schistosoma</i> (Blood fluck)	76
6.2.3. CLASS CESTODA (TAPEWORMS)	82
Characters	82
e.g. <i>Taenia</i>	82
ii- Subgrade: Pseudocoelomata	
ii.Subgrade: Pseudocoelomata	90
9- PHYLUM : NEMATA (NEMATODA or ROUND WORMS)	
9.1. General characters	91
9.2. Classification of Nematoda	91
e.g. ₁ <i>Ascaris lumbricoides</i> (Intestinal fluck)	91
e.g. ₂ <i>Ancylostoma duodenale</i> (Hookworm)	97
SELECTED REFERENCES	
DICTIONARY	
	101

Preface

Systematic Zoology nowadays is an exciting field in which rapid advances are being made both in theory and practice. It employs techniques in chemical, physical and mathematical sciences and takes regard of theoretical classification studies. It is of an immense importance to biologists working in other fields, as it is now recognized that precise identification is a vital aspect of any research work. Thus, it is not surprising that Systematic Zoology is one of the main core courses of Biology Programs in most universities.

For a long time in the Arab countries, an urgent need has been keenly felt for indigenous text books, which cover universities' syllabi in an adequate fashion. This fact has urged the author to compile this standard text book of "Principles of Systematic Zoology". In the preparation of this book, topics were selected with great care and summarized to present a clear conception of the subject avoiding unnecessary details. In addition to the simple English used in this book, each chapter was provided with an endnote of English-Arabic glossary for some difficult terms and words which would be useful to strengthen the students' scientific English vocabulary, particularly those who study in Arabic. All of these will hopefully met with the requirements of students in Arab countries.

This book is intended to introduce students to the diversity and classification of the animal kingdom. To fulfill this, the book was designed to focus on three issues: firstly, obtain knowledge about the history, general principles and objectives of Systematic Zoology (importance of systematics, definition of terms, theories of biological classifications and their history – types and concepts of classification ..etc). Secondly, characteristics (general structural patterns) and brief overview on classification of different animal phyla. Finally, explain and provide examples of how animals adapt to specific environmental conditions (connecting structure and function). The book explains the ecological importance of animals in their environments as well as their importance from an applied perspective. It also encompasses the study of general characters, classification and some representatives of both animal-like protists, and lower invertebrate phyla (Porifera, Cnidaria, Ctenophore, Platyhelminthes, Rotifera and Nematoda). The classification system adopted in this book is a synthesis from several authorized, recently published systems.

The book also contains a number of descriptive illustrations, photos, comparison tables for the different classes of each phyla, as well as concise information boxes containing amazing stories about some amazing animals; such as biochemical memory, hirudotherapy ..etc.

Needless to say that, all suggestions and criticisms for the improvement of this book will be gratefully accepted from the readers, instructors as well as students.

Prof. Mahmoud Desouky
2013

1. Introduction to Systematic Zoology

The will of Almighty God was to create the earth and the vast numbers of creatures on it in a highly diverse¹ form. Almighty God said:

"أَلَمْ تَرَ أَنَّ اللَّهَ أَنْزَلَ مِنَ السَّمَاءِ مَاءً فَأَخْرَجْنَا بِهِ ثَمَرَاتٍ مُخْتَلِفًا أَلْوَانُهَا وَمِنَ الْجِبَالِ جُدَدٌ بَيَضٌ وَحُمْرٌ مُخْتَلِفٌ أَلْوَانُهَا وَغَرَابِيبُ سُودٌ {٢٧}

وَمِنَ النَّاسِ وَالْدَّوَابِّ وَالْأَنْعَامِ مُخْتَلِفٌ أَلْوَانُهُ كَذَلِكَ إِنَّمَا يَخْشَى اللَّهَ مِنْ عِبَادِهِ الْعُلَمَاءُ إِنَّ اللَّهَ عَزِيزٌ غَفُورٌ". "سورة فاطر"

"Seest thou not that Allah sends down rain from the sky? With it We then bring out produce of various colours. And in the mountains are tracts white and red, of various shades of colour, and black intense in hue. And so amongst men and crawling creatures and cattle, are they of various colours. Those truly fear Allah, among His Servants, who have knowledge: for Allah is Exalted in Might, Oft-Forgiving."

Every organism, whether plant or animal, is unique² in itself and this uniqueness is the basis of the vast diversity displayed by the organisms in our world. There is a wide diversity in the flora (plants) and fauna (animals) in the world. With such a vast number of organisms, it becomes impossible to study every one of them at individual level. This task³ of studying the diversity of living organisms can be made easier and more effective if the various organisms are arranged⁴ into groups based on their similarities and differences. The branch of science that is involved with the purpose of arranging or grouping animals is called "Systematic Zoology" or "Animal Taxonomy".

1.1. IMPORTANCE OF CLASSIFICATION

1. It makes the study of such a wide variety of organisms easy.
2. It helps us to understand the interrelationship among different organisms.
3. Various fields of applied⁵ biology such as agriculture, public health and environmental biology depend on classification of pests⁶, disease vectors⁷, pathogens⁸ and components of an ecosystem⁹.
4. It serves as a base¹⁰ for the development¹¹ of other biological sciences such as biogeography.. etc.

1.2. WHAT IS SYSTEMATIC?

Systematic is *"the science of how organisms are related and the evidence¹² for those relationships"*. Systematics is the most elementary¹³ and most inclusive¹⁴ part of biology, most elementary because organisms cannot be discussed or treated in a scientific way until some taxonomy has been achieved, and most inclusive because systematics in its various branches gathers, utilizes, and

summarizes everything that is known about organisms, whether morphological¹⁵, physiological, or ecological¹⁶.

Systematic is divided primarily into phylogenetics¹⁷ and taxonomy¹⁸. Systematics examines the natural variation and relationships of organisms, (the field of taxonomy). It also deals with the relationships of different groups of organisms, in order to construct natural classification systems reflecting evolutionary relationships (the field of Phylogenetics). However, Many biologists use the terms taxonomy and systematic interchangeably.

1.3. DEFINITION OF TERMS

It is necessary at the outset¹⁹ to define basic terms used in taxonomic studies i.e. *systematic, taxonomy and classification*.

Systematics: According to Blackwedler and Boyden (1952) and Simpson (1961) *“Systematics is the scientific study of the kinds and diversity of organisms and any and all relationships among them according to element/system or part/whole relationships”*. The term was used by Linnaeus

Classification *“It is the ordering of animals into groups or sets on the basis of their relationships”*

Taxonomy: The term taxonomy was coined by De Candolle (1813). It is derived from the Greek words (“taxis” = arrangement and “nomous” = law) *“It is the theoretical study of classification including its bases, principles, procedures and rules”*.

1.4. HOW DID SYSTEMATIC START?

Man noticed the diversity of plants and animals, so he wanted to organize their world, so he began grouping, or classifying everything he saw.

1.5. HOW MANY SPECIES ARE THERE?

This is not an easy question to answer. About 1.8 million animal species have been given scientific names. Nearly 2/3 of these are insects. Estimates²⁰ of the total number of living species generally range from 10 to 100 million. It is likely the actual number is on the order of 13 to 14 million, with most being insects and microscopic life forms in tropical regions²¹. However, we may never know how many species are there because many of them will become extinct²² before being counted and described.

1.6. History and Different Kinds of Systematics

1.6.1. ARISTOTLE (384 – 322 BC.).

Aristotle was the first to attempt to classify all the kinds of animals in his book “**History of Animals**” (*Historia Animalium*). He grouped the types of animals according to:

- **The presence or absence of red blood:** Animals may be *Enaima* (with red blood) or *Anaima* (without red blood).
- **The type of environment:** Animals may be: *Terrestrial* (live on land), *Aquatic*: (live in water) or *Aerial* (live in air).
- **The mode of nutrition**²³: Animals may be *Herbivorous* (feed on plants as rabbit), *Carnivorous* (feed on animals as lion) or *Omnivorous* (mixed food as bear²⁴).

Aristotle's assumed²⁵ that creatures could be grouped in order from lowest to highest, with the human species being the highest.

1.6.2. IBN RUSHD .

In 1172, Ibn Rushd (Averroes) translated and abridged²⁶ Aristotle's book "de Anima" (Animals). This book was translated into Latin by Mitchell Scot.

1.6.3. CONCEPTS OF SPECIES.

John Ray (1672 – 1705) was the first to define²⁷ the “**Species**” the basic unit of classification. According to Ray **Species**: is a group of living organisms which are:

1. Morphologically similar
2. Interbreed²⁸ with each other to produce fertile²⁹ individual.
3. If they interbreed with other species they produce sterile³⁰ individuals. Example :Mule³¹ (produced from interbreeding of horse and donkey, Fig., 1-2).



Fig. (1-2): Mule is the infertile offspring of a horse and a donkey-an example of the gray area regarding interbreeding in the most common definition of a species.

However, More than twenty species concepts were proposed to explain the term ‘species’. The most common of them are:



Fig. (1-1): Aristotle

A. Agamospecies or Microspecies

A species of organism in which sexual reproduction does not occur, so that each generation is genetically identical to the previous ³² generation. Examples include many bacteria and some plants and fungi. The absence of sexual reproduction means that the biological species concept cannot be applied, and instead taxonomists must rely on identifying certain diagnostic traits to distinguish between closely related asexual lineages. Consequently, the boundaries of agamospecies are often hard to define.

- *Advantages*: Clear criteria and useful for microorganisms (hence the name) and some plants.
- *Disadvantages*: Some organisms may reproduce asexually, but have high mutation rates and are thus not identical copies.

B. Biological species concept (BSC) or Gamospecies.

Ernst Mayr invented the biological species concept in 1942. According to this concept, a species is defined as “a group of populations whose members have the potential to interbreed in nature and produce viable³³, fertile offspring but do not produce viable fertile offspring with members of other groups. However, the number of species to which this concept can be usefully applied is limited, since there is no way to evaluate the reproductive isolation of fossils. Furthermore, it does not apply to organisms that reproduce asexually all or most of the time.

C. Genetic species concept

This concept is based on similarity of DNA of individuals or populations. Techniques to compare similarity of DNA include DNA-DNA hybridization, and genetic fingerprinting (or DNA barcoding).

- *Advantages*: Can provide independent evidence³⁴ for morphological and biological species. For bacteria and small organisms genetic species concepts can be very useful and save a lot of time. With automated sequencing and web databases it is now very quick to analyse DNA.
- *Disadvantages*: Situations can arise where DNA samples get contaminated³⁵ with the DNA of parasites living on or in an organism. Communicating with non-specialists about DNA taxonomy can also be very difficult.

1.6.4. LINNAEUS (1770 – 1778)

By the time Carl (Carolus) Linnaeus (1707-1778) was born, there were many systems of classification in use. This, in fact, was the problem, there were too many

inconsistent³⁶ systems, and the same organism might have several different scientific names, according to different methods of classification. Linnaeus great work, the “*Systema Naturae*”, ran through twelve editions during his lifetime (1st ed., 1735). He is best known for his introduction of the methods of modern classification; he created systematic zoology and botany in their present form. If Linnaeus is now considered the father of taxonomy, his success rested on the work of his predecessors³⁷. However, he was the first, in his *System of Nature*, to combine a hierarchical³⁸ system of classification from kingdom to species with the method of binomial nomenclature, using it consistently to identify every species of both plants and animals then known to him.

A. Nomenclature of organisms

While classifying any animal, its classification is required first. There are two types of names for any organisms:

- i. **Common name:** Organisms are known by different names in different countries and language of the world. This poses a great problem in the study of such organisms.
- ii. **Scientific names:** The easiest way to solve problems resulting from the variation of common names of the organisms is to use one scientific name for each organism. Linnaeus puts “**Binomial nomenclature**”³⁹ system, which still used until now (the binominal system was actually first used by Gaspard Bauhin, 1623 but never caught on). According to this system, each animal has two-word generic name:

- *Genus name*: beginning with a capital letter.
- *Species name*: beginning with a small letter.

Both names are always “Latin” and “underlined” or “italic”. For example, the scientific name of man is “*Homo sapiens*”.



Fig. (1-3): Carl Linnaeus

B- The seven level system (Table ,1-1 and Fig., 1-4):

Each kingdom is classified into ► Kingdom ► Phylum⁴⁰ ► Class⁴¹ ► Order⁴² ► Family ► Genus ► Species. This can be remembered from the below statement “**Kings Play Chess On Funny Green Squares**”.

Table (1-1): The seven level classification system.

Taxonomic level	Character(s)
Species	The basic smallest unit of classification
Genus	A group of species that are fairly closely related
Family	- Genera are grouped into families, which are major groups of generally similar organisms; such as Felidae, which includes all cat-like animals from domestic cat to tiger to cheetah to jaguar - Family names always end in the letters "ae",
Order	- Families are grouped into orders, whose individuals may vary in many ways; such as the order of Carnivora, which includes cats, dogs and weasels⁴³. - Orders begin with a capital and usually end in "a" - but not always
Class	The class is a major division within the animal Kingdom, For example, the phylum Mollusca contains 4 classes: the Gastropoda, Cephalopoda, Pelecypoda and Scaphopoda,
Phylum	Below kingdom is the Phylum level of classification. There are only about 30 phyla in the animal kingdom. At this level, animals are grouped together based on similarities in organization. .

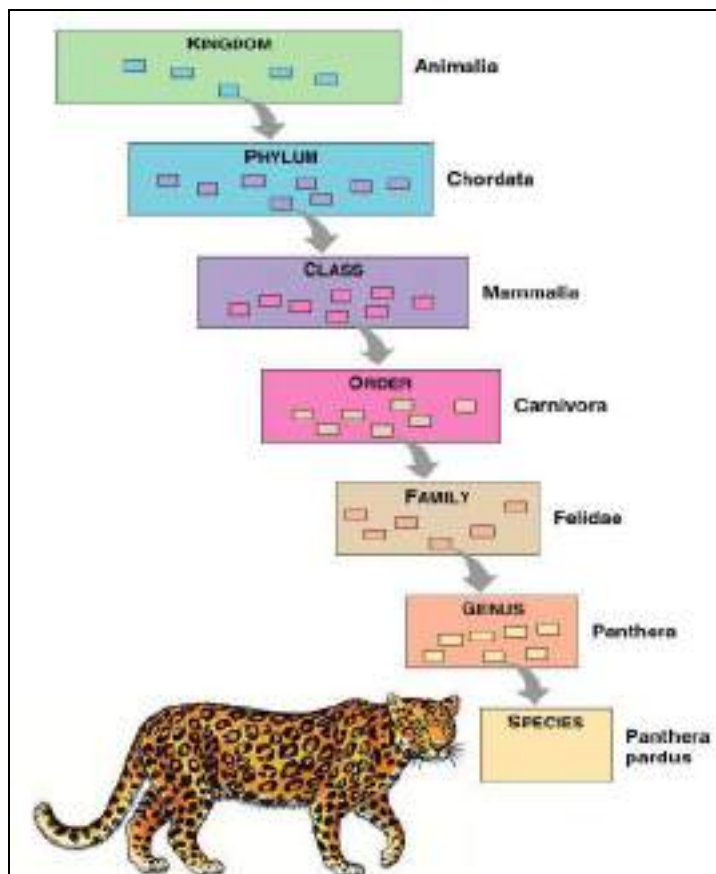


Fig. (1-4): The seven level classification system

1.6.5. KINGDOM SYSTEM (Table, 1-2)

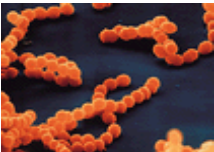
From well before Linnaeus, plants and animals was considered separate Kingdoms. Linnaeus used this as the top rank⁴⁴, dividing the physical world into

plant, animal and mineral kingdoms. With the discovery of the microscope in the 1600's many new organisms which have both animal and plant characteristics were discovered. This was the basis for the change in the classification system. The number of kingdoms increased, five and six-kingdom systems being the most common. The living organisms were classified into Kingdoms based on:

1. Presence or absence of a nuclear membrane.
2. Unicellularity or multicellularity.
3. Mode of nutrition.

Two kingdoms system As mentioned before Linnaeus classified living organisms into two kingdoms (Plantia and Animalia) according to the mode of nutrition.

Table (1-3): Five and six kingdom system

KINGDOM		No OF SPECIES	CHARACTERS	
Archaeobacteria	Monera	100,000	➤ Most primitive⁴⁵ and often live in extreme environments. ➤ Unicellular and no nucleus (PROKARYOTIC).	
Eubacteria			➤ No organized nucleus or nuclear membrane (PROKARYOTIC). ➤ Include bacteria and blue green algae.	
Protista		250,000	➤ Unicellular organisms (EUOKARYOTIC) with plant or animal-like characteristics. ➤ Include protozoa and all algae except the blue-green .	
Fungi		100,000	➤ Cells are usually organized into branched, multinucleate filaments⁴⁶ which absorb digested food from the external environment. ➤ Include yeasts, molds, and mushrooms.	
Plantae		250,000	➤ Multicellular - possess chloroplasts and cell walls. ➤ Make their own food – PHOTOSYNTHESIS.	
Animalia		1,500,000	➤ Multicellular organisms (Eukaryotes). ➤ Ingest their food – HETEROTROPHS.	

Six kingdom system (Table, 1-3) From around the mid-1970s onwards, there was an increasing emphasis⁴⁷ on molecular level⁴⁸ comparisons of genes (initially

ribosomal RNA genes) as the primary factor in classification. Based on such rRNA gene studies, **Carl Woese** divided the prokaryotes (Kingdom: Monera) into two groups, called **Eubacteria** and **Archaeobacteria**, stressing that there was as much genetic difference between these two groups as between either of them and all eukaryotes.

Woese attempted to establish⁴⁹ a "three primary kingdom" or system. In 1990, the name "**domain**" was proposed for the highest rank. The six-kingdom system shown in table (1-3) represents a blending⁵⁰ of the classic five-kingdom system and Woese's three-domain system. Such six-kingdom systems have become standard⁵¹ in many works.

1.6.6. CLADISTIC CLASSIFICATION

Cladistic classification system groups all organisms into three apparently monophyletic kingdoms, the *Eukaryota*, *Eubacteria*, and *Archaeobacteria* (alternatively called **Eukarya**, **Bacteria**, and **Archaea**). The kingdom Eukaryota includes eukaryotic organisms, and all organisms in the Plantae, Animalia, Fungi, and kingdom Protista. The kingdoms Eubacteria and Archaeobacteria both consist of single-celled prokaryotes, all of which Whittaker placed into the Monera kingdom. The Archaeobacteria (ancient bacteria) were originally considered more primitive than the Eubacteria. The Archaeobacteria includes the methanogens (methane-producing bacteria), halophiles (salt-loving bacteria), and thermophiles (heat-loving bacteria), all rather unusual prokaryotes which live in very extreme habitats.

Cladistics can be distinguished from other taxonomic systems, such as phenetics, by its focus on shared derived characters (synapomorphies). Previous systems usually employed overall morphological similarity to group species into genera, families and other higher level classification; cladistic classifications (usually trees called cladograms) are intended to reflect the relative recency of common ancestry or the sharing of homologous features.

1.6.7. CYTOTAXONOMY

Cytotaxonomy is dealing with the relationships and classification of organisms using comparative studies of chromosomes. The number, structure, and behaviour of chromosomes is of great value in taxonomy, with chromosome number being the most widely used character.

- **Chromosome number:** Chromosome numbers are usually determined at mitosis and quoted as the diploid number (2n). Chromosome numbers vary in animals from a diploid number of two in *Parascaris* to one of 446 in a North

African butterfly⁵² (*Lysandra atlantica*). In the majority of animals however, the number varies from 12 to 60.

- **Chromosome structure:** Another useful taxonomic character is the chromosomal structure especially in genera where species are found to have the same number of chromosomes. For example, there are four types of chromosomes according to the position of the centromere (the point of attachment of the chromosome to the spindle): telocentric, acrocentric, submetacentric and metacentric (Fig., 1-5).

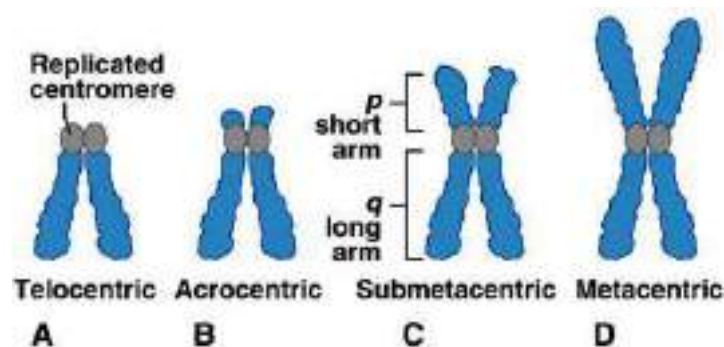


Fig (1-5): Types of chromosomes according to the position of centromere.

Karyotype: A karyotype is the number and appearance of chromosomes in the nucleus of a eukaryotic cell. The term is also used for the complete set of chromosomes in a species, or an individual organism. Karyotypes describe the number of chromosomes, and what they look like under a light microscope. Attention is paid to their length, the position of the centromeres, banding pattern, any differences between the sex chromosomes, and any other physical characteristics.

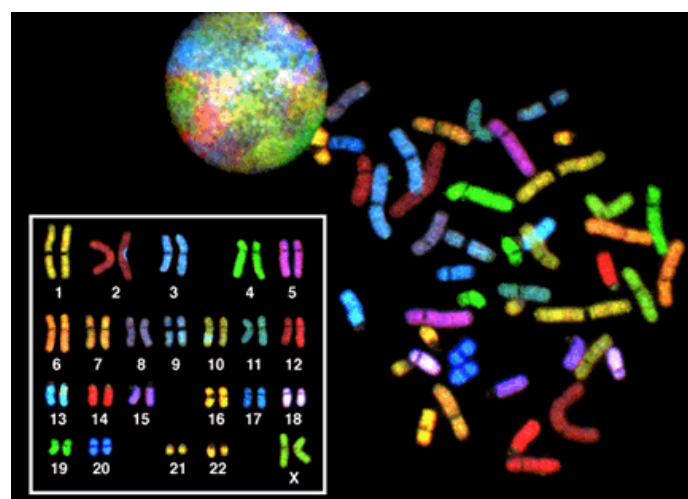


Fig. (1-6): Karyogram of Human male

1.6.8. MOLECULAR TAXONOMY⁵³

Every living organism contains DNA, RNA, and proteins. In general, closely related organisms have a high degree of agreement in the molecular structure of

these substances, while the molecules of organisms distantly related usually show a pattern of dissimilarity. Conserved sequences, such as mitochondrial DNA, are expected to accumulate mutations over time, and assuming a constant rate of mutation provide a molecular clock for dating divergence. Molecular phylogeny uses such data to build a "relationship tree" that shows the probable evolution of various organisms. Not until recent decades, however, has it been possible to isolate and identify these molecular structures (Fig., 1-14).

The most common approach is the comparison of homologous sequences for genes using sequence alignment techniques to identify similarity.

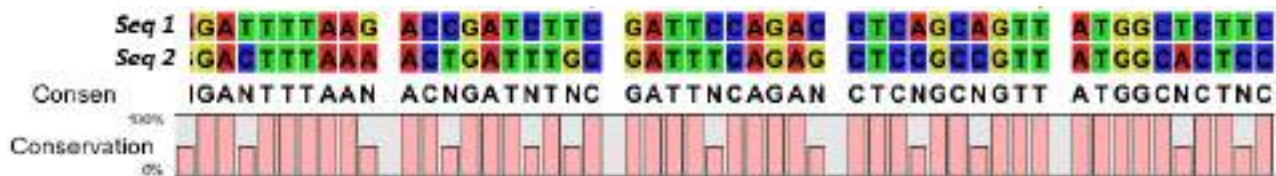


Fig. (1-14): DNA alignment

Another application of molecular phylogeny is in DNA barcoding, wherein the species of an individual organism is identified using small sections of mitochondrial DNA or chloroplast DNA. Another application of the techniques that make this possible can be seen in the very limited field of human genetics, such as the popular use of genetic testing to determine a child's paternity, as well as the emergence of a new branch of criminal forensics⁵⁴ focused on evidence known as genetic fingerprinting.

2

KINGDOM: PROTISTA

Subkingdom: Protozoa

I. KINGDOM: PROTISTA

Protista are predominately⁵⁵ unicellular organisms with plant or animal-like characteristics. Examples include protozoa and all algae except the blue-green algae. They have a true nucleus and nuclear membrane (eukaryotes). Protista is classified into two subkingdoms: **Protozoa** (Animal-like) and **Algae** (Plant-like). In animal taxonomy, we are concerned with Protozoa.

2. SUBKINGDOM: PROTOZOA

Approximately 65,000 protozoan species have been described⁵⁶. Protozoa are unicellular and small in size. Unicellularity restricts⁵⁷ the size of the organism. i.e. volume increases slower than surface area. *Why is this important?*

Answer: Life at small scale requires large surface area to size ratio and thus:

- Diffusion⁵⁸ of gases occurs across membranes.
- Food vacuoles⁵⁹ for feeding.
- Contractile vacuoles⁶⁰ for osmotic regulation⁶¹.
- Encystment⁶² for protection from environmental extremes.

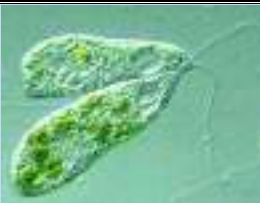
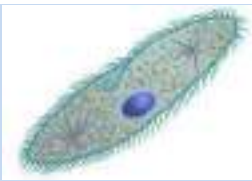
GENERAL CHARACTERS OF PROTOZOA

- 1- They are small microscopic organisms. They are the simplest and most primitive⁶³ animals.
- 2- They are unicellular i.e. single – celled animals that perform⁶⁴ all the vital activities characterising the animal body.
- 3- Many species live solitary⁶⁵ while few live in colonies⁶⁶.
- 4- Locomotary organelles⁶⁷ are present. They are in the form of pseudopodia⁶⁸, flagella⁶⁹ or cilia⁷⁰.
- 5- Nutrition may be Holozoic (animal-like), Holophytic (plant-like), Saprozoic (by diffusion) or Parasitic⁷¹.
- 6- There are no organelles for respiration or excretion which occur by simple diffusion through the general body surface.
- 7- Freshwater forms have an osmoregulatory system in the form of contractile vacuole.
- 8- All protozoa can reproduce asexually by binary fission⁷² or by multiple fission⁷³. In addition, some protozoa can reproduce sexually by forming male and female gametes as in conjugation.
- 9- Encystment commonly occurs to help in dispersion⁷⁴ and to resist unfavourable conditions.

CLASSIFICATION OF PROTZOA

Subkingdom Protozoa is divided into three Phyla according to their locomotory organelles (Table, 2-1).

Table (2-1): Classification of Protozoa

Phylum		Locomotory organoids	Examples	
1. Phylum: Sarcomastigophora	A. Subphylum <i>Mastigophora</i> (Flagellates)	Move by one or more flagella	- <i>Euglena</i> - <i>Trypanosoma</i>	
	B. Subphylum <i>Sarcodina</i> (Rhizopoda)	Move by pseudopodia	- <i>Amoeba</i> - <i>Entamoeba</i>	
2. Phylum: Ciliophora		Move by cilia	- <i>Paramecium</i>	
3. Phylum: Apicomplexa (Sporozoa)		Without locomotory organelles	- <i>Monocyst.</i> - <i>Plasmodium</i>	

2.1. PHYLUM: SARCOMASTIGOPHORA

They are the largest protozoan phylum comprising⁷⁵ about 18,000 species.

GENERAL CHARACTERS

1. Unicellular solitary or colonial.
2. Locomotion by flagella, pseudopodia, or both.
3. Autotrophic, saprozoic, or heterotrophic nutrition.
4. Single nucleus.
5. Asexual reproduction.

Sarcomastigophoraes are classified into two subphyla: Mastigophora and Sarcodina

2.1.1. SUBPHYLUM: MASTIGOPHORA (FLAGELLATES)

General characters

1. Includes protozoa which move by one or more flagella.
2. Nutrition autotrophic (plant- like) or holozoic (animal- like).

3. With one nucleus.
4. Free living or parasitic.
5. Body covered with pellicle.

Mastigophora are divided into two Classes (Table, 2-2).

Table (2-2): Classification of Mastigophora

A. Class: Phytomastigophora	B. Class: Zoomastigophora
1. Chromatophores present. 2. Autotrophic nutrition. 3. Flagella rarely more than one. 4. Free – living. 5. Store starch. e.g. <i>Euglena sp.</i>	1. Chromatophores absent. 2. Holozoic or parasitic nutrition. 3. Flagella one to many. 4. Free – living or parasitic. 5. Store glycogen. e.g. <i>Trypanosoma sp.</i>

A. Class: Phytomastigophora

***e. g. Euglena*¹**

Euglena is a mobile photosynthetic and photosensitive⁷⁶ cell. It is found in aquatic environments, almost freshwater ponds⁷⁷. Because they are autotrophs and produce their own energy from chlorophyll in the same manner of plants, a high enough population can make their habitat⁷⁸ appear quite green.

MORPHOLOGY⁷⁹

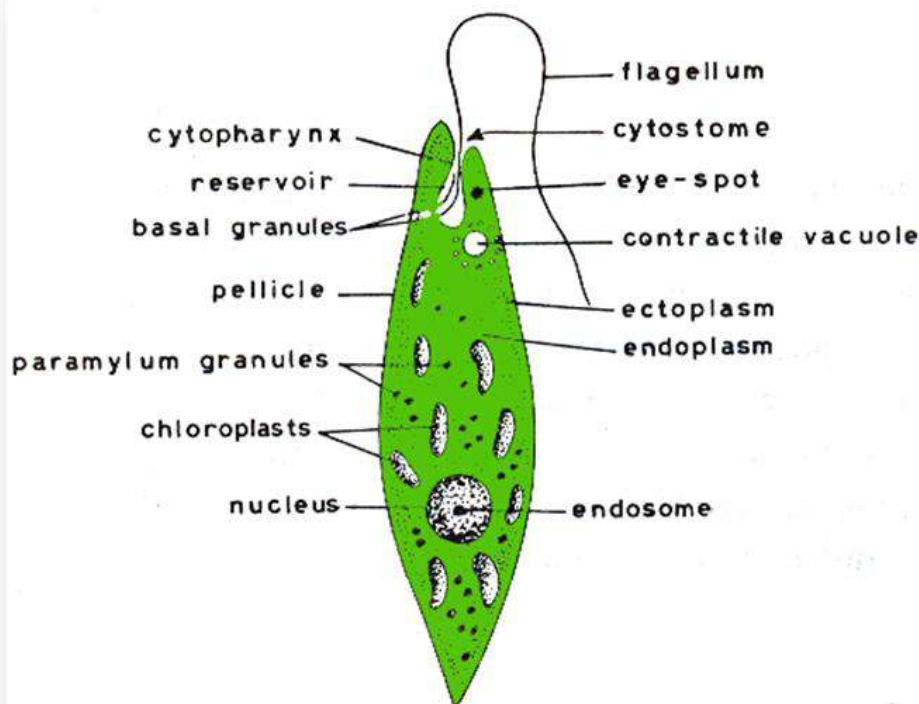


Fig. (2-1): Morphology of *Euglena*

¹ The word "Euglena" is formed from the two Greek words "eu" and "glene" which mean "good" and "eyeball" respectively, because of the clearly visible (with optical microscopes)

LOCOMOTION

Euglena moves in its environment by two methods:

A-Euglenoid movement: This is a slow worm-like movement⁸⁰. It is carried out by contraction⁸¹ and relaxation⁸² of the different parts of the body by the aid of muscles (Fig., 2-2).

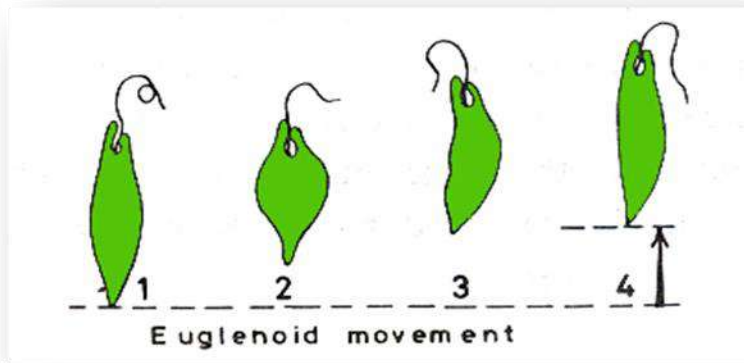


Fig. (2-2): Euglenoid movement

B- Flagellar movement: This type is faster and enables⁸³ the animal to swim rapidly in water. It is carried about by the active vibrations of its highly contractile flagellum. The flagellum lashes obliquely⁸⁴ backwards with waves passing along the flagellum from base to tip in a spiral manner⁸⁵. As a result, the whole body move forward through the water with a spiral rotation (Fig., 2-3). The flagellum beats at a rate of 12 times / second.

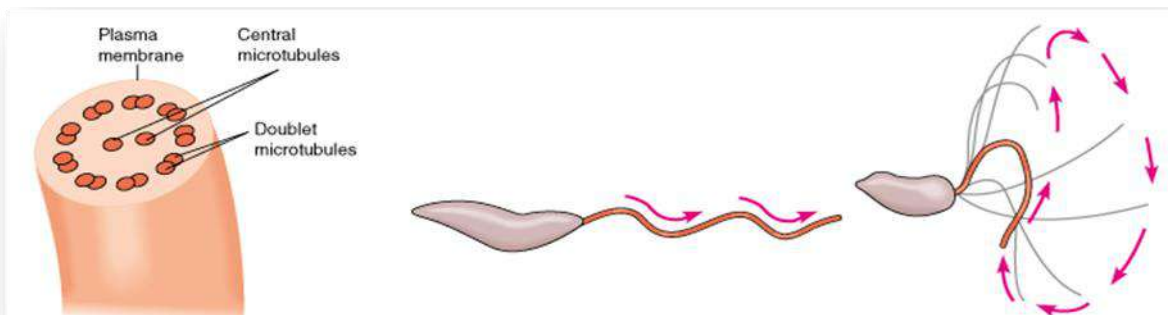


Fig. (2-3): Flagellar movement

NUTRITION⁸⁶

A- Holophytic (autotrophic) nutrition In the presence of sunlight, *Euglena* can synthesize⁸⁷ carbohydrates from CO_2 and water by the aid of⁸⁸ its chlorophyll - bearing chloroplast. This method of nutrition is identical to the process of photosynthesis in plants.

B- Holozoic (animal – like) nutrition in the absence of light, *Euglena* can absorb soluble food materials from the surrounding medium⁸⁹ through the body surface by pinocytosis⁹⁰.

OSMOREGULATION

Since the outer covering of *Euglena* is semi-permeable⁹¹ and the concentration of salts is higher in its cytoplasm than in the surrounding fresh water, water tends⁹² to flow into its body by osmosis. Osmoregulation is carried out by the “contractile vacuole system” as following:

- a- Excess⁹³ water collects as minute droplets⁹⁴ in the small vacuoles.
- b- The small vacuoles empty in the large central vacuole.
- c- The large vacuole bursts⁹⁵ into the reservoir which evacuates⁹⁶ water into the exterior.

RESPIRATION & EXCRETION

- Exchange of O_2 and CO_2 takes place by simple diffusion⁹⁷.
- Soluble excretory products⁹⁸ pass also from the cytoplasm to the surrounding environment by simple diffusion.

N.B. CO_2 resulting from respiration is utilized⁹⁹ in photosynthesis and O_2 produced by photosynthesis is used in respiration.

REPRODUCTION¹⁰⁰

Euglena reproduces asexually by one of the following methods

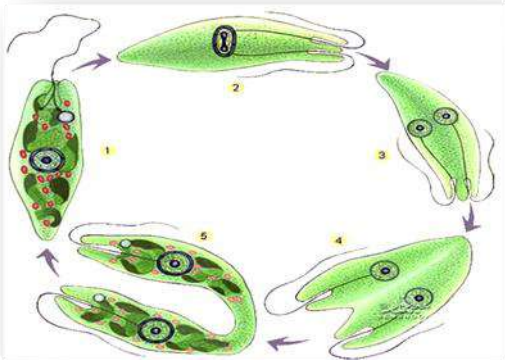


Fig. (2-4): Longitudinal binary fission in *Euglena*



Fig. (2-5): Encystment of *Euglena*

Longitudinal binary fission¹⁰¹ in suitable conditions¹⁰², *Euglena* multiplies by a simple longitudinal binary fission into two daughter individuals (Fig., 2-4).

B-Encystement: In unsuitable condition¹⁰³, *Euglena* rounds up and secretes¹⁰⁴ a thick gelatinous cyst¹⁰⁵ around itself. The encysted animal can withstand¹⁰⁶ the adverse¹⁰⁷ conditions of life. Encystment is normally followed by a longitudinal binary fission with the formation of two daughter *Euglena* (Fig., 2-5). When the conditions become suitable, the daughter individuals become liberated¹⁰⁸ from the cyst.

Euglena: an alga or an animal?

Some phycologists¹⁰⁹ believe that *Euglena* is considered¹¹⁰ as an alga because it possesses¹¹¹ chloroplasts and exhibits autotrophic nutrition. However, most zoologists believe that *Euglena* should be considered as animal because of:

- Its ability¹¹² to perform holozoic nutrition.
- The presence of some animals characters such as eye spot, flagellum and contractile vacuole.
- Longitudinal binary fission.

Such characters are not found in any algae.

B. Class:- Zoomastigophora

e.g₁. Trypanosoma²

Trypanosoma is the causative agent¹¹³ of disease known as **sleeping sickness**, which in many parts of Africa considers as the first problem in economic and social progress¹¹⁴. *Trypanosoma* lives as a parasite in the blood of many vertebrates (**definite host**¹¹⁵). The life cycle also involves blood-sucking invertebrate host (**intermediate host**¹¹⁶) mainly Tse Tse fly. Man hosts 3 species of *Trypanosoma* namely *Trypanosoma gambiense*, *Trypanosoma rhodesiense* and *Trypanosoma cruzi*. It transmitted to man by Tse Tse fly.

MORPHOLOGY

- It has fusiform body covered with hard **pellicle**.
- There is a large oval **nucleus** with a large central **endosome**.
- A long **flagellum** joined to the body by a thin **undulating membrane**¹¹⁷. The flagellum extends freely in front of the body.
- At the base of the flagellum, there is a granule known as **basal granule** or **blepharoplast**. Very close to the blepharoplast is a larger granule known as **parabasal granule**. (Fig., 2-6).

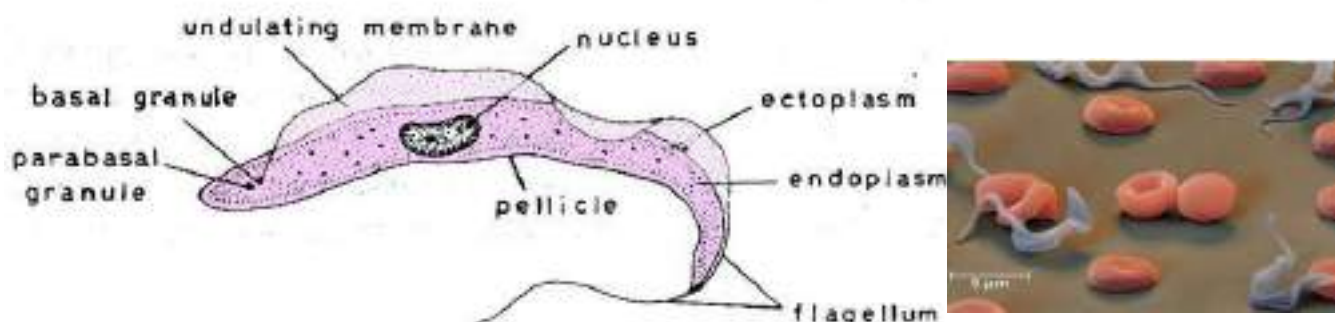


Fig. (2-6): Morphology of *Trypanosoma*

² is derived from the Greek word "trypano" meaning auger or screw-like and "soma" meaning body,

LOCOMOTION

Trypanosoma swim in the blood plasma of the host by the vibratile movements of the flagellum and undulating membrane.

LIFE CYCLE OF *T. gambiense* & *T. rhodesiense*. (Fig., 2-7)

Life cycle is completed within two hosts:

A-Primary host¹¹⁸: Man and other vertebrates.

B-Secondary host: TSE TSE fly.

1-Life Cycle In Man

A-Infection¹¹⁹: If an infected tse tse fly bits a healthy person, the parasite¹²⁰ enters his blood with the fly's saliva¹²¹.

B-Multiplication¹²²: Inside the blood plasma of human host, the parasite multiplies rapidly by longitudinal binary fission for about two weeks (a period known as *incubation period*¹²³) before the symptoms¹²⁴ of the disease start to appear.

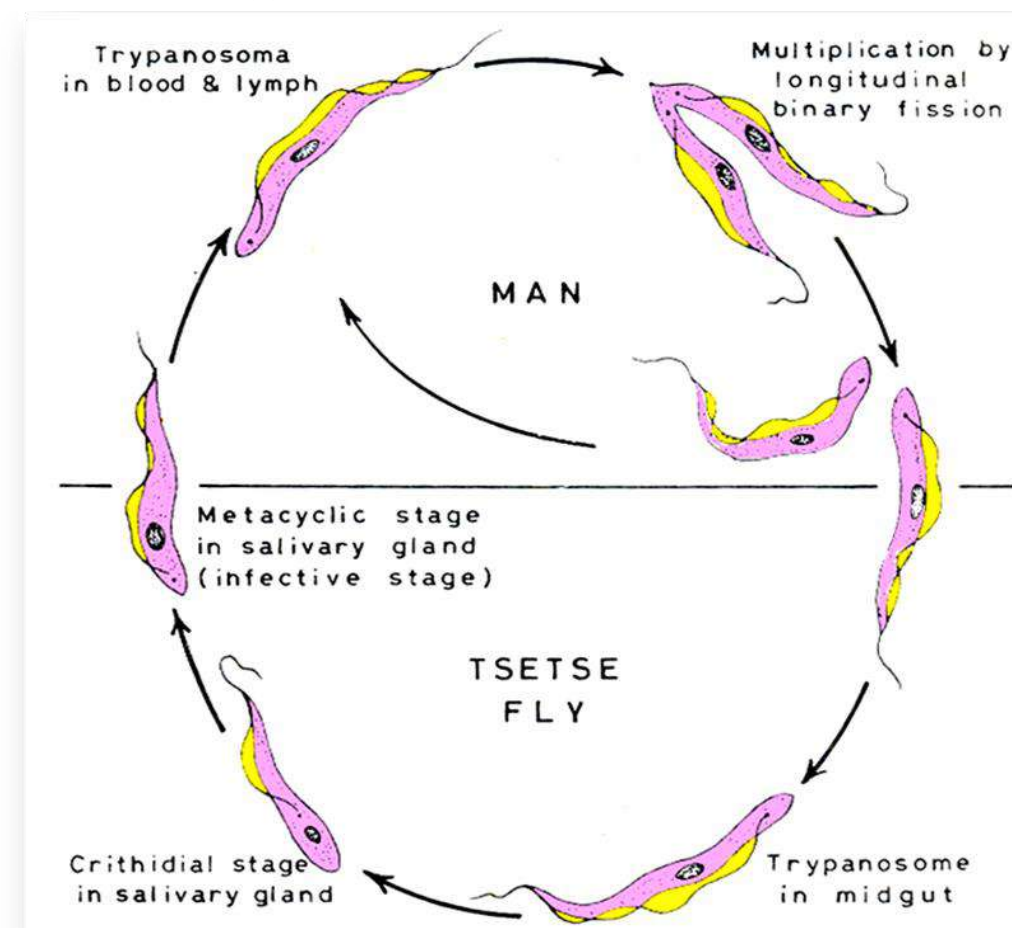


Fig. (2-7): Life cycle of *T. gambiense*

2- Life cycle in tse tse fly

A-Transfer to tse tse fly: when tse tse fly bits an infected person the trypanosomes are taken with sucked blood into the midgut¹²⁵ of the fly.

B-Development in midgut: in the midgut, the parasites divide by longitudinal binary fission producing a large number of *immature stages*¹²⁶.

C-Development in salivary glands¹²⁷:

1. After 10 –12 days, the immature forms migrate¹²⁸ to the salivary glands.
2. The parasite continues to multiply in the salivary glands by binary fission producing a stage known as **crithidial stage**. It has a narrow undulating membrane. The basal and parabasal granules lie in front of the nucleus.
3. Multiplication by binary fission continues for few more days when another stage known as the **metacyclic stage** (its basal and parabasal granules lie behind the nucleus).
4. Metacyclic stage is the infective stage¹²⁹, which may infect another human host.

HOST-PARASITE RELATIONSHIP¹³⁰

Trypanosoma lives in the blood plasma and affect the human host in the following ways:

1. It consumes¹³¹ a large amount of blood glucose.
2. The excretory products of the parasite are toxic¹³² to the human host.
3. When the parasites invade¹³³ the tissues of the brain, they produce a great damage and cause coma¹³⁴ (hence the name **sleeping disease**) and finally death of the host.

e.g., *Leishmania donovani*³

Leishmania is an endoparasite lives inside the macrophage cells of several vertebrates¹³⁵. There are two stages:

A- *Leishmania* stage

- Round with central large nucleus.
- With parabasal body and blepharoblast.
- With short flagellum which does not extend outside the body.
- Found in phagocytes¹³⁶ of final host.

B- *Leptomonad* stage

- Spindle¹³⁷ shape with large nucleus.
- With free flagellum arising from the blepharoblast.
- Found in the gut of sand fly (intermediate host).

³ modern Latin, from the name of William B. Leishman (1856–1926), British pathologist

LIFE CYCLE (Fig., 2-8)

Leishmania completes its life cycle in two hosts: man and sand fly (*Phlebotomas sp*).

a- In Man

1. The parasites are introduced¹³⁸ into the human blood with the bite of an infected sand fly.
2. They find their way into macrophages and assume **Leishmanial** form.
3. They undergo binary fission to produce large number of leishmanial stages.
4. The macrophage rupture¹³⁹ and the parasites released¹⁴⁰ into the blood.

b- In sand fly

1. While feeding, the sand fly ingests¹⁴¹ the leishmanial forms.
2. In the gut, the parasite developed into **Leptomonad** stage that multiplies by longitudinal binary fission.
3. Leptomonads migrates into the buccal cavity and become ready to infect another host.

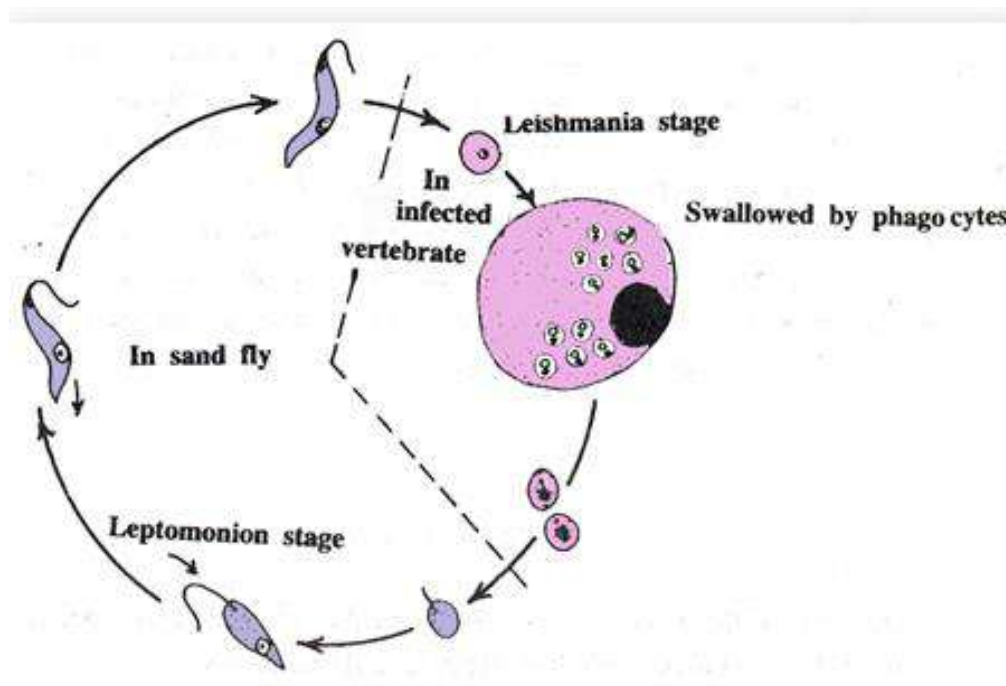


Fig. (2-8): Life cycle of *Lieshmania*

HOST PARASITE RELATIONSHIP

Leishmaniasis currently infects 350 million men, women, and children in 88 countries around the world and there are three kinds :**Cutaneous**, **Mucocutaneous** and **Visceral** Leishmaniasis.

- *L. Donovanii* causes a disease known as *visceral leishmaniasis* (*Kala-Azar*)¹⁴² (Fig., 2-9). or black fever characterized by:
 - Enlargement¹⁴³ of the liver and spleen.

- Anaemia, weakness and fever.
 - Darkening of the skin.
- *L. tropica* causes a disease known as *cutaneous leishmaniasis*¹⁴⁴ (also called oriental sore¹⁴⁵ or Baghdad sore). It infects the skin of hands, legs and face causing a sore at the bite site, which heals¹⁴⁶ in a few months to a year, leaving an unpleasant looking scar. This form can progress¹⁴⁷ to visceral forms (Fig., 2-9).



Fig. (2-9): Visceral and Cutaneous Leishmaniasis

2.1.2. SUBPHYLUM: SARCODINA

GENERAL CHARACTERS

- Mostly free living.
- Locomotory organoids in the form of pseudopodia.
- Holozoic nutrition.
- Asexual reproduction.

e.g., *Amoeba*⁴

MORPHOLOGY

The living *Amoeba* appears under the microscope as an irregular jelly-like mass which is constantly changing its shape due to the formation of finger-like protoplasmic projection known as **pseudopodia** (Fig., 2-10). The body is covered with thin **plasma membrane**. The cytoplasm is differentiated into an outer clear **ectoplasm** and an inner granular **endoplasm**. The cytoplasm contains: oval **nucleus** with **centrosome**, **contractile vacuole** and many **food vacuoles**.

⁴ mid 19th century: modern Latin, from Greek *amoibē* 'change, alternation'

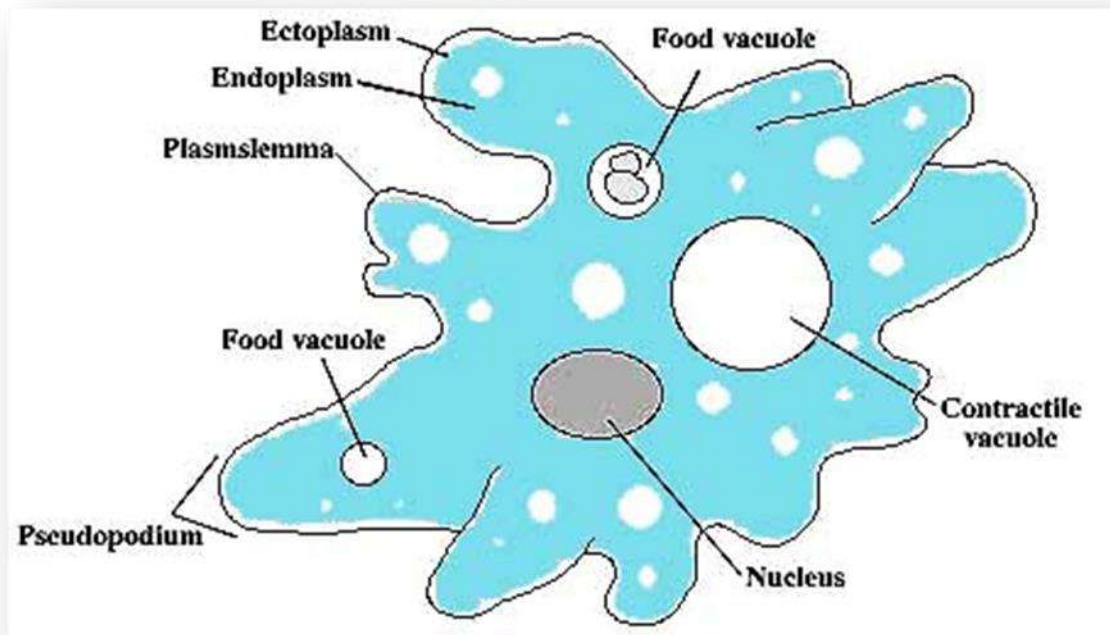


Fig. (2-10): Morphology of *Amoeba*

LOCOMOTION: (Amoeboid movement)

Amoeba move and capture¹⁴⁸ food by means of protoplasmic protrusions¹⁴⁹ known as pseudopodia. The pseudopodium is produced as following:

1. The colloidal state¹⁵⁰ of the ectoplasm is changed from plasmagel to plasmasol.
2. The internal pressure causes the plasmasol from the endoplasm to flow out at this weak point forming the pseudopodium.
3. Then plasmasol is changed again into plasmogel.
4. A similar process takes place at the other end of the body where a pseudopodium is drawn¹⁵¹. (Fig., 2-11).

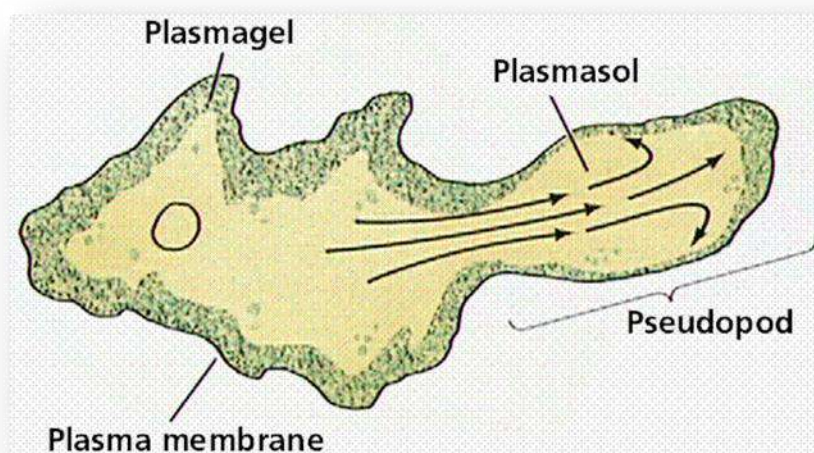


Fig. (2-11): Formation of pseudopodium

NUTRITION, Fig. (2-12).

Nutrition in *Amoeba* is holozoic (animal – like) and takes place as following:

1. **Feeding**: when an amoeba comes in contact with food particles¹⁵² (e.g. small protozoa, bacteria, microscopic plants.... etc.), it flows around it by a number of pseudopodia, forming a **food cup**.
2. **Formation of food vacuole**. The food cup gradually encloses¹⁵³ the food together with a drop of water and thus a **food vacuole** is formed inside the cytoplasm.
1. **Digestion**¹⁵⁴: food vacuole acts¹⁵⁵ as a temporary stomach where food is digested by the action of enzymes secreted¹⁵⁶ from the cytoplasm.
2. **Assimilation**¹⁵⁷: the digested food materials are absorbed by diffusion into the cytoplasm and distributed in the cell.
3. **Egestion**¹⁵⁸: The remaining undigested materials are egested by bursting of food vacuole at any point of the surface (Fig., 2-12).

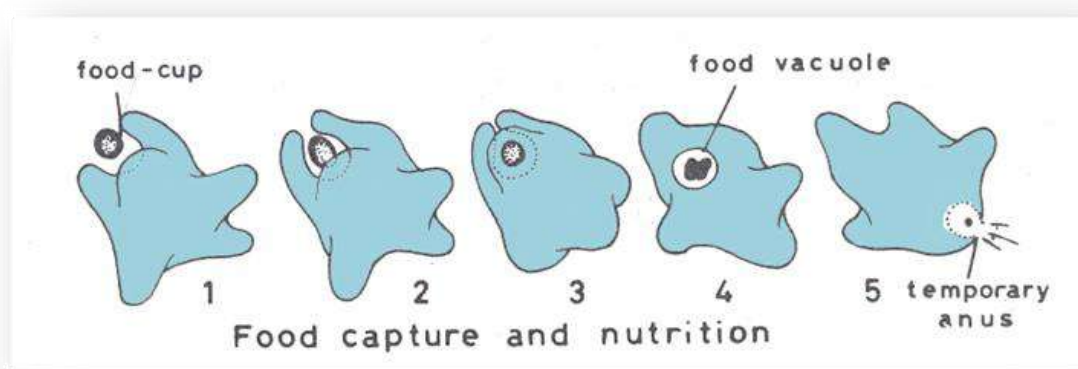


Fig. (2-12): Nutrition in *Amoeba*

OSMOREGULATION

The protoplasm of *Amoeba* is more concentrated¹⁵⁹ than the surrounding medium. So, water diffuses into it by osmosis and may lead to bursting of *Amoeba*. The regulation of water content or osmoregulation is carried out by the contractile vacuole which collect excess water, enlarges and then bursts at any point of the surface where its water content is expelled¹⁶⁰ to outside.

RESPIRATION

Gaseous exchange takes place by simple diffusion through the permeable plasma membrane. O₂ diffuses from outside (high concentration) to the cytoplasm (low concentration). CO₂ diffuses from cytoplasm (high concentration) to the surrounding water (low concentration).

EXCRETION¹⁶¹

Amoeba has no special excretory organs. The harmful¹⁶² excretory substances diffuse to the surrounding medium through the plasma membrane by simple diffusion.

REPRODUCTION

Amoeba asexually reproduces by one of the following methods:

A-Binary fission: It takes place during suitable conditions of food and temperature as following (Fig., 2-13).

1. *Amoeba* grows in size and withdraw¹⁶³ its pseudopodia.
2. It then divided into two parts.
3. Each part feeds and grows into new individual.

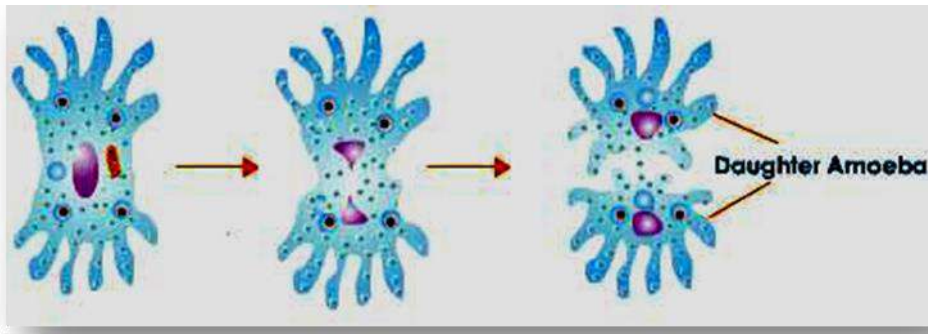


Fig. (2-13): Binary fission in *Amoeba*

B- Regeneration¹⁶⁴: It takes place also in suitable condition. When an *Amoeba* is cut into two or more pieces, each piece, containing part of the nucleus, will grow into a complete *Amoeba*.

C-Encystment: It takes place during unsuitable condition, such as the drying up of the water, as following (Fig., 2-14).

1. *Amoeba* withdraws its pseudopodia, become spherical and forms a resistant cyst¹⁶⁵ around itself.

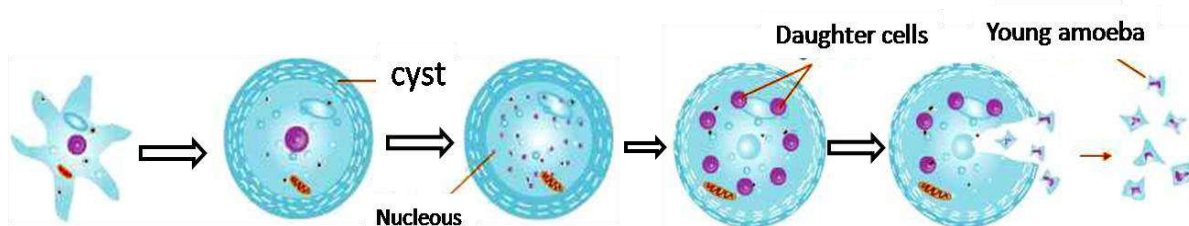


Fig. (2-14): Encystment in *Amoeba*

1. The nucleus divides repeatedly to form a large number of daughter nuclei.
2. Each daughter nucleus becomes surrounded by portion of the cytoplasm forming a small *Amoeba*.
3. When the environmental conditions improved¹⁶⁶ the wall of the cyst rupture and the daughter *Amoeba* become liberated.

D-Sporulation¹⁶⁷: It is similar to encystment but no external cyst is formed. Instead¹⁶⁸, each daughter nucleus is protected by formation of spore around

itself. When the condition improved, this cyst disintegrate to set them free (Fig., 2-15).

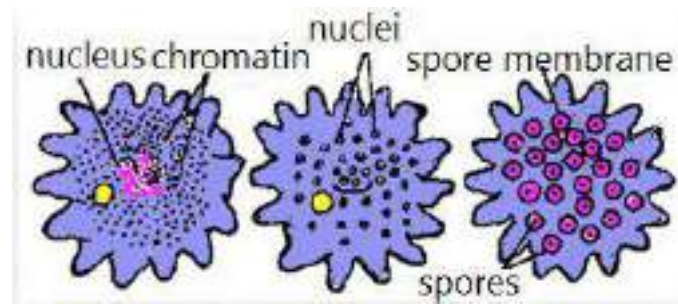


Fig. (2-15): Sporulation in *Amoeba*

***e.g2. Entamoeba histolytica*⁵**

This is an intestinal parasite of man.

MORPHOLOGY

Three forms are recognized in the life cycle: Trophozoite, Precystic stage and cyst.

1-Trophozoite¹⁶⁹ (trophic stage)

- It is spherical but at one end there is a single ectoplasmic pseudopodium.
- The cytoplasm is differentiated¹⁷⁰ into outer clear ectoplasm and an inner granular¹⁷¹ endoplasm containing food vacuoles (Fig., 2-16).
- It has single nucleus with central endosome.
- The surface is bounded¹⁷² by thin plasmalemma.

Two types of trophozoites are recognised:

- a. **Minute¹⁷³ trophozoite:** 10-20 μm in diameter. It lives in the lumen of the intestine¹⁷⁴ and feed on bacteria.
- b. **Large trophozoite:** when minute trophozoite invades¹⁷⁵ the mucosal layer¹⁷⁶ of intestine, it feeds on cellular elements and blood cells and develops into large trophozoite.

2-Precystic stage

- a. It is also found in the lumen of intestine.
- b. It is small in size.
- c. The cytoplasm is free from food vacuoles

3-Encysted stage (Infective stage):

The precystic stage is transformed into the mature cyst as following:

- a. It rounds up and secretes a thin protective cyst around itself.
- b. The nucleus divides twice by mitosis to produce 4 nuclei.

⁵ modern Latin, from Greek *entos* 'within' + *ameba*

c. It stores 2 chromatin bodies (protein reserve¹⁷⁷).

REPRODUCTION AND LIFE CYCLE (Fig., 2-16).

- A- Binary fission:** The trophozoite multiplies asexually by binary fission in the lumen of the large intestine.
- B- Encystment:** it is the transformation of trophozoites into cyst. The trophozoite rounds up and secretes a thin protective cyst around itself. The nucleus divides into 4 daughter nuclei and chromatoid material are stored in the cytoplasm.

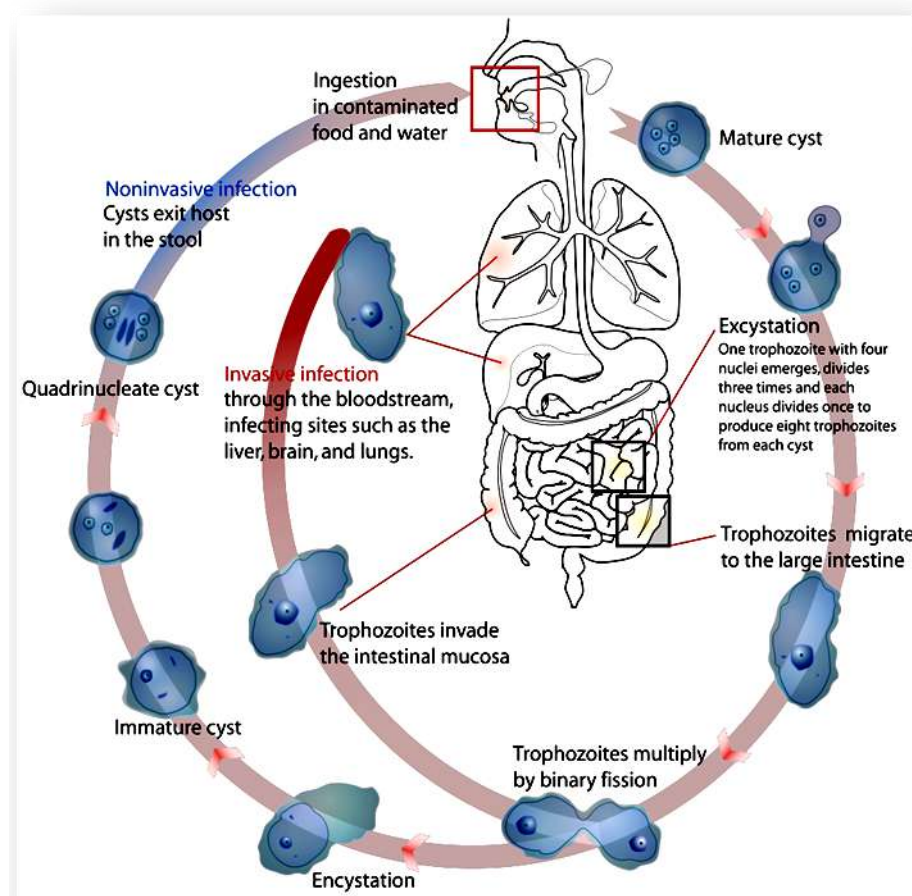


Fig. (2-16): Life Cycle of *E. histolytica*

- C- Infection of new host:** The mature cysts are the infective stage.
1. It passes out with the feces¹⁷⁸ and can survive¹⁷⁹ outside for sometimes.
 2. A new host acquires¹⁸⁰ the infection by ingestion of the encysted stage of the parasite in contaminated food¹⁸¹ or drinking water.
 3. This stage passes into the intestine without any change in the stomach.
- D. Excystation:** It is process of transformation¹⁸² of cysts into trophozoites:
1. In the small intestine, the cyst dissolved¹⁸³ by the action of trypsin enzyme and four nucleated individual are liberated.
 2. The four nuclei divide once more producing eight – nucleated individual.

3. This is followed by cytoplasmic division. Thus 8 small uni - nucleated trophozoites are produced.

HOST PARASITE RELATIONSHIP (effect of parasite on the host)

There are two types of infection in man:

- 1- **Harmless¹⁸⁴ infection:** the small trophozoites live in the lumen of the intestine, feed on bacteria and are harmless.
- 2- **Pathological infection¹⁸⁵:** the large trophozoites which invade the mucosal wall of the intestine, penetrate¹⁸⁶ into the deeper tissue causing bleeding¹⁸⁷ and ulcers¹⁸⁸ (Fig., 2-17) and developing a disease known as **Amoebic dysentery¹⁸⁹**. Moreover, some of trophozoites may penetrate to the blood streams and reach liver, lungs, brain.... etc. producing some ill effects.



Fig. (2-17): Intestinal lesion and numerous microulceration of large intestine due to amoebiasis

E.g3 Entamoeba coli

It differs from *E. histolytica* in the following (table, 3):

Table (2-3): Comparison between *E. histolytica* and *E. coli*.

<i>E. histolytica</i>	<i>E. coli</i>
➤ It may attack the wall of intestine. <u>Trophozoite</u> ➤ small 10 – 20 μ. ➤ with single pseudopodium. ➤ with small central endosome. <u>Cyst (infective stage)</u> ➤ small (12 μ). ➤ with two chromatin bodies with four nuclei. ➤ harmful causing diseases.	➤ It never attacks the wall of intestine. ➤ large 20 – 30 μ. ➤ with two pseudopodia. ➤ with large eccentric acrosome. ➤ large (17 μ). ➤ two chromatin bodies and eight nuclei . ➤ harmless.

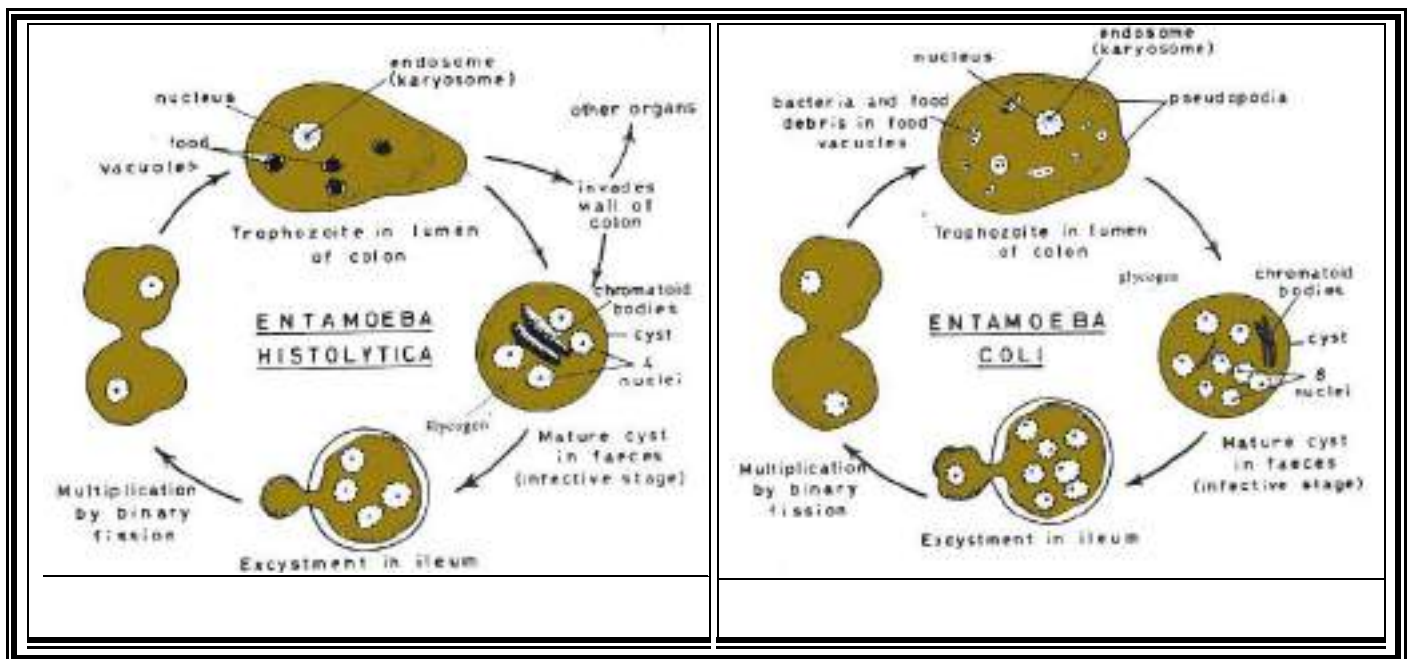


Fig. (2-18): Life cycle of *Entamoeba histolytica* and *E. coli*

e.g₄ . *Elephidium* (The Foraminefera)

Foraminefera are amoeboid protozoa which are mostly marine¹⁹⁰. Their calcareous shells¹⁹¹ represent the major constituents of the ocean¹⁹². So, they play a major role in the geological history of the earth. For example, the great pyramids were built from lime stone deposition of such shells.

MORPHOLOGY

The young foraminefiran resembles ¹⁹³*Amoeba* but it secretes many chambered shell around itself. Pseudopodia project from numerous minute pores to the exterior to form network¹⁹⁴. The food is captured by this pseudopodia network and enclosed within a food vacuole (Fig., 2-19).

REPRODUCTION AND LIFE CYCLE

Elehhidium is dimorphic i.e. exists in two forms during life cycle (Fig., 2-18). This phenomenon¹⁹⁵ is called "alternation of generation"¹⁹⁶.

1- *Microspheric Form (Schizont)*:

- Has a small central shell chamber.
- With many nuclei.
- Reproduces asexually by multiple fission. The protoplasm flows outside to cover the shell and divides into a number of small amoeboid bodies; each of them secretes a shell around itself and develops into a macrospheric form.

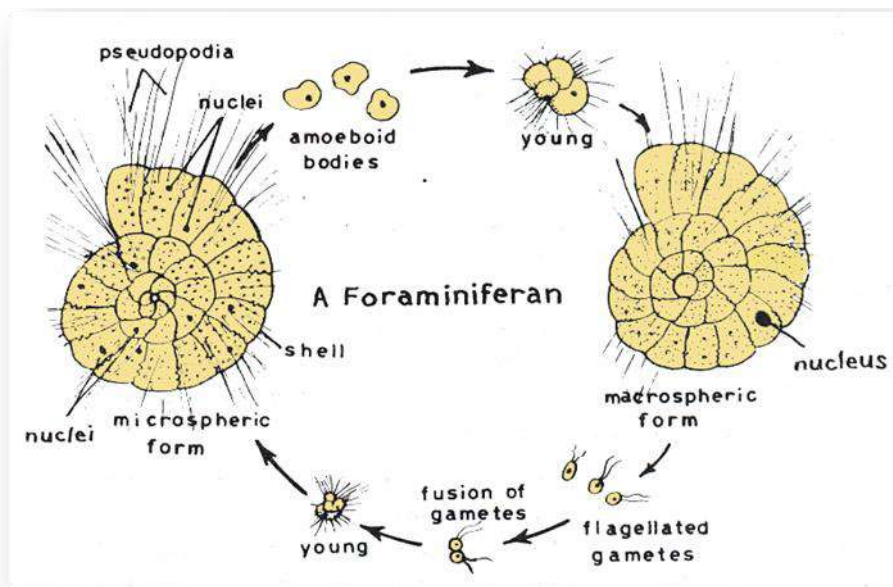


Fig. (2-19): Life cycle of foraminifer

2- Macrospheric Form

- Has a large central shell chamber.
- With one large nucleus.
- Reproduce sexually as following:
 - a. When mature¹⁹⁷, the protoplasm divides to produce flagellated gametes which swim into water.
 - b. Each gamete unites with a similar gamete from another individual to form a Zygote that develops into a microspheric form to complete the life cycle.

2.2. PHYLUM: CILIOPHRA

GENERAL CHARACTERS

- Move by cilia.
- With nuclear dimorphism.
- Mouth or gullet present.
- Reproduction asexual or sexual.

*e.g. Paramecium*⁶

This protozoan lives in freshwater ponds and streams containing decaying vegetation.

MORPHOLOGY (Fig., 2-20)

- It has a slipper-shaped¹⁹⁸ body with convex¹⁹⁹ dorsal surface.
- The body is covered by a firm pellicle and the cytoplasm is differentiated into an outer clear ectoplasm and an inner granular endoplasm.

⁶ mid 18th century; modern Latin, from Greek *paramēkēs* 'oval', from *para*- 'against' + *mēkos* 'length'

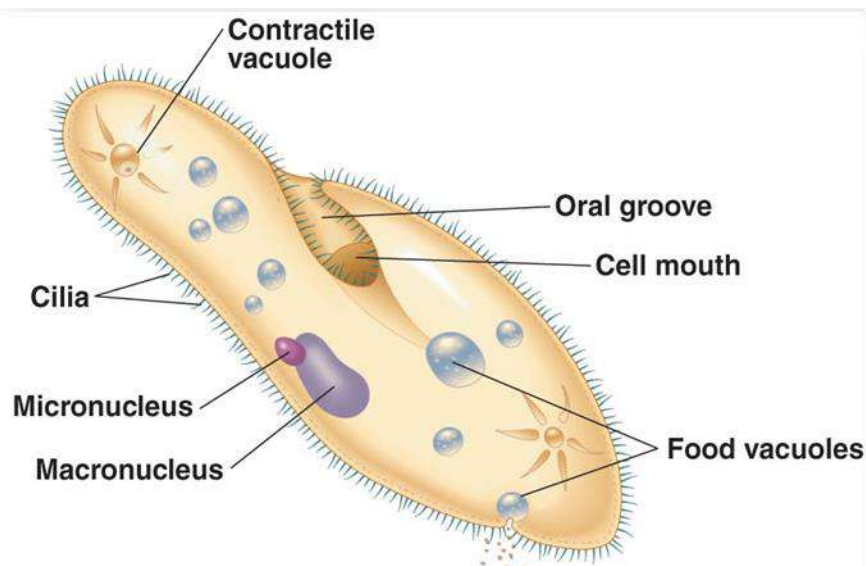


Fig. (2-20): Morphology of *Paramecium*

- The body surface is provided by a layer of small hair-like processes ²⁰⁰known as cilia.
- In the flat surface of the body there is an oral groove that extends into the cytoplasm forming cytopharynx (cell mouth).
- It is characterized by the presence of two nuclei: a large kidney-shaped ²⁰¹**macronucleus** and a small rounded **micronucleus**.
- The cytoplasm includes a number of food vacuoles as well as two contractile vacuule systems.

LOCOMOTION (ciliary movement)

Paramecium swims rapidly in water by means of well - coordinated movement of cilia found on its body. A cilium beats and stricks ²⁰²the water so that the organism move. The animal not move in a straight line but it follows left spiral pass and at the same time it rotates along its longitudinal axis ²⁰³(Fig., 2-21). This type of movement is caused by three components:

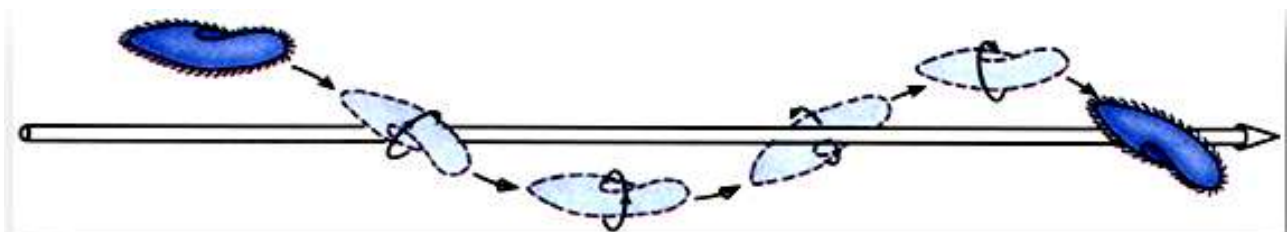


Fig. (2-21): Spiral locomotion of *Paramecium*

- a. The backward beating of the cilia propels ²⁰⁴the animal forward in water.
- b. The cilia arranged and beat obliquely to the right causing the body to roll over on its left side.

- c. The spiral nature of the movement is by the large cilia along the oral groove²⁰⁵, which are larger and beat more strongly.

NUTRITION

Paramecium feeds on small living organisms (bacteria, algae, other protozoa) as following:

- a. **Feeding:** While feeding, the cilia of oral groove beat strongly, so that food particles are sucked with water current into the oral groove and then follow through the vestibule to the cytopharynx.
- b. **Formation of food vacuole:** Food particles are taken with a drop of water in a food vacuole into the cytoplasm.
- c. **Digestion and Assimilation:** The food vacuole circulates in the cytoplasm where digestive enzymes are secreted into it. The digested soluble food materials are then absorbed and assimilated.
- d. **Egestion:** The undigested particles are ejected through the cytoproct or temporary anus²⁰⁶ (Fig., 2-22).

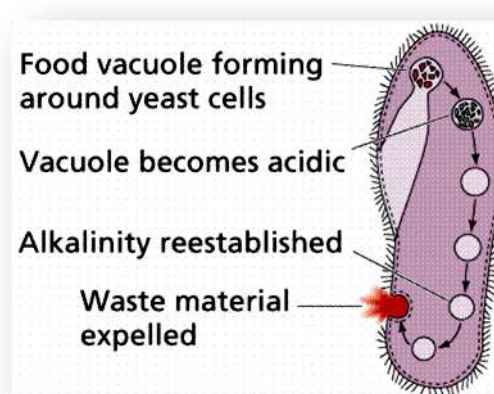


Fig. (2-22): Feeding in *Paramecium*

OSMOREGULATION

By two contractile vacuole systems as in other protozoa (Fig., 2-23).

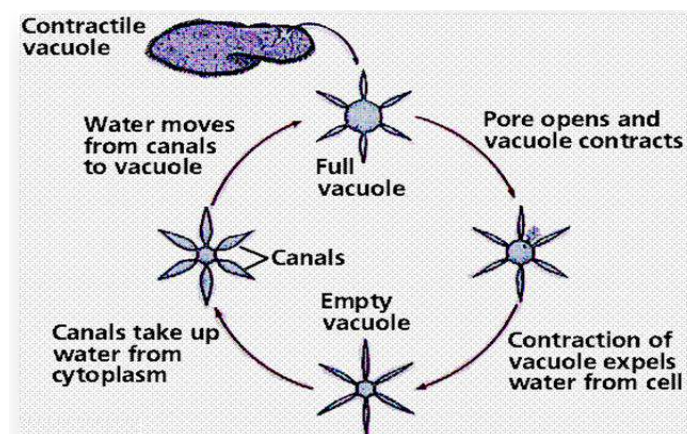


Fig. (2-23): Osmoregulation in *Paramecium*

RESPIRATION & EXCRETION

By simple diffusion as in others protozoa.

REPRODUCTION

A- ASEXUAL REPRODUCTION

During normal conditions, *Paramecium* reproduces by transverse binary fission as in other protozoa (Fig., 2-24).

B-SEXUAL REPRODUCTION

I- Conjugation²⁰⁷:

Repeated binary fission causes the daughter paramecia to be less viable²⁰⁸. Conjugation is necessary for the continued vitality of the species. Conjugation is a temporary union of two individuals for mutual exchange of genetic materials. It occurs during unfavourable conditions and involves following steps (Fig., 2-25):

1. Two paramecium of opposite mating types come in contact with their ventral surface. Pellicle and ectoplasm at the point of contact degenerate to form a cytoplasmic bridge. This united paramecium is called **conjugants**.
2. Micronucleus undergoes two successive divisions one of which is reduction division. So, 4 haploid nuclei are produced in each conjugant, three nuclei of them disappear in each conjugant.

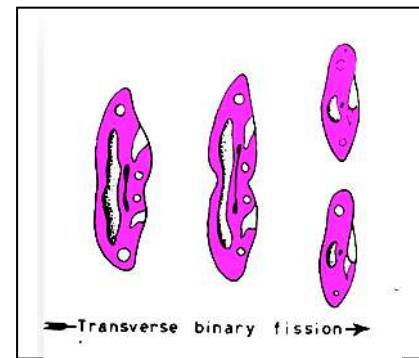


Fig.(2-24): Binary fission

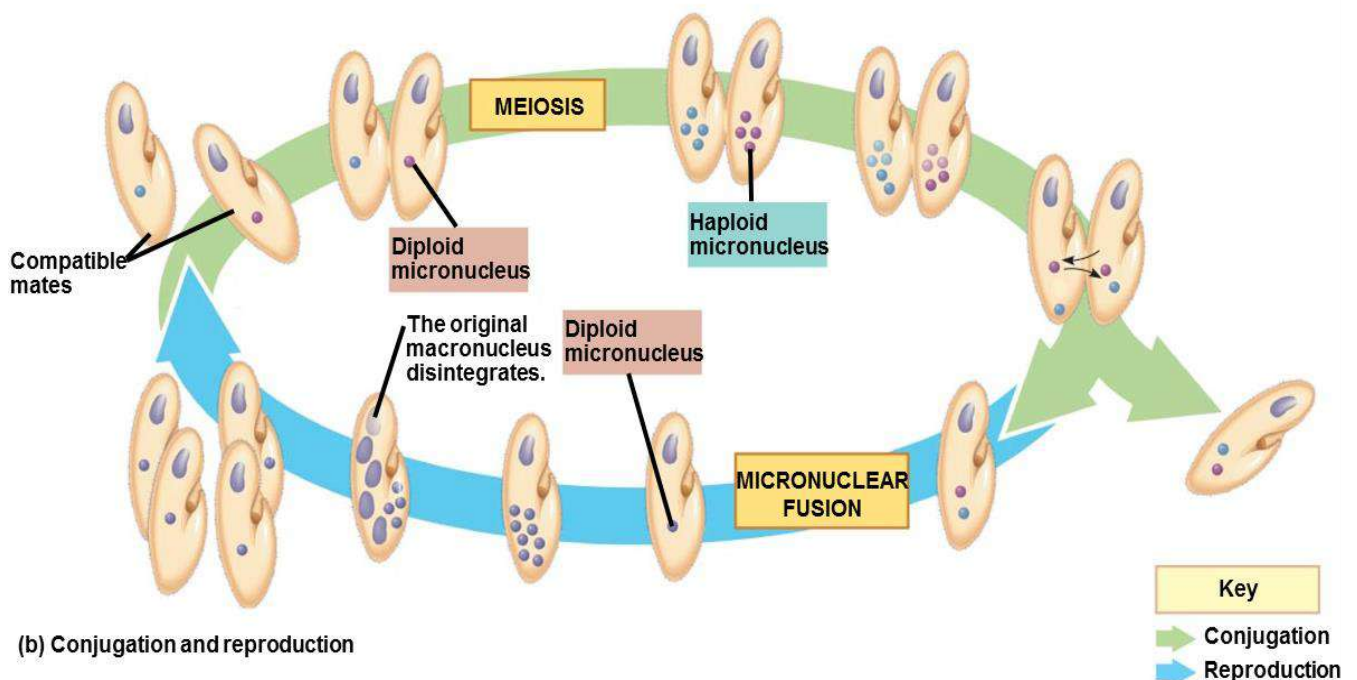


Fig. (2-25): Conjugation in *Paramecium*

3. The remaining nucleus divides unequally to produce smaller **male pronucleus** (n) and larger **female pronucleus** (n), but they are genetically identical. Male

pronucleus is active and migratory whereas female pronucleus is inactive and stationary.

4. Male pronucleus of each conjugant cross the cytoplasmic bridge and fused with female pronucleus to form diploid zygote nucleus.
5. The conjugants then separate from each other after 12 to 48 hours of the union. They are called **exconjugants**.
6. The original macronucleus disintegrates. Zygote nucleus of each exconjugants divides three times to produce eight nuclei.
7. Out of eight, four become macronuclei whereas other four become micronuclei.
8. Two round binary fission yield four daughter cells.

In this way, 8 paramecia are produced as a result of conjugation. They are metabolically active and can undergo repeated binary fission.

SIGNIFICANCE OF CONJUGATION:

Nuclear Reorganization: In conjugation new and metabolically active macronucleus is produced by reorganization of micronuclear materials.

Rejuvenation: In conjugation old, weak and defective macronucleus is replaced by new one which can control metabolism and growth.

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

II-Autogamy²⁰⁹:-

It is similar to conjugation but occurs within one individual and thus gives pure lines (Fig., 2-26). It runs as following :

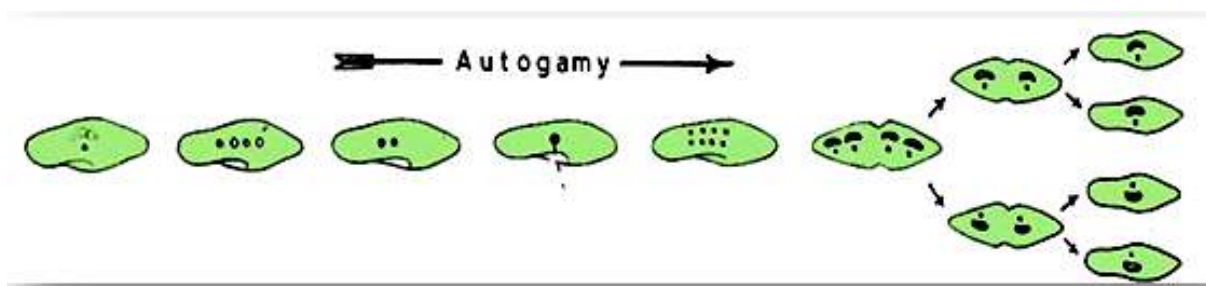


Fig. (2-26): Autogamy in *Paramecium*

1. In one *Paramecium* micronucleus undergoes two successive divisions one of which is reduction division. So, 4 haploid nuclei are produced in each conjugant.
2. Out of four three nuclei disappear in each conjugant.
3. The remaining nucleus divides into two equal nuclei (n).
4. The two nuclei fuse to form zygotic nucleus (2n).

5. The original macronucleus disintegrates. Zygote nucleus divides three times to produce eight nuclei; four of them enlarge to become macronuclei (2n).
6. The cytoplasm then undergoes two repeated division producing four daughter paramecia, each with two nuclei (macronucleus and micronucleus).

Table (2-4): Comparison between conjugation and autogamy

Conjugation	Autogamy
➤ Occurs between two individuals. ➤ Involves rearrangement and exchange of genetic materials. ➤ Leads to more variation. ➤ 8 paramecia are produced.	➤ Occurs within one individual. ➤ Involves rearrangement of genetic materials only. ➤ Produce pure line of individuals. ➤ 4 paramecia are produced.

2.3. PHYLUM: APICOMPLEXA (SPOROZOA)

The Apicomplexa are a large group of Protozoa, most of which possess a unique²¹⁰ organelle called apicoplast, an apical complex structure involved in penetrating the host's cell (Fig., 2-27). They are unicellular, spore-forming, and exclusively animal parasites. Motile structures such as flagella or pseudopods are absent except in certain gamete stages.

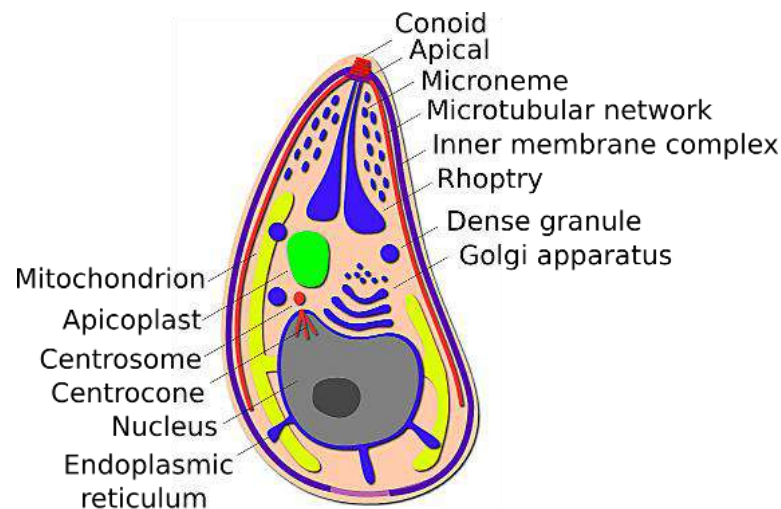


Fig. (2-27): structure of Apicomplexa

GENERAL CHARACTERS

1. They have no locomotary organelles.
2. They reproduce by spores.
3. Most are parasitic.
4. Saprozoic nutrition.
5. The life cycle is complex and involves asexual and sexual generation.

*e.g. Plasmodium*⁷

Four species of *Plasmodium* infect man and cause a disease which is commonly known as **Malaria**, *P. vivax*, *P. ovale*, *P. malariae*, and *P. falciparum*. The most dangerous species is *P. falciparum* which causes malignant²¹¹ tertian malaria for human and other mammals²¹².

Plasmodium species are transmitted by **anopheles mosquitoes**²¹³ (Fig., 2-29). Both sexes of mosquitoes feed on nectar²¹⁴. Because nectar's protein content alone is insufficient²¹⁵ for oogenesis (egg production) one or more blood meals is needed by the female. Only female mosquitoes bite transmits disease.

PLASMODIUM LIFE CYCLE

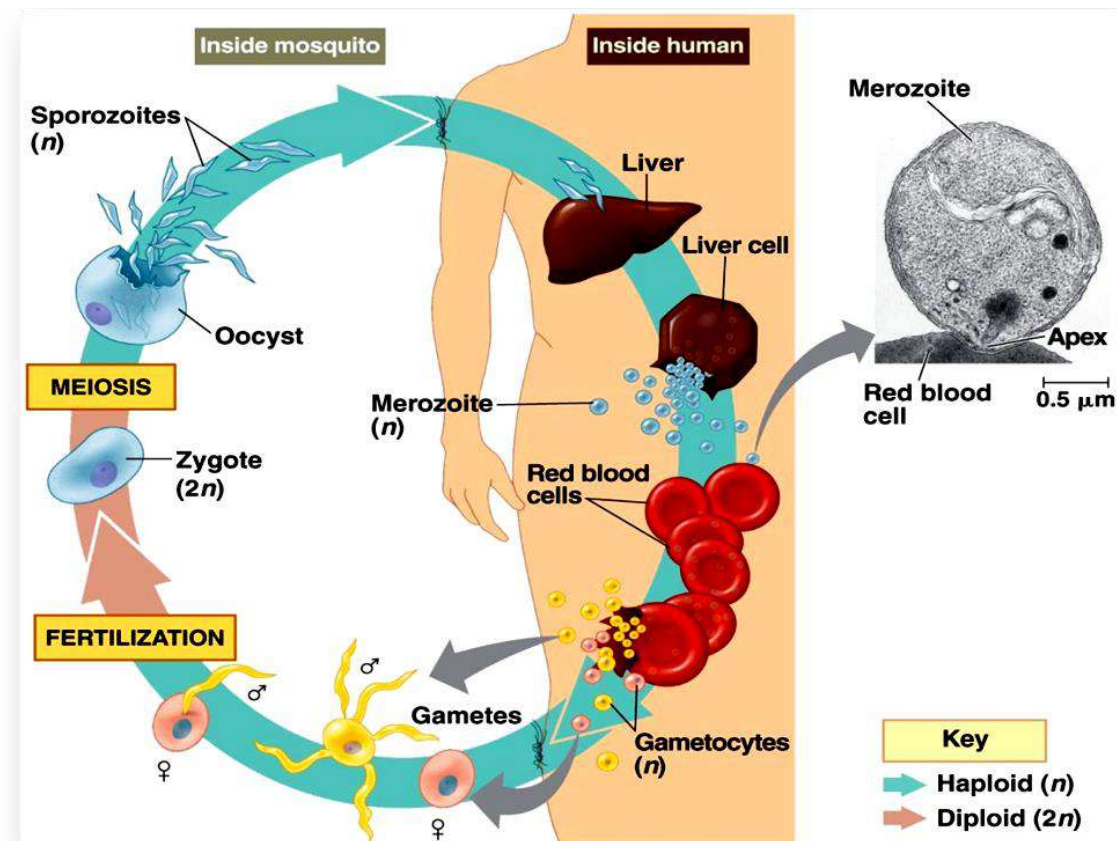


Fig. (2-28): Life cycle of *Plasmodium malariae*

There are three phases of development in the life cycle of malaria parasite: Tissue phase²¹⁶, Erythrocytic phase²¹⁷ and Invertebrate phase²¹⁸ (Fig., 2-28).

A- Tissue phase: (Fig., 2-29)

1. Human infection is initiated²¹⁹ when **sporozoites** (minute fusiform organism) are injected with the saliva during mosquito feeding.

⁷ late 19th century: modern Latin, based on late Latin *plasma* 'mould, formation'

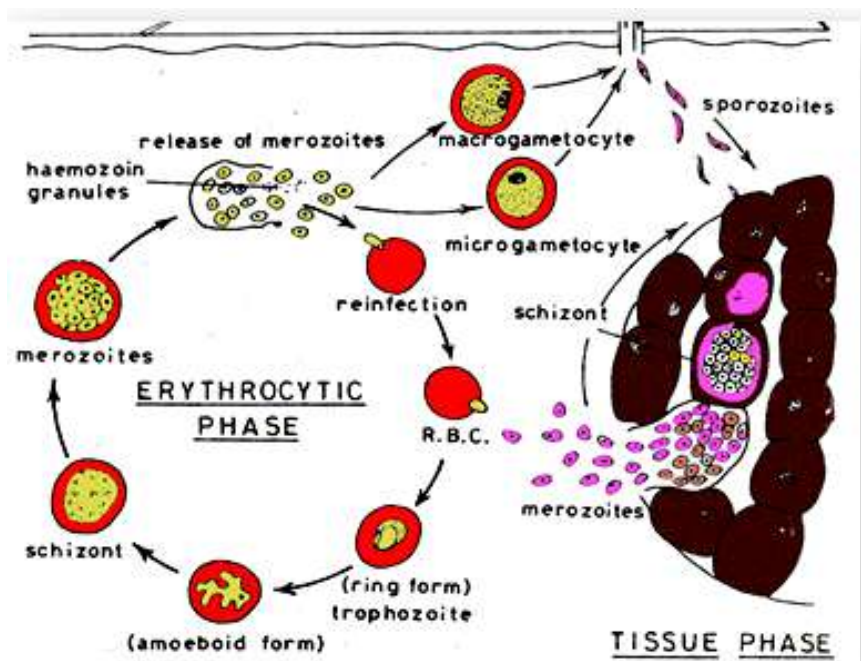


Fig. (2-29): Tissue phase and erythrocytes phase of *Plasmodium malariae*

2. The sporozoites enter the circulatory system and within 30-60 minutes will invade a liver cell (hepatocytes).
3. After invading the hepatocyte, the parasite undergoes an asexual replication. This replicative stage is called **exoerythrocytic schizogony**. Schizogony refers to a replicative process in which the parasite undergoes multiple rounds of nuclear division without cytoplasmic division followed by a budding, or segmentation to form **merozoites**.
4. Merozoites are released into the circulatory system following rupture of the host hepatocyte.

B- Erythrocytic phase (Fig., 2-30)

1. **Merozoites** released from the infected liver cells invade erythrocytes (red blood cells).
2. Inside the erythrocyte, the parasite undergoes a trophic²²⁰ period followed by an asexual replication forming young trophozoite which is often called a **ring form**.
3. As the parasite increases in size, this 'ring' morphology disappears and then become adult **trophozoite**. The parasite ingests the host cell cytoplasm and breaks down the haemoglobin. The haemoglobin digestion is the malaria pigment, or **hemozoin**. These golden-brown granules have been long recognized as a distinctive feature of blood-stage parasites.
- 6- Nuclear division marks the end of the trophozoite stage and the beginning of the **schizont** stage.

- 7- Erythrocytic schizogony consists of 3-5 rounds of nuclear replication and releases the merozoites at the end of each cycle. These merozoites invade new erythrocytes and initiate another round of schizogony.
- 8- Sexual Stage. As an alternative to schizogony some of the parasites will undergo a sexual cycle and differentiate into either **(male) microgametocytes** or **(female) macrogametocytes**.

C- Invertebrate phase (Fig., 2-30).

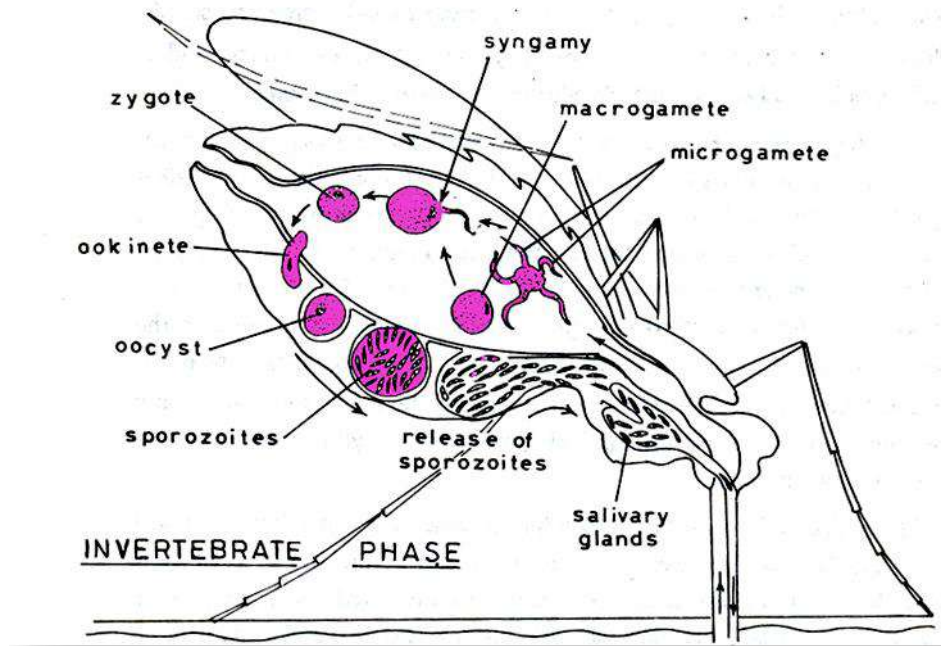


Fig. (2-30): Invertebrate phase of *Plasmodium malariae*

1. When female mosquito sucks the blood of an infected host, the microgametes and macrogametocytes enter its alimentary canal²²¹.
2. The microgametocyte undergoes three rounds of nuclear replication.
3. Exflagellation: These eight nuclei then become associated with flagella that emerge from the body of the microgametocyte.
4. The highly mobile microgametes fuse with a macrogamete to form **zygote** that develops into an **ookinete**.
5. The ookinete penetrates the midgut epithelium of the mosquito and develops into an **oocyst**. The oocysts undergo an asexual replication, called sporogony, to form several thousand **sporozoites**.
6. The sporozoites make their way to the salivary gland and become ready to infect another host

N.B.: The life cycle of *plasmodium* illustrate the phenomenon known as "**Alternation of Generation**" as it involves the alternate succession of sexual generation (reproducing by gametes) and asexual generation (reproducing by schizogony or sporogony).

HOST – PARASITE RELATIONSHIP

Plasmodium is the causative agent of a **Malaria** disease. Malaria is widespread in tropical and subtropical regions, (22 countries), including parts of the Americas Asia, and Africa. Each year, there are approximately 350–500 million cases of malaria, killing between one and three million people, the majority of whom (90% of malaria-related deaths) are in sub-Saharan Africa.

The symptoms²²² of malaria appears during erythrocytes phase. In the blood, the plasmodia parasites destroy the red blood cells, which carry vital oxygen to the tissues of the body. The classic symptom of malaria is cyclical occurrence of sudden coldness followed by rigor²²³ and then fever and sweating²²⁴ lasting for few hours, in addition to joint pain, vomiting²²⁵ and anaemia (caused by haemolysis) and retinal damage²²⁶.

Malaria can result in:

1. Anaemia due to the destruction of red blood cells by the parasites.
2. The remains of the destroyed red blood cells clump together and cause blockages in the blood vessels. This can result in brain damage or kidney damage, which is potentially fatal²²⁷.
3. The parasite also produce **Lecithinase** enzyme which damage the mitochondria and thus inhibits the respiratory process of erythrocytes.

ECONOMIC IMPORTANCE OF PROTOZOA

Protozoa, though minute and apparently insignificant, are of considerable economic value to mankind. They are beneficial as well as harmful:

A- BENEFICIAL²²⁸ PROTOZOA

The Protozoa are useful in the following ways:

1. **Food:** Protozoa form the first link in many food chains ending in man. They furnish²²⁹ food for the small crustaceans²³⁰ and worms, which are eaten by larger animals, like crabs, lobsters, clams and fishes, which ultimately come to human table.
2. **Industry**²³¹. The siliceous and calcareous shells of marine Protozoa (Foraminifera and Radiolarida) sink down and collect on the sea floor. These skeletal deposits are put to many commercial uses. Some are employed as filtering agents, others are made into chalk.
3. **Building Material.** The skeletal deposits in due course of time change into the limestone rocks. These rocks are used as building material. For example, the great Egyptian pyramids are built of stones carved out from the limestone beds composed of the shells of foraminifera.

4. **Oil Exploration.** The skeletal deposits of Foraminiferidae and Radiolaridae are often found in association with oil deposits. These, therefore, help to locate this important fuel.
5. **Scientific Investigation.** Many Protozoa are employed in biological and medical researches.
6. **Insect Control.** Protozoa keep many harmful insects under check by parasitizing their bodies.

B. HARMFUL PROTOZOA.

The Protozoa are harmful in the following ways:

1. **Reduction of Soil Fertility²³².** About 200 to 300 species of Protozoa, including flagellates, amoeboid forms and ciliates, inhabit the soil and feed on nitrogen-fixing bacteria. This decreases the production of nitrates and reduces soil fertility.
2. **Pollution²³³ of Water.** The Protozoa of fecal origin contaminate drinking water in open reservoirs. Some free-living Protozoa render the water of open quiet reservoirs and unfit it for drinking by giving it an unpleasant odour.
3. **Destruction of Wooden Articles.** Some flagellates live in the intestines of termites and help them in the digestion of wood. Without these flagellates, the termites would die.
4. **Destruction of Food Animals.** Phosphorescent Dinoflagellates like *Gonyaulax* and *Noctiluca*, when present in large number, turn the ocean red. This gives the water foul odour, kills food animals like fish, clams, oysters and mussels, rendering them unfit for human consumption. Certain parasitic protozoa also destroy useful animals. For Example, *Trichomonas foetus* causes abortion²³⁴ in cattle :
5. **Production of Diseases.** About 14 species of Protozoa live as parasites in the human body and cause diseases, some of them are serious or fatal.

3

II. Kingdom: Animalia

II. KINGDOM: ANIMALIA

3. Basics of Animals Classifications

About 1.3 million living species of animals have been identified. Several characteristics, taken together, sufficiently define the group.

Animals differ from plants in:

1. Contain centrioles and asters.
2. Lack chlorophyll, plastids and cell walls.
3. Exhibit both embryonic and larval stages.
4. Exclusively heterotrophic.

3.1. GENERAL CHARACTERS OF ANIMALS

The following features characterize the animals:

1. Exhibit multicellular construction.
2. Composed of eukaryotic cells.
3. Nutrition is by ingestion²³⁵ (heterotrophic).
4. Nervous tissue and muscle tissue are unique to animals.
5. All animals, and only animals, have *Hox* genes that regulate the development of body form. Although the *Hox* family of genes has been highly conserved, it can produce a wide diversity of animal morphology.
6. Most animals reproduce sexually, with the diploid stage usually dominating²³⁶ the life cycle. After a sperm fertilizes an egg, the zygote undergoes rapid cell division called **cleavage**²³⁷. Cleavage leads to formation of a **blastula**. The blastula undergoes gastrulation, forming a **gastrula** with different layers of embryonic tissues (Fig., 3-1).

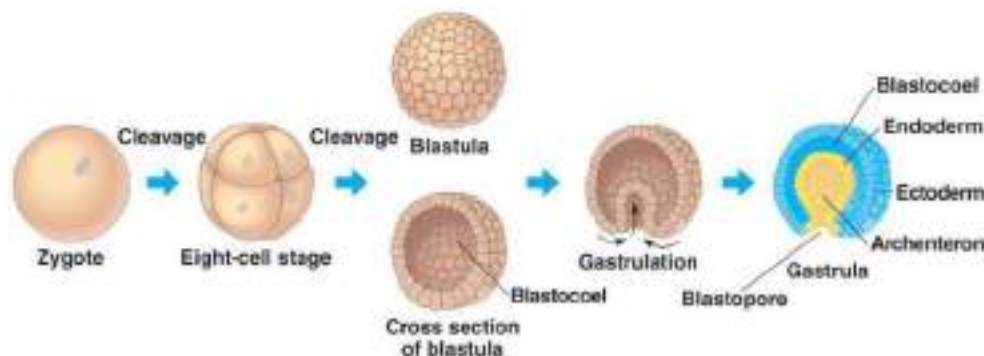


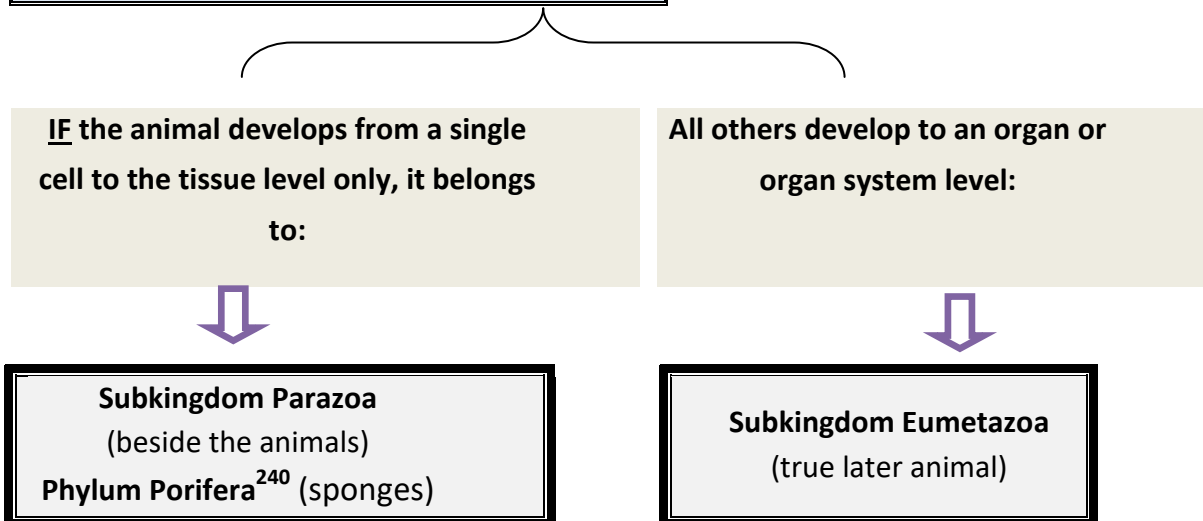
Fig. (3-1): Early embryonic development of animals.

3.2. BASICS OF CLASSIFICATION OF ANIMAL KINGDOM

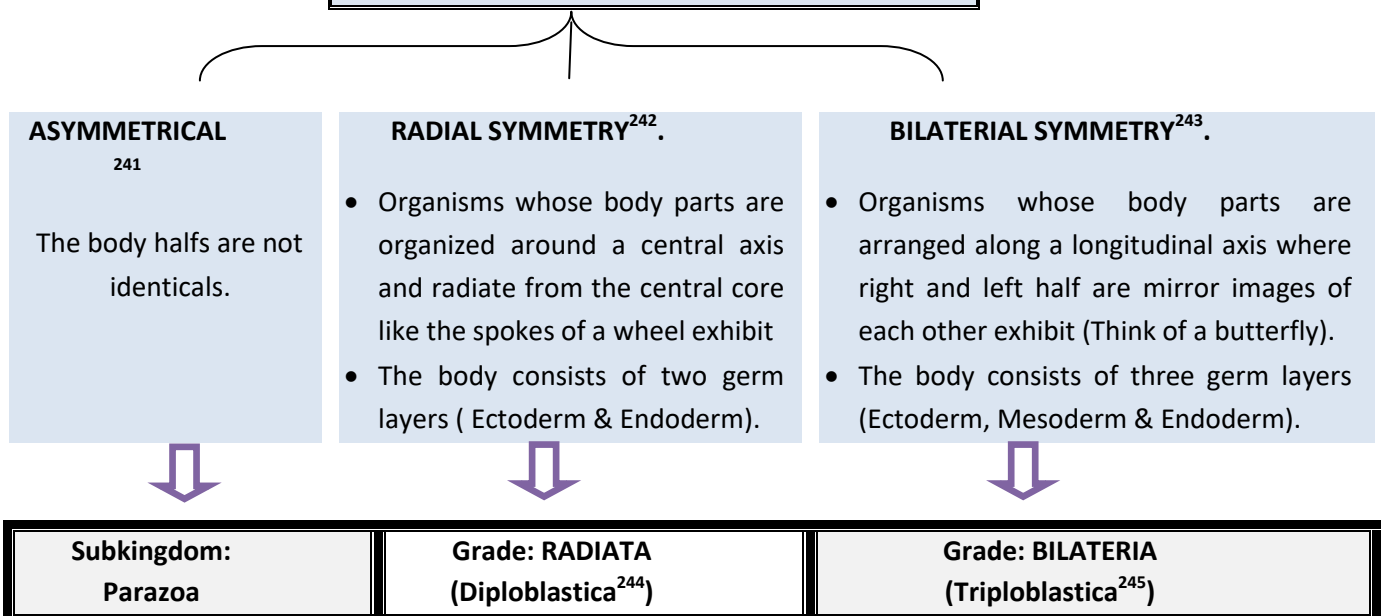
About 1.3 million living species of animals have been identified. They are classified according to the following bases:

- Level of Organization²³⁸, Type of Body Symmetry²³⁹, Type of Body Cavity and Embryonic Development

3-2.1. Level of Organization



3.2.2. Type of Body Symmetry



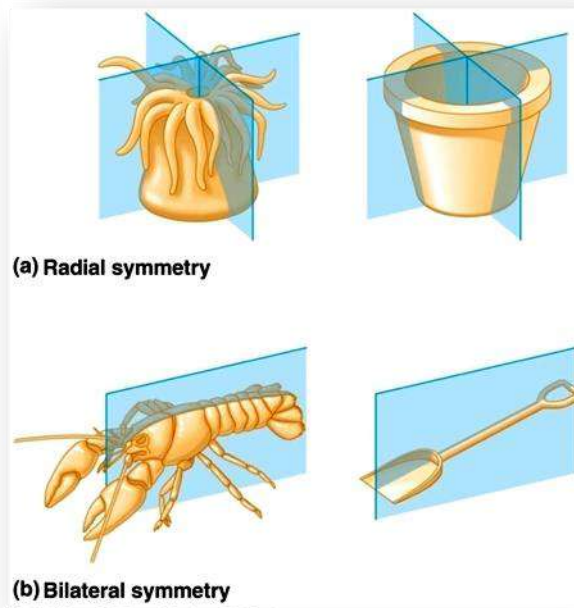


Fig. (3-2): Classification of animals according to the types of body symmetry.

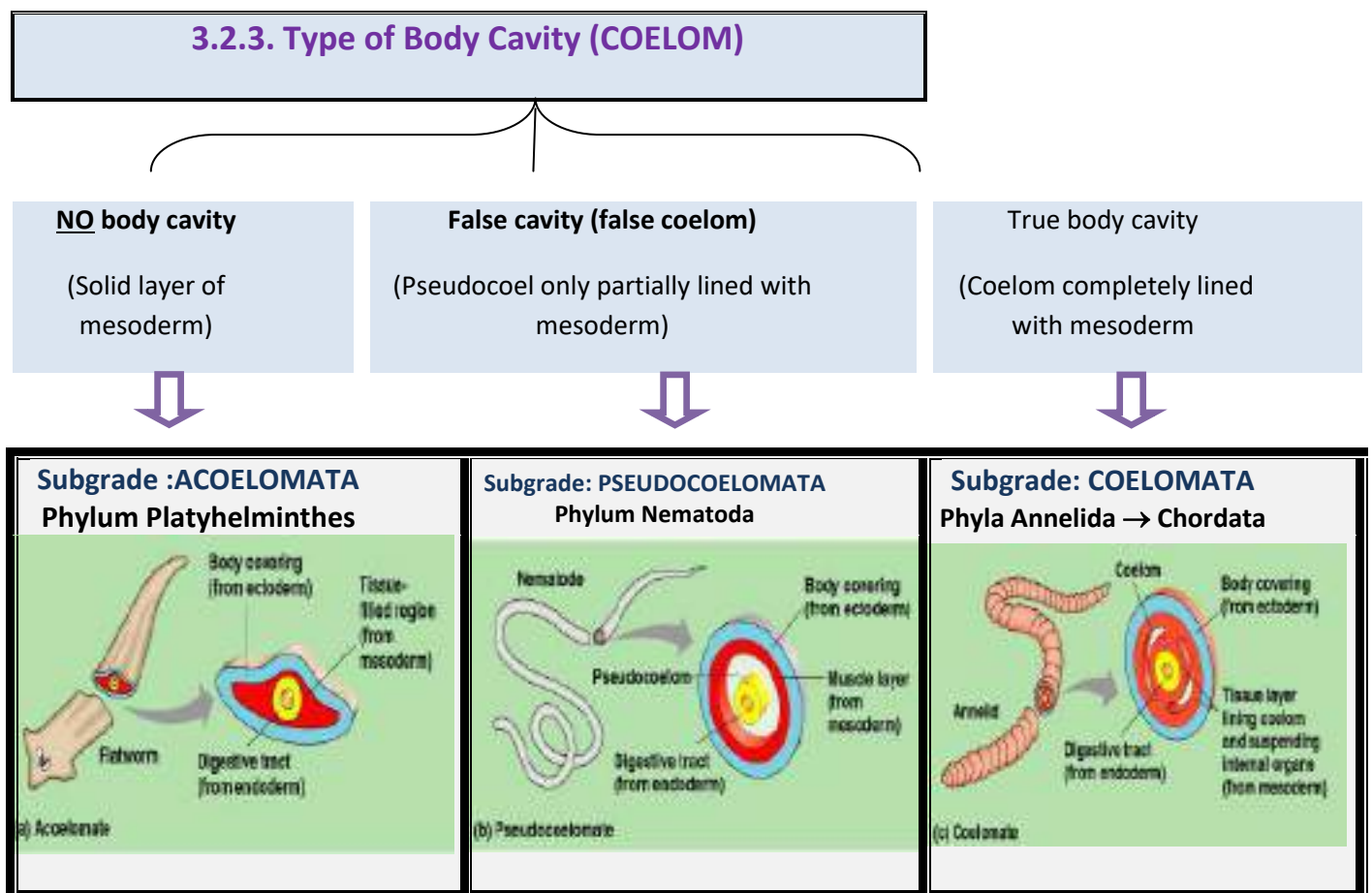


Fig. (3-3): Classification of animals according to the type of body cavity.

The morphology-based tree divides bilaterians into two clades: **deuterostomes** and **protostomes**.

3.2.4. Type of Embryonic Development

If the first opening into the blastocoel is the mouth



Protostome.

If the second opening into the blastocoel is the mouth



Deutrostome.

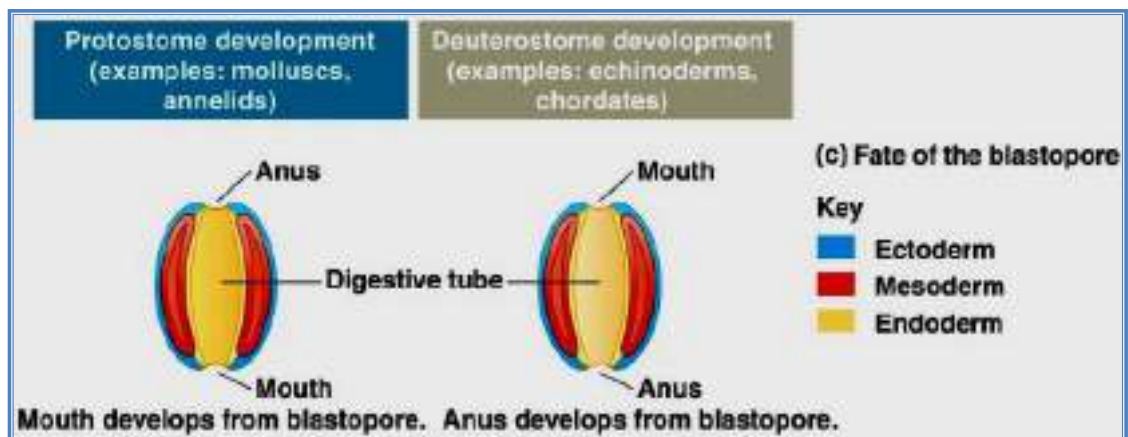


Fig. (3-4): Classification of animals according to their embryonic development.

Classification of Animal Kingdom

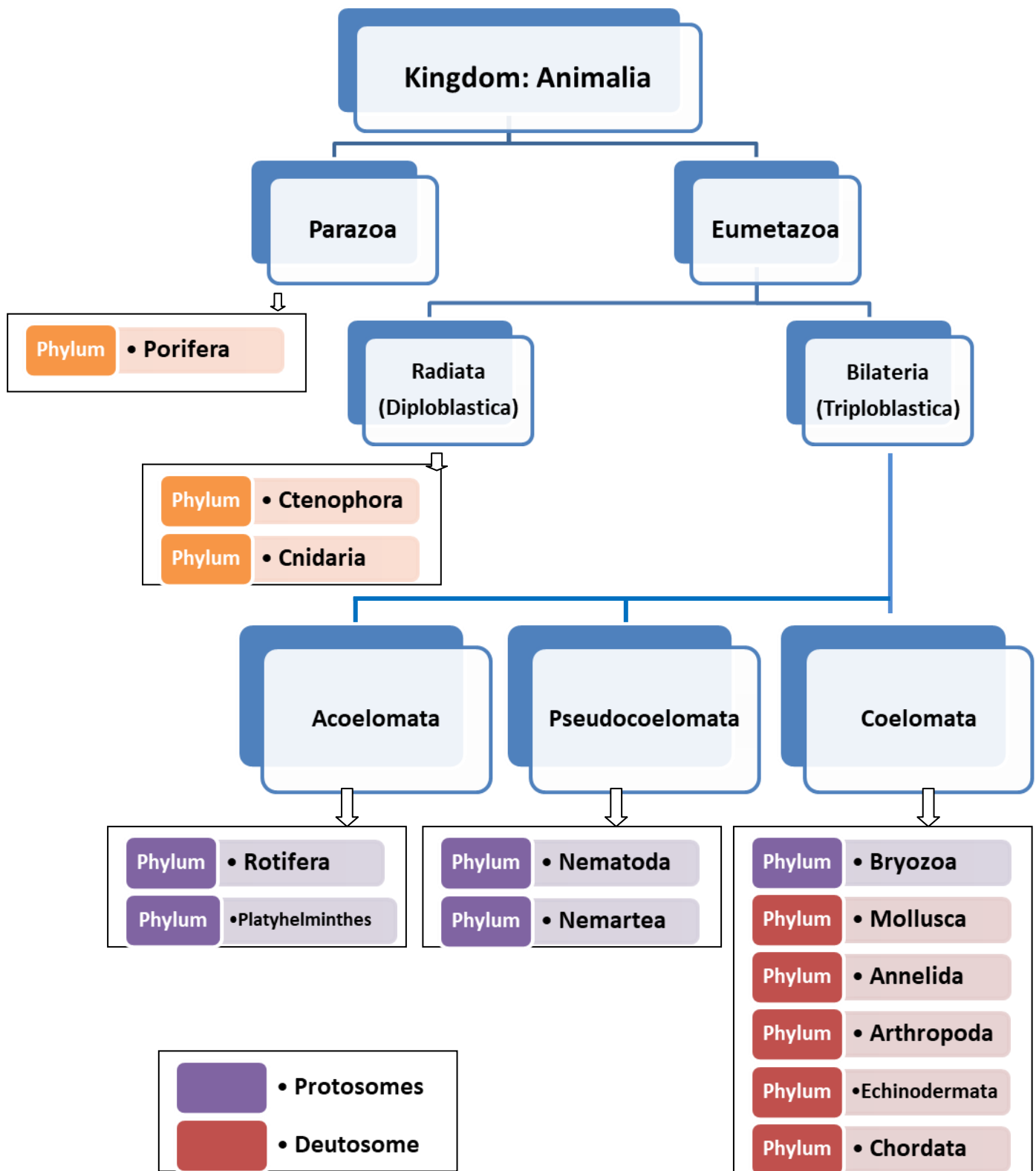


Fig. (3-5): Classification of Animal Kingdom.

SUBKINGDOM: PARAZOA

4. Phylum: Porifera (Sponges)

Parazoa literally translated as "beside the animals". They are aside from the mainstream of animal evolution; thus they are often called Parazoa. Parazoa includes only one phylum: Porifera (Sponges). Sponges are sessile²⁴⁶ and mostly marine animals which show little or no detectable movement. They are regarded as the most primitive multicellular animals that possess no proper organs. More than 10,000 species have been described to date.

4.1. GENERAL CHARACTERS OF PORIFERA

The sponges are intermediate between Protozoa and Metazoa. They have the following characters:

1. They are sessile and aquatic (mostly marine). They depend on water current to bring in food and oxygen and carry away wastes²⁴⁷.
2. The body is multicellular but there is no coordination²⁴⁸ between the activities of the cells and therefore, they do not form proper tissues²⁴⁹.
3. Porifera means pore-bearing. The body is perforated²⁵⁰ by numerous pores, canals and chambers²⁵¹ through them water flows into the central "Paragastric Cavity".
4. They are holozoic and digestion is intracellular²⁵².
5. They respire and excrete by simple diffusion.
6. They have no sensory or nerve cells. So, coordination of their activities is limited.
7. They have a skeleton²⁵³ made of calcareous spicules or organic spongin fibers or both.
8. Reproduction either sexually (by budding and regeneration) or asexually (by forming gametes). Development includes larval stage²⁵⁴ known as "Amphiblastula".

4.2. MORPHOLOGY

Sponges lack symmetry, and unlike all other marine invertebrates, they have no true tissues or organs. Neither do they have nerve or muscle cells. The body of a sponge is hollow²⁵⁵, and composed of a simple aggregation²⁵⁶ of cells, between which there is little coordination. However, these cells perform a variety of bodily functions and appear to be independent²⁵⁷ of each other. The cells are embedded²⁵⁸ in a gelatinous matrix which is supported²⁵⁹ by an internal skeleton of spicules of silica, calcium carbonate, or fibrous protein known as 'spongin'. The sponge's body encloses a vast network of chambers and canals that connect to the open pores on their surface.

4.3. THE COMPLEXITY OF ORGANISATION

Regarding body organization, sponges have three structural grades with increasing complexity which are Ascon, Sycon and Leucon (Fig., 4-1a&b and table, 4-1).

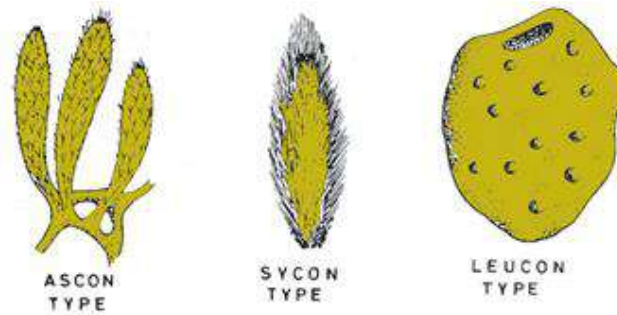


Fig. (4-1a): Grades of sponges (Morphology).

Table (4-1): Comparison between grades of sponges.

Characters	Ascon	Sycon	Leucon
Colonisation	• Live in colony	• Solitary.	• Solitary.
Shape	• Tube or vase – shaped.	• Vase – shaped.	• Spherical.
Body wall	• Thin and perforated.	• Thick and folded.	• Thick and highly folded
Paragastric cavity	• Lined with flagellated cells.	• Flagellated chamber lined with pinacocyte	• Very Reduced
Water current passes through:	1-Ostia. 2-Paragastric cavity. 3-Osculum ²⁶⁰ .	1-Ostia ²⁶¹ . 2-Inhalant canal. 3-Flagellated chamber. 4-Paragastric cavity. 5-Osculum.	1-Ostia. 2-Inhalant canal. 3-Subdermal cavities. 4-Flagellated chamber. 5-Exhalant canal. 6-Paragastric cavity. 7-Osculum.
Example	• <i>Leucosolenia</i>	• <i>Sycon</i>	• <i>Euspongia</i>

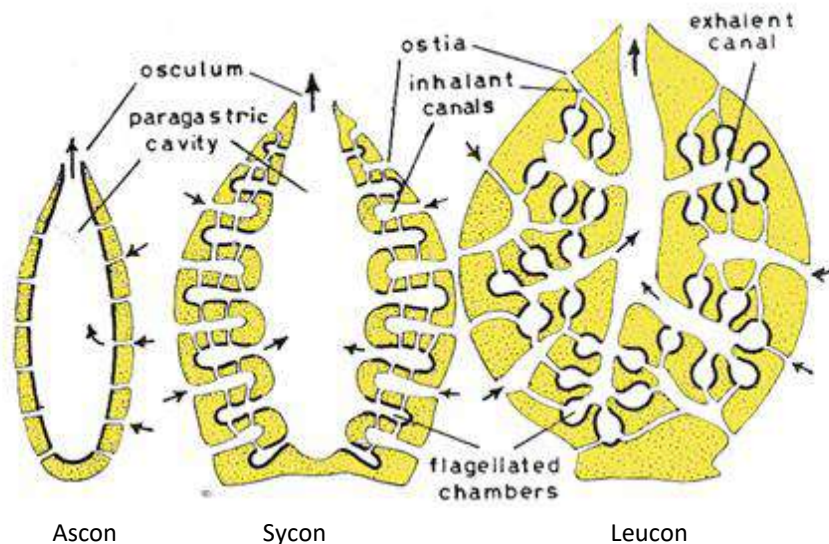


Fig. (4-1b): Grades of sponges(L.S.).

4.4. BODY WALL

The body wall consists of two layers: Outer dermal layer²⁶² and Inner gastric layer²⁶³. (Fig., 4-2).

Dermal layer

Consists of two layers:

1. **Outer covering layer:** of thin flattened cells known as *pinacocytes*.

2. **Inner skeletogenous layer:** which contains scattered cells embedded in a jelly substance. These cells are:

a. Scleroplasts: Which secrete spicules.

b. Amocbocytes: They wonder²⁶⁴ in the jelly substances and act to:

- Transport food and other substances.
- Give rise to the reproductive cells.
- They can differentiate²⁶⁵ into any cell type.

C. Porocytes: Tubular cells which form the pores.

Gastric layer

- Consists of **choanocytes**²⁶⁶: These are rounded cells with flagellum and collar and lining²⁶⁷ the paragastric cavity (Fig., 4-3).
- Their functions are:
 - Collection and digestion of food particles.
 - The beating of their flagella create the water current.

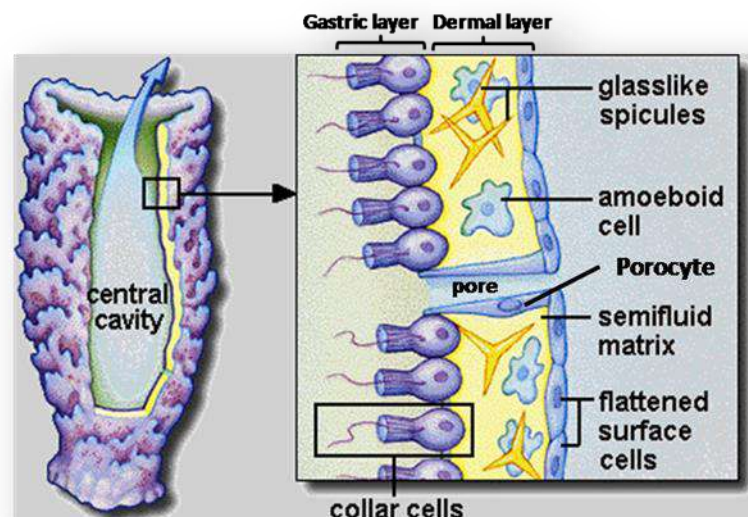


Fig. (4-2): Histological structures of sponges.

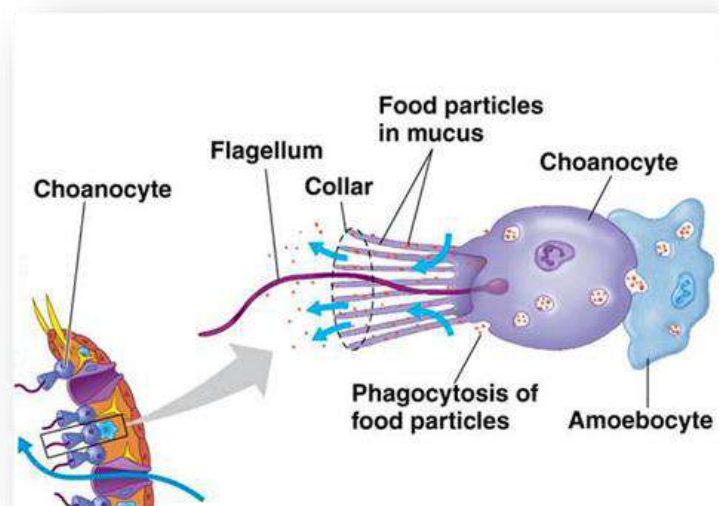


Fig. (4-3): Structure of choanocyte.

4.5. SKELETON

All sponges have a definite skeleton which provides a framework that supports the animal. It may be mineral in nature (calcareous or siliceous) or composed of protein and other components (spongin fibers).

The mineral skeleton is formed for the most parts by units called spicules, either scattered throughout the sponge or united to form fibres; spicules are classified as **megascleres**, which function in support, and **microscleres**, which function in protection and also add in support. Some are composed of a calcareous skeleton while others use silica for the same purpose. Still others are comprised of a softer spongy material known as **spongin**. In all species, however, this skeleton is made up of a complex arrangement of spicules, which are spiny strengthening rods with a crystalline appearance. The skeleton of sponges is of great taxonomic significance (Fig., 4-4).



Fig. (4-4): Skeleton of sponges.

4.6. WATER CURRENT²⁶⁸

Sponges feed by drawing²⁶⁹ a current of seawater in through their entry pores, **the ostia**, (sing., ostium) to the paragastric cavity, filtering out food particles, then ejecting²⁷⁰ the water out through their exit pores, **the oscula**. This flowing water provides²⁷¹ both food and oxygen, as well as being a means for waste removal²⁷² (Fig., 4-5).

4.7. NUTRITION & RESPIRATION

In general, sponges feed by filtering bacteria from the water that passes through them. Some sponges trap²⁷³ about 90% of all bacteria in the water they filter, but others appear to be less efficient²⁷⁴ at capturing bacteria. These may specialize in feeding on other organisms or smaller bits of organic matter. Still other sponges harbour²⁷⁵ symbiotic²⁷⁶ unicellular algae such as green algae, dinoflagellates, or cyanobacteria, which supply them with food and allow salt accumulation for the skeleton. Sponges are characterized by the possession of a feeding system unique among animals. Unlike all other animals, Poriferans do not have mouths. Instead²⁷⁷, they simply pump²⁷⁸ water through their bodies, drawing it in and expelling it via pores. Food particles (such as diatoms, protozoa, etc.) suspended in water adhere to the outer surface of the collar of the choanocytes. They are then passed down to the base of the choanocytes where they

become ingested by these cells then passed to the amoebocytes to complete their digestion. Intracellular digestion occurs within food vacuoles. The digested food is then distributed into other cell types. Deprived of²⁷⁹ its nutrients, the water is then expelled through the oscula.

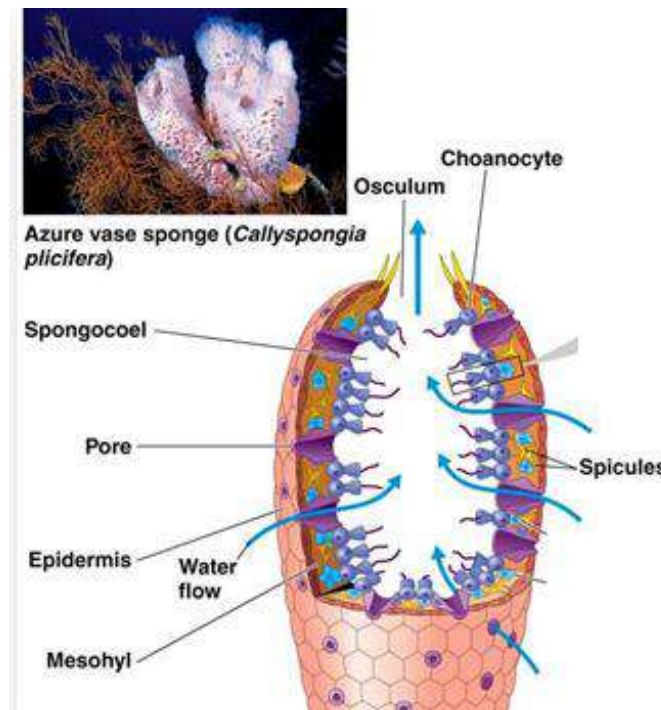


Fig. (4-5): Water current of sponges.

4.8. REPRODUCTION

4.8.1. Asexual reproduction:

- Budding.** Sponges usually reproduce by developing buds which grow to form new individual. The buds may be separated or remain attached to form a colony.
- Regeneration.** Sponges have the capacity²⁸⁰ to replace lost parts. If a living sponge is broken into pieces, or even blended²⁸¹, the cells aggregated and a complete individual may grow from each piece. This process is known as "somatic embryogenesis".

- Gemmule formation.** In unsuitable conditions, fresh water sponges develop internal buds known as gemmules. Gemmules are developed from a group of amoebocytes rich in food reserves which gather²⁸² and become surrounded by protective cyst (Fig., 4-6). As the sponges die, gemmules are freed.

Gemmules withstand²⁸³ unfavourable conditions. When conditions become favourable, a small pore, aggregate and grow into a new sponge.

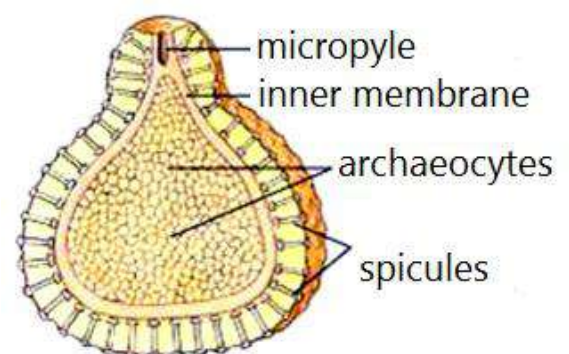


Fig. (4-6): Gemmule of sponges

4.8.2. Sexual reproduction (Fig., 4-7):

Sponges may be unisexual (i.e. there is male and female) or hermaphrodite²⁸⁴. The process of sexual reproduction requires the production and release of large numbers of male sperm cells that are often released in dense clouds. Fertilization takes place and a zygote is formed. Zygote divides forming single – celled **blastula** that gradually developed into **amphiblastula**. The amphiblastula escapes and lives as free swimming larva for some times thus disposing²⁸⁵ the species. The amphiblastula then rotates. The flagellated cells invaginate²⁸⁶ so that a double wall **gastrula** is formed.

1. The gastrula soon settle down on the rocks and develops into a sponges. Where:
Flagellated cells ----► choannocytes and Granular cells -----► Pinacocyts.

4.10. SOME ECONOMIC IMPORTANCE OF SPONGES

The soft elastic skeletal frameworks of certain species of the class Demospongiae, as *Spongia officinalis*, *S. graminea*, *Hippospongia communis*, have been familiar household items since ancient times. In ancient Greece and Rome, sponges were used to apply paint, as mops²⁸⁷, and by soldiers as substitutes for drinking vessels. During the Middle Ages, burned sponge was reputed²⁸⁸ to have therapeutic value²⁸⁹ in the treatment of various diseases. Natural sponges are now used mostly in arts and crafts²⁹⁰ such as pottery²⁹¹ and jewelry making²⁹², painting and decorating, and in surgical medicine. Synthetic sponges have largely replaced natural ones for household use. Below are some other uses of sponges.

A. As Food for other organisms

Even though sponges are rarely taken as food by other animals, crustaceans²⁹³ are found leading parasitic life on them and some molluscs²⁹⁴ like nudibranchs²⁹⁵ depend on them for their diet.

B. As commensals²⁹⁶:

Sponges serve as protective houses for animals like crustaceans, molluscs, small fishes, etc. In addition to the protection, the animals that live inside the sponge get a rich food supply from the water circulating through them. Moreover, Sponges allow certain forms of algae to live on their surface.

C. Commercial uses:

The dried, fibrous skeleton of many sponges like *Spongia*, *Hippospongia* and *Euspongia* are used for the purpose of bathing(bath sponges), polishing, washing cars, walls, furnitures, and scrubbing floor etc. The skeleton of some sponges like *Euplectella* are of great commercial value and used as decorative pieces.

D. Medical uses:

Some chemical substances secreted by sponges have anti-inflammatory²⁹⁷, antibiotic and anti-tumoral activities and are used in the production of medicines.

The Venus Flower Basket - Symbol Of Love

One of the most beautiful of all the creatures that live in the oceans is the rare and very seldom seen Venus Flower Basket (*Euplectella aspergillum*). It only grows on the ocean floor at depths of three thousand to five thousand feet, in the warm tropical waters of the South Pacific, mostly around the Philippines and Japan. This glass sponge of the Class Hexactinellida frequently acts as hosts to other organisms. One of the most intriguing²⁹⁸ of these symbiotic relationships concerns decapods shrimps of the Family Spongicolidae, known as wedding shrimps. These shrimps enter the sponge at a pre-reproductive stage and eventually form sexual pairs that remain entrapped within the sponge for the rest of their lives. The shrimp inside of the basket clean it, and in return, the spongocoel offers a secure environment for the shrimps, with its constant circulation of clean water, a continuous supply of food particles and relative safety from many predators. It is also speculated that the bioluminescent light of bacteria harnessed²⁹⁹ by the sponge may attract other small organisms. Male and female shrimps breed, and when their offspring are tiny, the offspring escape to find a Venus Flower Basket of their own.

It has long been the custom in Asian culture, particularly in Japan, to present the dried skeleton of a glass sponge containing the pair of shrimps as a wedding gift. This is to celebrate the lifetime bond that will hopefully exist between the bride and groom, The Japanese name for hexactinellid sponges, Kairou-Douketsu (meaning “**together for eternity**³⁰⁰”), reflects this long term involvement.



The Venus Flower Basket



Sponge dwelling shrimp

B. SUBKINGDOM: EUMETAZOA

i. GRADE: RADIATA

Grade Radiata includes organisms whose body parts are organized around a central axis and radiate from the central core like the spokes of a wheel exhibit.

5- Phylum : Cnidaria³⁰¹

Cnidaria (Gr. *knide* = nettle³⁰²) includes the polyps, hydroids, jellyfishes, sea anemones and corals. They are first multicellular animals to have tissues, a digestive cavity and two germ layers. Cnidarians show a distinct advance³⁰³ in structure over the Porifera., their cells are much more specialized, with a higher coordination than in sponges, maintained by unpolarized nervous system in the form of a network. Similar cells, therefore work together to perform a common function, thus begin to form “tissues” . On other word, they reach the tissue grade of organization. This phylum includes plant-like colonies of colourful sea anemones³⁰⁴, massive reef-building corals³⁰⁵, as well as the free swimming jelly fishes³⁰⁶.

5.1. GENERAL CHARACTERS OF CNIDARIA

Cnidarians show the following characters:

1. They are simple aquatic, mostly marine and radially symmetrical.
2. They possess central cavity known as *Coelenteron* or “*Gastrovascular cavity*” opened by a single opening.
3. They are diploblastic i.e. the body is formed of two layers, an outer ectoderm and an inner endoderm separated by mesoglea.
4. They are the only animals which possess **nematocysts** (stinging cells³⁰⁷ used for defense³⁰⁸ and food capture).
5. The digestive cavity have a single opening which serves as both mouth and anus³⁰⁹ (incomplete digestive system). Digestion is partly extracellular³¹⁰ (in the gastrovascular cavity) and partly intracellular³¹¹ (inside the endodermal cells).
6. Respiration and excretion takes place by simple diffusion.
7. They possess a simple nerve net.
8. They reproduce asexually,by budding or regeneration, and sexually, by formation of gametes.

They exhibit the phenomenon of **alternation of generations** i.e. most cnidarians exhibit two different forms in the life cycle (Fig., 5-1):

- **Hydra – like polyp**: sessile hydroid form.
- **Medusa** : free – living jelly fish.

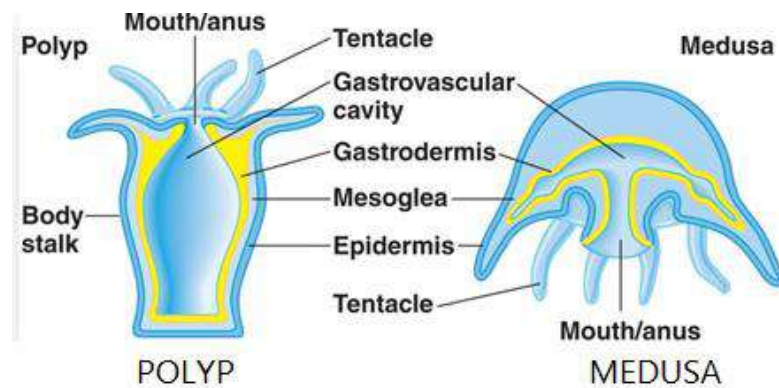


Fig. (5-1): Dimorphism in Cnidaria

5.2. CLASSIFICATION OF CNIDARIA

Cnidarians are classified into four classes (table, 5-1) which are:

Table (5-1): Classification of Cnidaria

CLASS	MAIN CHARACTERS	EXAMPLE(S)
Hydrozoa	➤ Most marine, few freshwater. ➤ Both polyp and medusa in most species. ➤ Polyp stage often colonial.	<i>Hydra – Obelia</i> 
Scyphozoa	➤ All marine. ➤ Polyp stage absent or reduced. ➤ Free swimming medusa up to 2 mm in diameter.	<i>Aurelia</i> 
Actinozoa (Anthozoa)	➤ All marine. ➤ Medusa stage completely absent. ➤ Most sessile; many colonial.	Sea anemon, most corals 
Cubozoa	➤ All marine. ➤ Box shaped medusa. ➤ Complex eyes.	Box jellies, Sea waspes 

5.2.1. CLASS: HYDROZOA

GENERAL CHARACTERS

1. Chiefly marine (few being freshwater) , solitary or colonial.

2. Alternation of generation is the typical form although a suppression³¹² of one phase may exist.
3. Mesoglea non - cellular.
4. Gastrodermis (endodermis) without nematocysts.
5. Medusa with velum, nerve ring and ectodermal gonads.

e.g.1 *Hydra*⁸

HABITAT³¹³ It is a simple cylindrical³¹⁴ cnidarians, lives in cool and clean freshwater ponds, lakes³¹⁵ and streams³¹⁶. It usually attaches to submerged³¹⁷ objects like weeds, sticks and stones near the surface where oxygen is more abundant³¹⁸.

Morphology

Its size ranges from 2 to 20 mm in length. *Hydra* has a tubular body attached to the substratum by a simple adhesive³¹⁹ foot called the **basal disc**³²⁰. Gland cells in the basal disc secrete a sticky fluid that allows for attachment. At the free end of the body is a **mouth** opening surrounded by 4-12 thin, mobile **tentacles**³²¹. The adult *Hydra* may bear buds and gonads³²² on the surface of its body (Fig. 5-2).

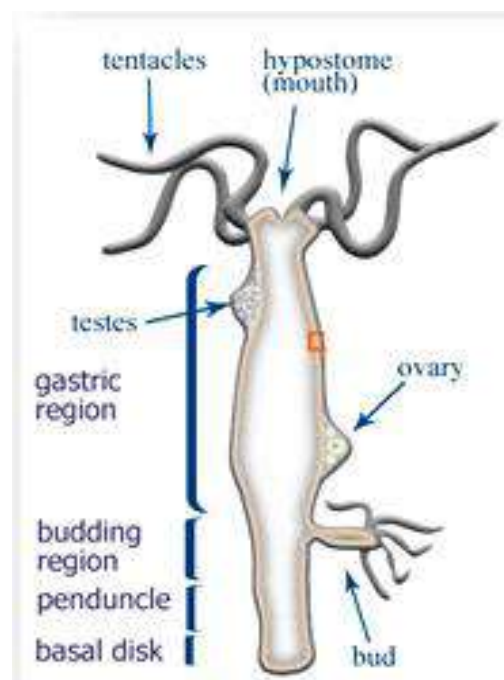


Fig. (5-2): Morphology of *Hydra*

CELLULAR STRUCTURE (BODY WALL) (Fig., 5-3).

Body wall of *Hydra* is built up of two layers, the outer **ectoderm** and the inner **endoderm (gastroderm)**. Inbetween the two layers there is a jelly – like **mesoglea**. The different cell types are listed in Table (5-2):

⁸ a many-headed snake whose heads grew again as they were cut off, killed by Hercules...

Greek myth a monster with nine heads, each of which, when struck off, was replaced by two new ones a many-headed serpent or monster in Greek mythology that was slain by Hercules and each head of which when cut off was replaced by two others

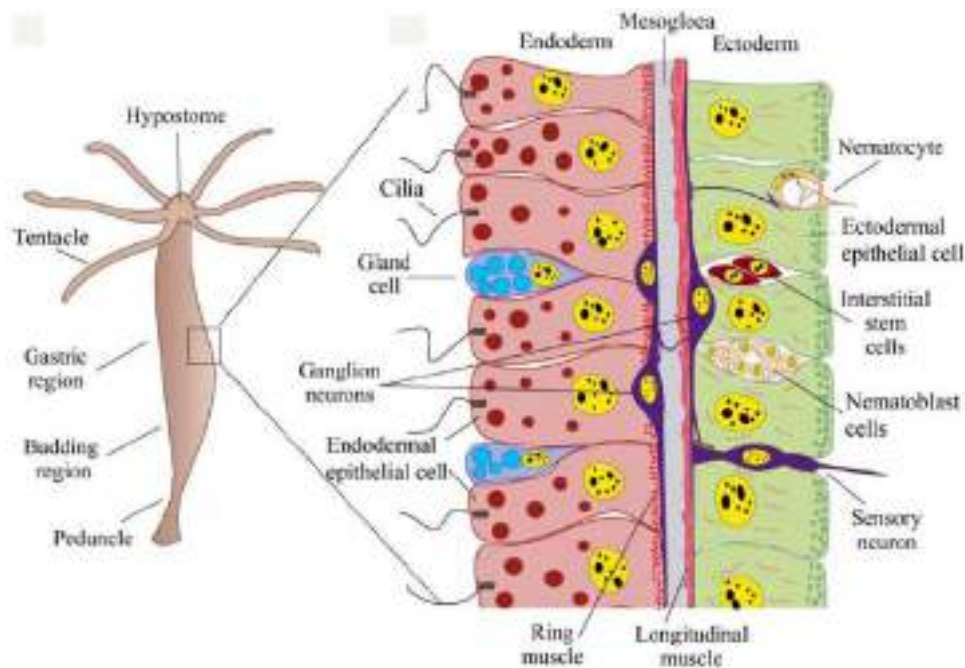


Fig. (5-3): Histological structures of body wall of *Hydra*

Table (5-2): Types of cells found in the body wall of *Hydra*.

Layers	Cell type	Structure	Function
Epidermis	▪ Ectodermal epithelial cells	Large cone- shaped cells.	• Movement. • Support. • Secrete thin cuticle.
	▪ The interstitial cells ³²³	Small rounded cells.	• They can differentiate into any cell type including gametes³²⁴.
	▪ The nerve cells (Neurons)	Each consists of cell body and two or more fibrils that connect to form a nerve – net ³²⁵ .	• Coordinate the activities of all cells.
	▪ The sensory cells ³²⁶	Narrow columnar cells connected with the nerve net.	• Have a sensory function.
	▪ The mucous cells ³²⁷	They are most numerous on the basal disc and contain a large number of secretory granules.	• Produce mucous secretion for attachment.
	▪ The cnidocytes ³²⁸ (Nematoplasts)	See above	• Food capture • Defense • Locomotion
Mesoglea	• Inbetween ectoderm and endoderm lies a thin homogeneous³²⁹ acellular layer known as mesoglea that acts as a basement membrane³³⁰ for cells and have some muscle fibers.		
Endoderm (Gastrodermis)	Endodermal epithelial cell (musculo-nutritive cell)	Tall columnar cells have muscle tails. Some carry flagella and others produce pseudopodia.	• Engulf food for intracellular digestion inside food vacuoles • Its flagella create a current inside the gastrovascular cavity.
	▪ The gland cells	-Without muscle tails. -Did not reach mesoglea	• They secrete enzymes for extracellular digestion.
	• In addition, Interstitial cells, Nerve cells, Sensory cells are also found in the gastrodermis		

The cnidocytes (Nematocysts):

These are specialized cells lie in groups specially on tentacles. Cnidocytes contain specialized structures called nematocysts with a coiled thread inside (Fig., 5-4). At the narrow edge of the cnidocyte is a short trigger³³² hair called a **cnidocil**. Upon contact with a prey³³³, or an enemy, the contents of the nematocyst are explosively discharged³³⁴, firing a dart-like thread³³⁵ containing toxic substance which can paralyse³³⁶ the prey.

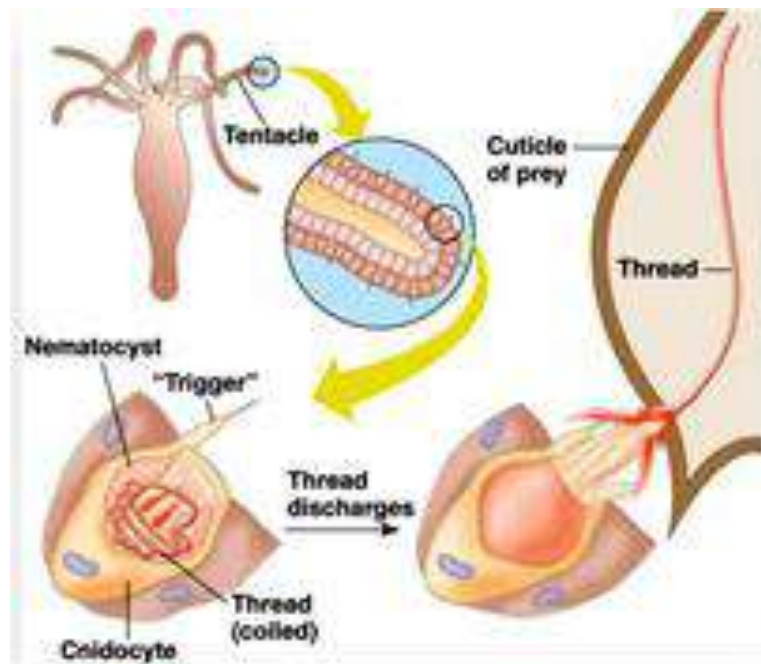


Fig. (5-4): Structure of cnidocyte.

Three kinds of nematocysts (Fig., 5-5) were found in *Hydra*:

1-Penetrant³³⁷ nematocysts. (Fig., 5-4)

It is the largest and has armed thread tube. When this type is stimulated³³⁸ from a prey or an enemy, water rushes inside the capsule, which swells up. The lid is forced open, the thread is suddenly shot out of the capsule and pierces³³⁹ the skin of the prey or the enemy causing a paralysis by the action of poisonous secretions

2-Volvent³⁴⁰ nematocyst

It is similar to the penetrant one, but smaller and its thread is smaller. The thread is discharged and wrapped around³⁴¹ the processes³⁴² of the prey's body thus seizes it.

3. Glutinat mematocytes which are of two types:

- **Small** :have long armed adhesive thraed.
- **Large** :have long unarmed adhesive thread.

Both respond to mechanical stimuli and used for food collection and locomotion.

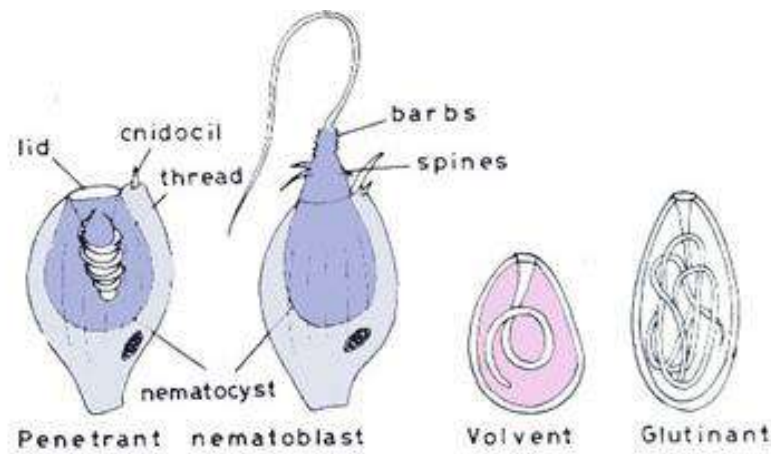


Fig. (5-5): Types of cnidocyte

LOCOMOTION

Hydra is essentially sessile and lives attached to the substratum. Occasionally³⁴³ it moves from one place to another by one of the following methods (Fig., 5-6):

a-Gliding³⁴⁴

Hydra can glide over the substratum with the help of mucous secretions and amoeboid movement of the cells of the basal plate .

b-Walking

1. The animal elongates its body, bends over³⁴⁵ and then attaches the tentacles to the substratum with the help of glutinate nematocysts.
2. The basal disc is then freed and moved near the tentacles where it attached.
3. The tentacles are then freed, the body assumed an upright position and the process is repeated (Fig., 5-6).

c-Somersaulting³⁴⁶

1. The animal elongates, bends over and attaches the tentacles to the substratum.
2. It then frees its basal disc, swing³⁴⁷ it over the tentacles and attaches it to the substratum on the other side of the tentacles.
3. The tentacles are then freed, the body assumed an upright position and the process is repeated (Fig., 5-6).

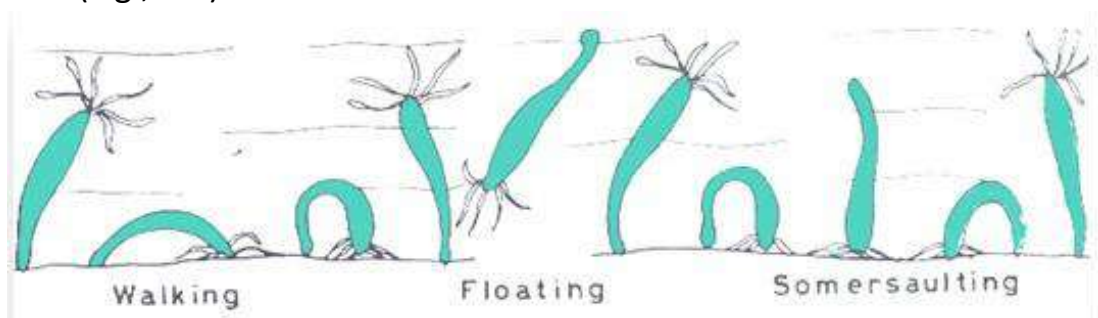


Fig. (5-6): Locomotion in *Hydra*

d-Floating

Sometimes *Hydra* floats on water surface with current. Its pedal disc's gland cells sometimes secrete gas which assumes the shape of an air bubble. Due to this air

bubble *Hydra* detaches³⁴⁸ itself from the substratum and hangs obliquely downward and thus floats along (Fig., 5-6).

NUTRITION

a- Feeding: *Hydra* is mainly holozoic and carnivorous. It feeds on small aquatic organisms which present within the reach of its tentacles. If such organism touches one of the tentacles, a large number of nematocysts shot into it and thus the prey is paralyzed. The tentacles then cooperate³⁴⁹ to bring the prey to the mouth. The mouth swallows³⁵⁰ the prey and passes it into the gastrovascular cavity.

b- Digestion: Digestion occurs in two phases:

- *Extracellular digestion:* The prey is partially digested within the gastrovascular cavity by the action of digestive enzymes secreted from glandular cells.
- *Intracellular digestion:* Partially digested food is engulfed³⁵¹ by the endodermal epithelial cells where the process of digestion is completed inside food vacuoles. The digested food is then distributed to all parts of the body by diffusion from cell to cell.

c- Egestion Undigested remains are passed into the gastrovascular cavity and then expelled³⁵² through the mouth, which therefore acts as an anus. Therefore the digestive system is incomplete.

REPRODUCTION

a-Asexual reproduction (Fig., 5-7).

Hydra has high ability of regeneration and budding due to the presence of interstitial cells

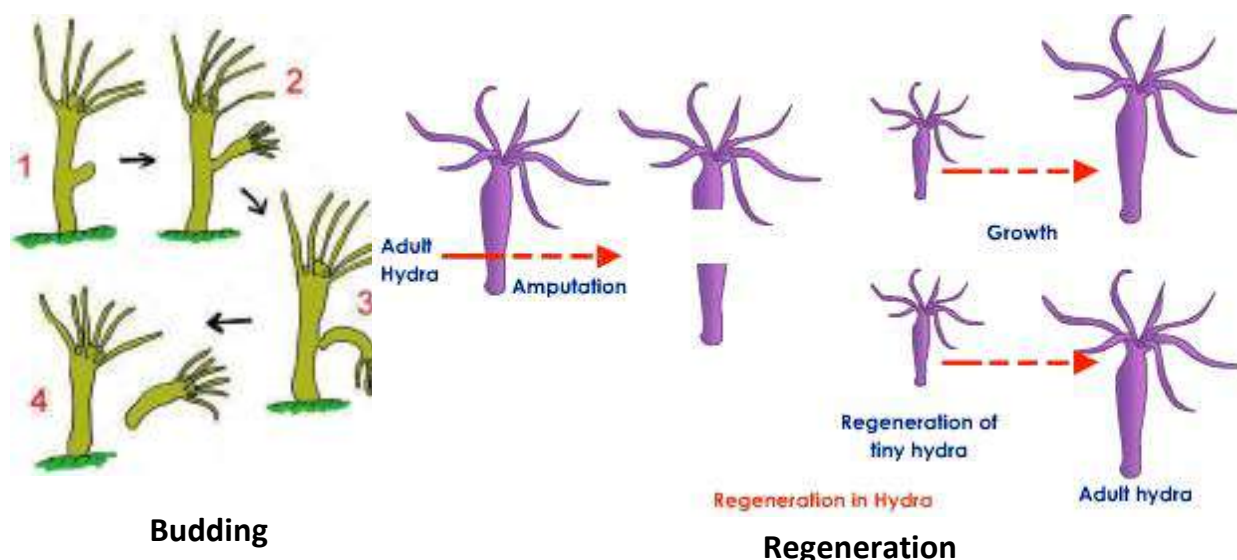


Fig. (5-7): Asexual reproduction in *Hydra* .

1-Budding³⁵³

- a. A protrusion occurs at one side of the body and grows gradually to form a bud.
- b. A crown of tentacles is formed
- c. The bud detaches from the body to form a new individual

2 - Regeneration *Hydra* has a great ability of regeneration due to the presence of a large number of interstitial cells. If *Hydra* is cut into pieces, each piece will develop into a complete individual.

b-Sexual reproduction (Fig., 5-8).

With the beginning of an unfavourable season, *Hydra* starts to develop gonads and reproduce sexually as following:

1. Some species of *Hydra* are hermaphrodite and in others the sexes are separate. However, the ovary produces one mature ovum while the testis produces a large number of sperms which discharge and are carried out by water to fertilize the ova inside the ovary of another individual.
2. After fertilization, the zygote undergoes repeated division (cleavage) forming a single-layered hollow **blastula** with a central cavity known as blastocoel.

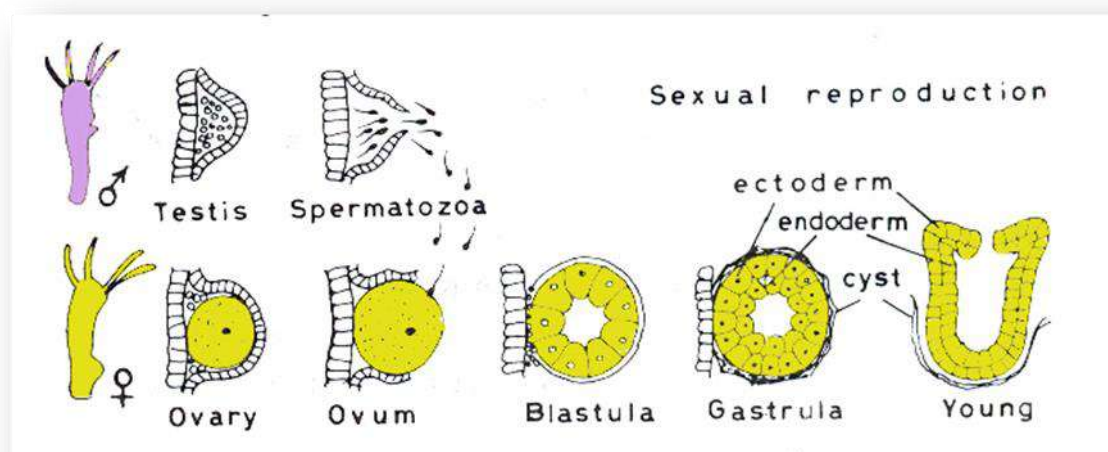


Fig. (5-8): Sexual reproduction in *Hydra*

3. The embryo then develops into **gastrula** in which the cells become arranged in two layers; the outer ectoderm and the inner endoderm.
4. The embryo secretes a protective cyst around itself and settles in the bottom.
5. When the environmental conditions improved³⁵⁴, the embryo escapes from the cyst, gradually elongates, attaches at one end and develops tentacles and mouth at the other end. The cells differentiate and the embryo develops into a young *Hydra*.

Immortality Of Hydra

P. Brien(1955) and others observed that Hydra is at least potentially immortal. Just below the tentacles, there is a growth zone where interstitial cells give rise to all other cell of

the body. With the formation of new cells, old cells are pushed towards the end of tentacles and oral discs, from there they are shed out. In about 45 days the older body cells are replaced. This process of cell replacement is an endless process. It has also been shown that, if interstitial cells of growth zone are destroyed, then Hydra live only for few days.

.g₂ Obelia⁹

This is a marine cnidarian which is **dimorphic**. i.e. it exists in two forms which alternate in the life cycle (Hydra – like polyp or colony & Medusa).

1. THE COLONY (Fig., 5-9a):

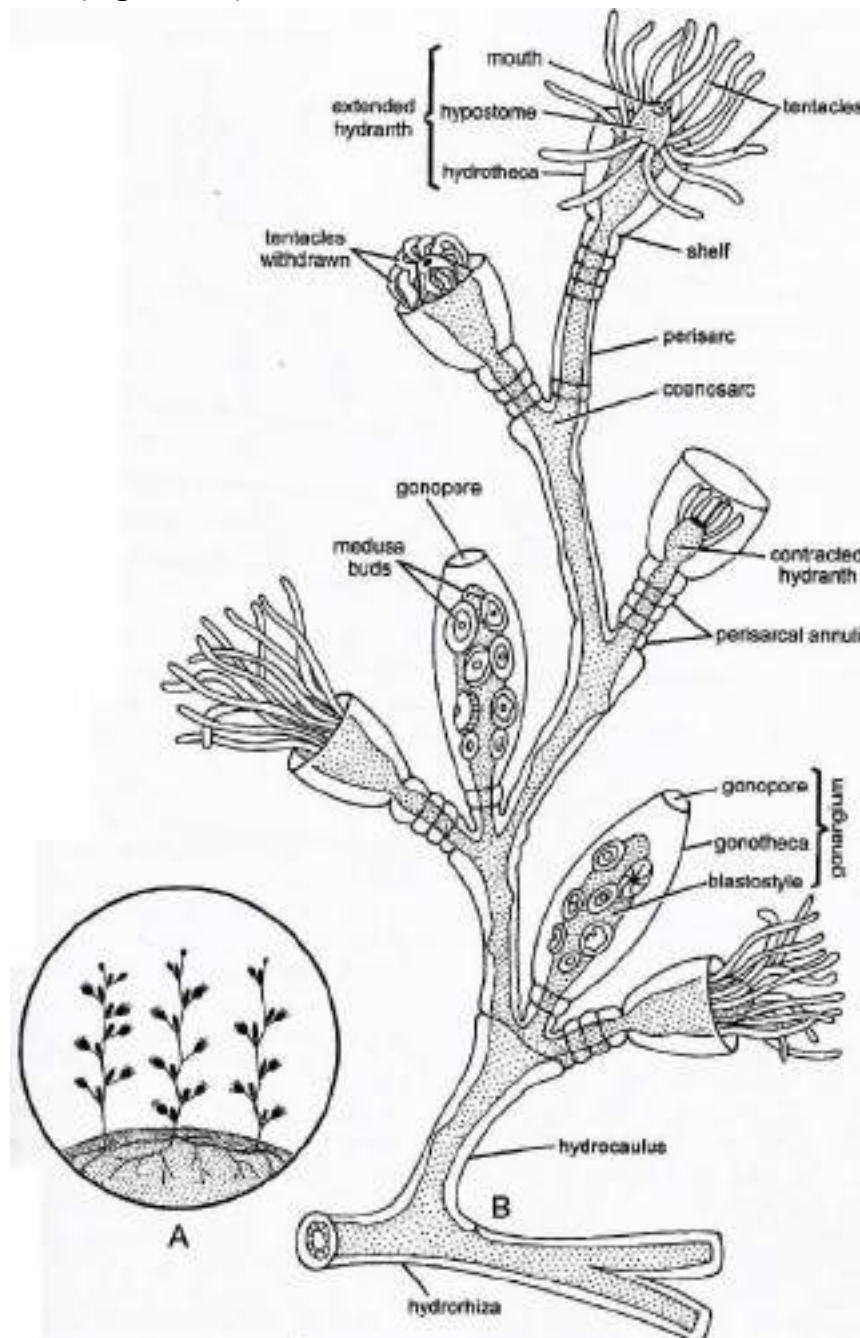


Fig. (5-9a): Colony of Obelia.

⁹ = a narrow fascia or band of colour

The colony of *Obelia* consists of a branching root-like horizontal portion known as the **hydrorhiza**, which extends over the surface of the substratum, and one or more upright stems, each called a **hydrocaulus**. Short branches arise alternately on both sides of the hydrocaulus; each ending in a small individual or polyp. The polyps are of two kinds ; hydranth and blastostyle.

- a. **Hydranth**: It is hydra-like polyp, has mouth and tentacles and covered with *hydrotheca*. The hydranths feed the colony in a similar way as in *Hydra*. They capture small organisms by means of their tentacles which are richly supplied with nematoblasts (cnidocytes). The paralyzed prey is passed through the mouth into the gastrovascular cavity of the hydranth where digestion starts. Partly digested food is then circulated through the whole colony by the beating of the flagella of the endodermal cells. The food is thus distributed to all parts of the colony and digestion is completed within food vacuoles in the endodermal cells.
- b. **The blastostyle**: This is a modified³⁵⁵ polyp which usually develops in the angles where hydranths arise. It is an elongated hollow body which has no mouth or tentacles and enclosed within *gonotheca*. Its function mainly in asexual reproduction to produce medusa by budding.

2. **THE Medusa** (Fig., 5-9b): This is a small free living with bell- like body. Tentacles 16 in young and numerous in adult. The gastrovascular cavity is restricted and differentiated into manubrium, four gastric cavity, four radial canals and circular canal. There are eight sense organs, the statocysts. The medusa brings about sexual reproduction and dispersion. it has four gonads and reproduces sexually by gametes (sexual generation).

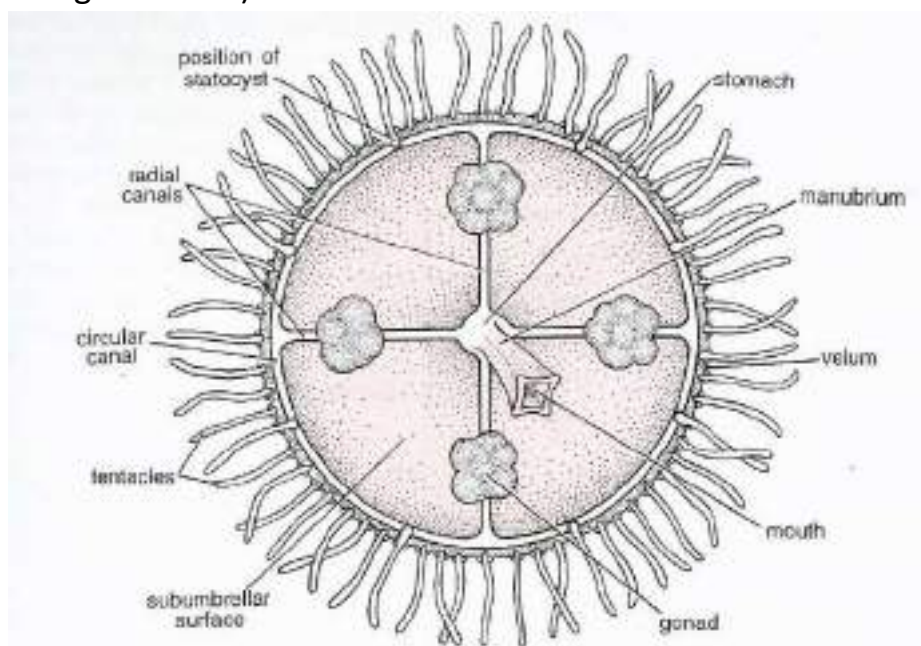


Fig. (5-9b): Medusa of *Obelia*.

The differences between polyp and medusa are summarized in table (5-3)

Table (5-3): Comparison between polyp and medusa of *Obelia*

Hydroid Polyp	Medusa
• Live in colony. • Body is long and cylindrical. • Fixed zooid. • Enclosed in protective hydrotheca. • Tentacles usually 24. • The gastrovascular cavity is a single cavity. • There is no sense organ. • The polyp feeds and protects the colony. • Without gonads. • Reproduces asexually by budding.	• Live solitary • Body is short and umbrella-shape. • Free – living zooid. • Without any covering. • Tentacles 16 in young and numerous in adult. • The gastrovascular cavity is restricted and differentiated into manubrium, radial canals and circular canal. • There are eight sense organs, (the statocysts). • The medusa brings about sexual reproduction and dispersion of the colony. • With four gonads. • Reproduces sexually by gametes.

REPRODUCTION AND LIFE CYCLE

The life cycle exhibits alternation of generation where the colony and medusa alternate in the life cycle. The colony reproduces asexually to produce medusa while medusae reproduce sexually to produce colony.

a-Asexual reproduction Hydroid colony of *Obelia* reproduces asexually by budding. The colony increases in size and adds new stems, hydranths and blastostyles by budding. The blastostyle also produces medusae by budding. When fully developed, the medusae escape and swim freely in water.

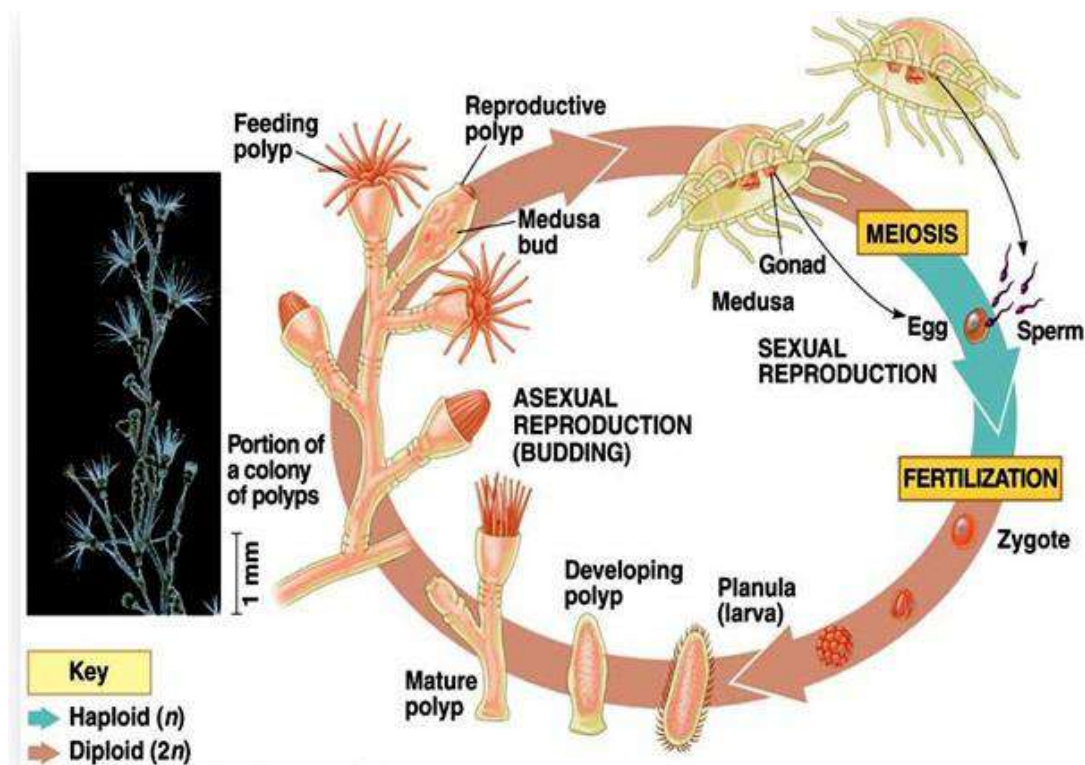


Fig. (5-10): Life cycle of *Obelia*.

b-Sexual reproduction (Fig.,5-10).

The male and female medusae are separate. The medusae reproduce sexually by producing gametes as following:

1. The mature ova and sperms are shed into seawater by rupture of gonads.
2. After fertilization, the zygote develops into **planula larvae**.
3. The planula larva swims freely with the help of cilia and settles on the rock.
4. It fixes itself and developed into a small polyp.
5. The small polyp gives rise to a new colony by repeated budding.

1.3. ECONOMIC IMPORTANCE OF CNIDARIA

1.3.1. RELATION WITH OTHER ORGANISMS

The cnidarians are predaceous. Many forms carry on relationship with them as they could easily be used as food. Various types of relationships with other animals can be studied under following headings:

a. Commensal relations

Commensalism is a phenomenon where one organism living in or on another, with only one of the two benefiting³⁵⁶. Many hydroids live commensally on sponges, molluscs and floating plant species. For example, *Hydractinia* grows on the shell of some snails. Hermit crab (*Eupagurus prideauxi*) can recognize the particular species of sea-anemones by touching. The hermit crab carries the anemone about in an inseparable partnership where the crab moves to a large shell due to growth. The anemone is also detached and placed on the new shell. The hermit crab is protected from its enemies by the stinging power of the anemone due to nematocysts and may share food caught by the anemone. In return, the anemone also benefits as it is carried about by the hermit crab getting better chances to obtain food and also shares food particles dropped by the crab. This is an example of *mutualism*³⁵⁷.

b.Symbiotic relations

Several species of unicellular algae called *Zooxanthellae* live as intracellular symbionts in the gastrodermal cells of different regions in a number of cnidarians. During day time the algae produce oxygen by photosynthesis by utilizing carbon dioxide which is produced by the cnidarians' cells' respiration. During photosynthesis food and oxygen are produced which are utilized by the cnidarians.

5.3.2. RELATIONS TO MAN

a. Food : as food, the cnidarians are little used by man. However, some jelly fishes are eaten in the oriental region. Two species of sea-anemones are also eaten in Italy under the name of Ogliole.

b. Corals : The stony corals produce calcareous reefs and ultimately dry lands. Corals of geological part were favorable sites for accumulation of petroleum deposits. The hard coral lime can be used for building purposes.

c. Decorative materials: Some corals are very beautiful and have been used in decorative art from old times. The red coral commonly known as *red moonga* is used in jewellery. Others are used in indoor aquariums ..etc.

d. Biological experiments: Cnidarians are used in laboratories to demonstrate the phenomenon of budding, grafting, regeneration etc .

e. Harmful cnidarians: The cnidarians, possessing the nematocysts or stinging cells directly affecting man . *Aurelia* can produce an uncomfortable³⁵⁸ burning sensation. *Physalia*, the Portuguese man-of-war, is one of the most dangerous free-swimming species.. It can inflict³⁵⁹ painful and often serious stings. Its poison is neurotoxic affecting the nervous system to man and brings about collapse and unconsciousness³⁶⁰ .

B- GRADE: BILATERIA

In contrast to the Radiata (Cnidaria and Ctenophora), the remaining eumetazoa phyla: the Bilateria are characterised by bilateral symmetry, i.e. the body can be divided into two symmetrical halves through one plane (Fig., 6-1). Bilateral symmetry starts early in development but may be masked³⁶¹ later by secondary radial condition, as in echinodermates³⁶², or only modified by spiral coiling as in gastropod molluscs. A definite anus is common to all bilateral phyla except platyhelminthes³⁶³.

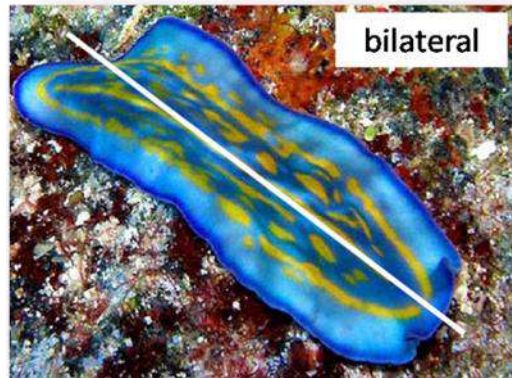


Fig . (6-1): Bilateral symmetry

All Bilateria are triploblastic (i.e. with three germ layers: ectoderm, mesoderm and endoderm) (Fig., 6-2).

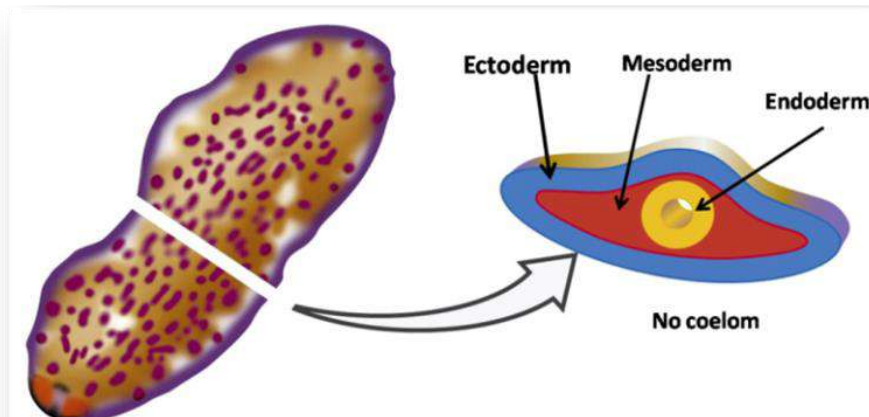


Fig 6-2): All Bilateria are tribloplatic.

According to the type of body cavity (coelom), the Grade: Bilateria is divided into three subgrades namely: Acoelomata, Pseudocoelomata and Coelomata.

i.Subgrade: Acoelomata

The acoelomates are radiates which lack body cavity. The mesodermal layer arises by cell proliferation from the ectoderm and endoderm and the resulting mesodermal cells fill the whole of the blastocoel (Fig., 6-3). Acoelomata includes only two Phyla: Platyhelminthes and Nemertea.

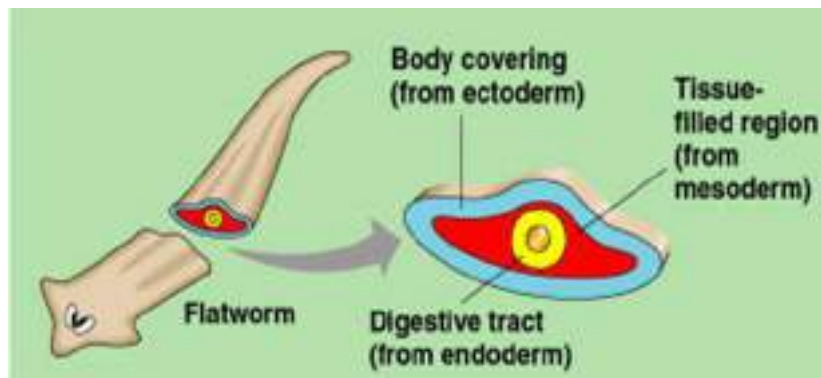


Fig . (6-3): Acoelomate animals have no coelom.

6. PHYLUM: PLATYHELMINTHES (Flat worms)

Platyhelminthes or flat-worms are bilateria with dorsoventrally flattened bodies displaying definite cephalization³⁶⁴. They are the lowest triploblastic animals, and the first to develop distinct organs and systems.

6.1. GENERAL CHARACTERS

1. They are free - living or parasitic triploblastic (i.e. have three germ layers) and acoelomate (i.e. possess no coelom). Parenchyma fills the internal space of the body.
2. They have soft dorsoventrally flattened and bilaterally symmetrical bodies.
3. They display definite cephalization , i.e. the anterior end forms the head.
4. Muscle layers are well developed.
5. The digestive system, if present, is simple with only a mouth, but no anus.
6. Respiratory and circulatory systems are absent.
7. The excretory system consists of a basic units known as **flame cells**³⁶⁵ connected together by one or more excretory ducts³⁶⁶.
8. Nervous system is primitive and ladder-like. It consists of a pair of cerebral ganglia³⁶⁷ (brain) and 1-3 pairs of longitudinal nerve cords³⁶⁸.
9. The majority are hermaphrodite with complicated reproductive system including internal gonads, genital ducts, accessory genital glands³⁶⁹ and copulatory organs.

6.2. CLASSIFICATION OF PLATYHEMLMINTHES

This phylum includes a group of free-living aquatic forms (turbellaria) and two other groups of very important parasites: the flukes (Trematoda) and the tapeworm (Cestoda) (Table, 6-1).

Table (6-1): Classification of Platyhelminthes.

Character	CLASS: TURBELLARIA	CLASS: TREMATODA	CLASS: CESTODA
Habits	Free – living& aquatic	Parasitic & unsegmented.	Parasitic & segmented.
Body wall	Ciliated, without cuticle ³⁷⁰ .	With minute spicules and tegument.	Smooth and with cuticle
Digestive system	Incomplete	Incomplete	Absent.
Nutrition	Carnivorous.	Holozoic feeding.	Saprozoic feeding.
Suckers ³⁷¹	Without suckers.	With two suckers.	With four suckers
Example(s)	<i>Planaria</i>	<i>Fasciola</i> - <i>Schistosoma</i> .	<i>Taenia</i> .



6.2.1. CLASS: TURBELLARIA (TRICLADIDA)

Turbellarian (about 5,000 species) are non-parasitic flatworms. They are common to many parts of the world, living in both saltwater and freshwater (ponds and rivers). Their name is given by Ehrenberg in 1831, refere to the disturbance (turbellae³⁷²) caused in water by their cilia. Some species are terrestrial and are found in or on the soil, and on plants in humid³⁷³ areas. Primarily free-living, planarians are characterized by a soft, broad, leaf-shaped body with cilia and a three-branched digestive tract (as reflected in the name Tricladida).

GENERAL CHARACTERS

1. Unsegmented leaf-like bodies.
2. Have ciliated epidermis without cuticle.
3. The mouth is usually ventral and the pharynx is protractible.
4. Life cycle is simple.
5. Planarians range in size from about 3 to 12 mm. The head has two eyespots known as ocelli that act as photoreceptors³⁷⁴ and are used to move away from light sources.

e.g. Planaria

Planaria inhabits freshwater bonds, streams and springs. It adheres into submerged plants, stones or any other objects.

MORPHOLOGY

The *Planaria* has a soft, flat, wedge-shaped³⁷⁵ body that may be black, brown, gray, or white and is about 1.3 cm long. The blunt, triangular head has two eye pots “ocelli” ; pigmented areas that are sensitive to light. There are two auricles (ear-like projections) at the base of the head, which are sensitive to touch and the presence of certain chemicals. The mouth is located in the middle of the underside of the body, which is covered with cilia. A common genital opening lies behind the mouth (Fig., 6-4).

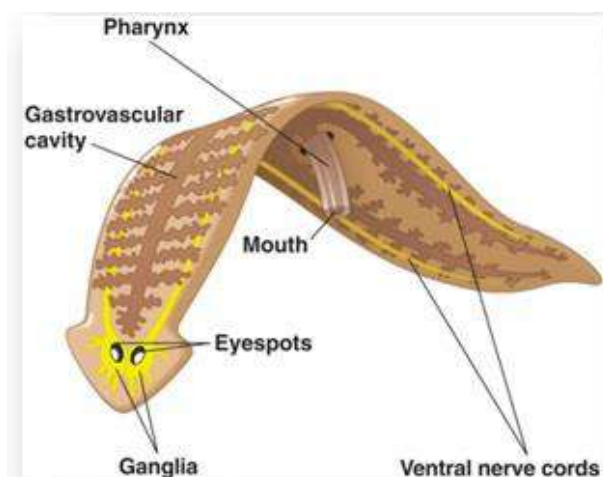


Fig . (6-4): Morphology of *Planaria*.

6.2.2. CLASS: TREMATODA

Trematoda have received a wide spread medical and veterenary³⁷⁶ attention because many species are known to be the causative agents of some diseases of man and his demostic animals³⁷⁷.

CHARACTERS

1. They live as parasites either on or in other organisms.
2. Outer body lacks cilia; tegument has a layer of glycoproteins that are important in protection and absorption.
3. Incomplete digestive system.
4. Possess two suckers:
 - **Oral sucker**³⁷⁸ encircling the mouth.
 - **Ventral sucker** or **acetabulum**; used for attachment to host' tissues.

CLASSIFICATION OF TREMATODA

Trematoda are classified into three orders, **Monogenea**³⁷⁹, **Aspidogastrea** and **Digenia**³⁸⁰ (Table, 6-2). Some taxonomists consider Monogenea as a separate class belong to Phylum Platyhelminthes and others cosidered these three as classes instead of Trematoda.

Table (6-2): Classification of Trematoda

Order: Monogenea (Heterocotylea)	Order: Aspidogastrea	Order: Digenea (Malacocotylea)
• Aquatic ectoparasite. • With direct life cycle. • Use one host. • e. g. <i>Diplozoon</i>	• A small group intermediate between Monogenea and Digenea but nearer to Digenea • e.g. <i>Aspidogaster</i>	• Endoparasite (over 9,000 species). • With complicated indirect life cycle. • Requires two hosts to complete life cycle: • e.g <i>Fasciola</i>

Order: Digenea

CHARACTERS

1. Some are very important parasites of man.
2. Most are hermaphroditic, Schistosomes are exception being dioecious³⁸¹.
3. Some can reproduce parthenogenetically³⁸².
4. Often have complex life cycles that alternate between sexual and asexual stages.
5. Most require at least two different hosts to complete their life cycle:
 - ❖ **Definitive host (primary host)**
 - The host in which the parasite matures and reproduces sexually.
 - The host in which eggs are released.
 - ❖ **Intermediate host**
 - Hosts in which larval stages develop and undergo asexual reproduction.
 - Results in an increase in the number of the individuals.

E.g.₁ *Faciola* (liver flukes³⁸³)

It is a common endoparasite of sheep and cattle (sometimes man). It lives in the bile ducts³⁸⁴ of the liver and causes serious losses in such animal due to destruction of the liver.

MORPHOLOGY

The adult fluk has a leaf –like body, 25-75 mm in length. It has a **head cone** at the anterior end of the body. It has two suckers; **oral sucker** encircling the **mouth** and a **ventral sucker**. The latter is used for fixing the worm to the wall of bile ducts. The **genital atrium** lies between the two suckers while the **excretory pore** is located at the posterior end (Fig.,6-11).

HISTOLOGICAL STRUCTURE (Fig., 6-12a&b).

- **Body wall:** There is no epidermis, instead the body wall consists of thick living **tegument** which represents surface extension of tegument forming cells. Pinocytotic vesicles³⁸⁵ may be present in the tegument. The deep part of the tegument is rich in mitochondria. The tegument is rich in sharp spinules³⁸⁶ used to fix the worm to the wall of the bile ducts.
- **Musculatures:** The muscles are differentiated into circular, longitudinal and vertical muscles.
- **Parenchyma:** Scattered cells that fill the internal spaces.

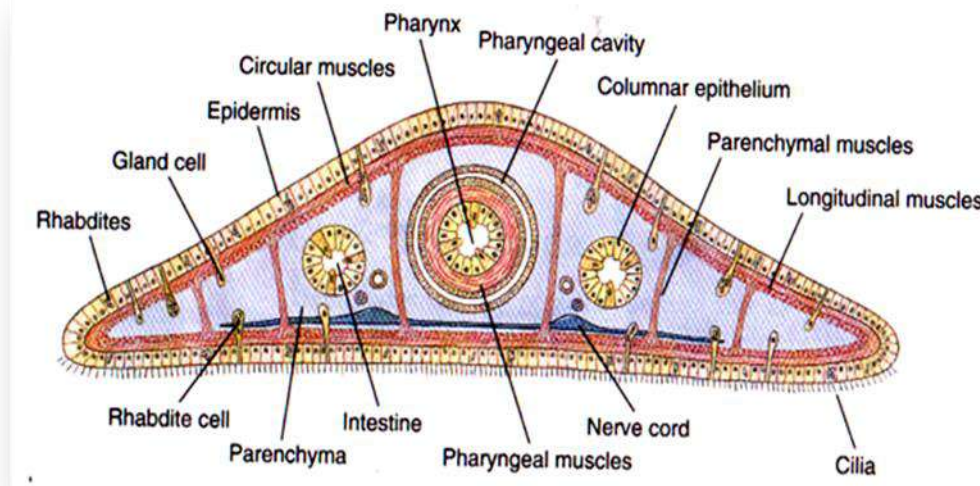


Fig. (6-12a):T.S. of *Fasciola*

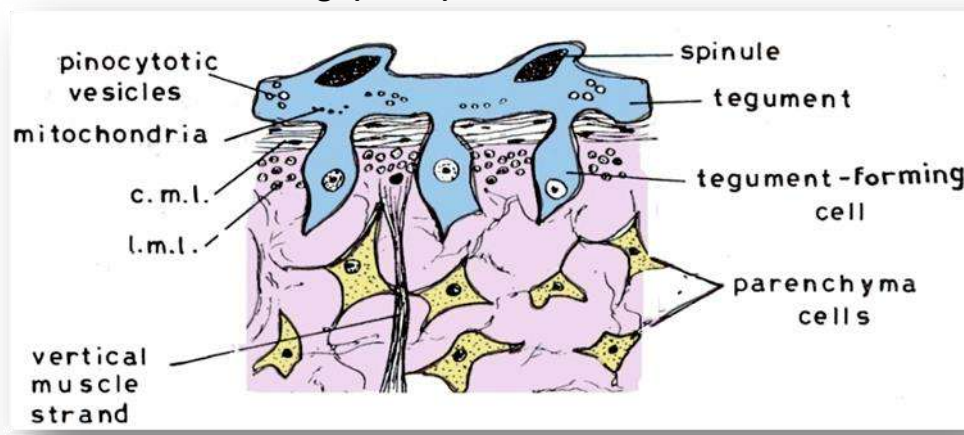


Fig. (6-12b):Histological structure of body wall of *Fasciola*.

DIGESTIVE SYSTEM AND FEEDING

- *Fasciola* is a parasite and the digestive system is very simple. It consists of mouth (bounded by the oral sucker), short oesophagus³⁸⁷, and two intestinal caeca branched into lateral diverticula (Fig., 6-13).
- *Fasciola* feeds on bile and blood of the host which is ingested by the mouth and reach to the intestinal caecae where they are digested and absorbed. Moreover, simple sugar and protein may be taken from the blood plasma of the host by pinocytosis through the tegument.

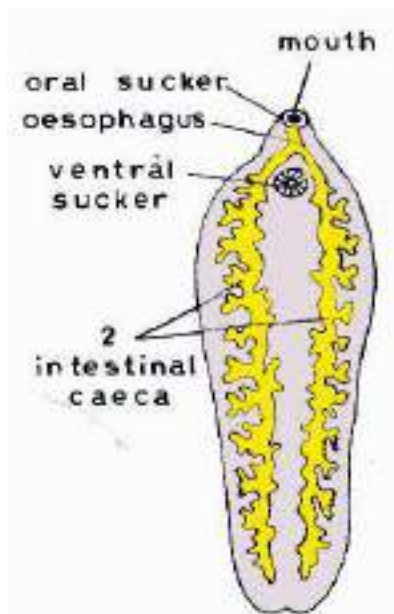
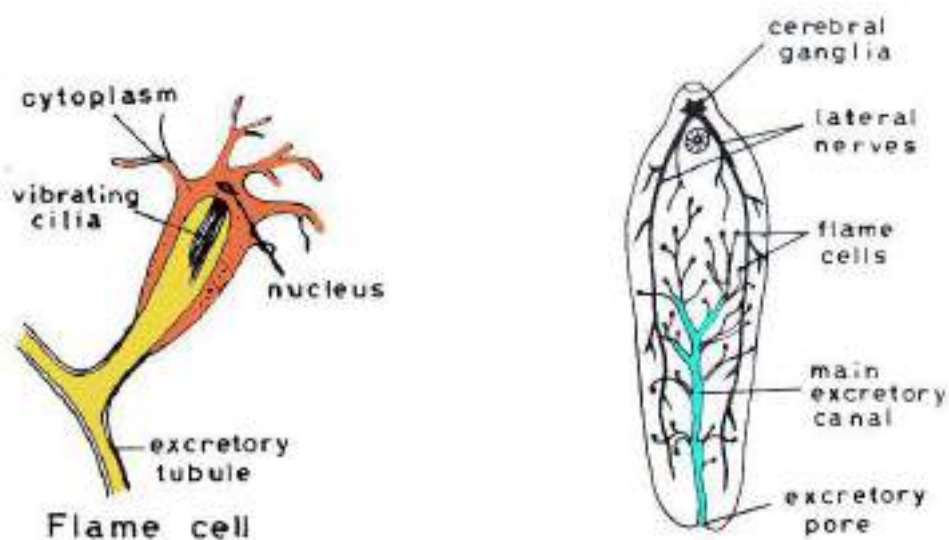


Fig. (6-13): Digestive system of *Fasciola*

EXCRETORY SYSTEM AND EXCRETION

The excretory system consists of a large number of branched tubules which ramify throughout the parenchyma and collect in main long. excretory canal that opens to the exterior by the excretory pore. The terminal ends of tubules have excretory unit known as Flame cell or Solenocytes (Fig., 6-14).



Excretory and Nervous system

Fig. (6-14): Excretory system of *Fasciola*.

Flame cell: It is the excretory unit in *Fasciola*. It has branched protoplasmic processes and a hollow cytoplasm with a large nucleus. A tuft of flickering cilia hang down in the cavity and move like the candle flame.

The flame cells collect waste products and excess water from the parenchyma and drive them, with help of cilia, down the excretory tubules to the exterior.

REPRODUCTIVE SYSTEM

Fasciola is hermaphroditic i.e. it possesses both male and female reproductive system in the same individual (Fig., 6-15).

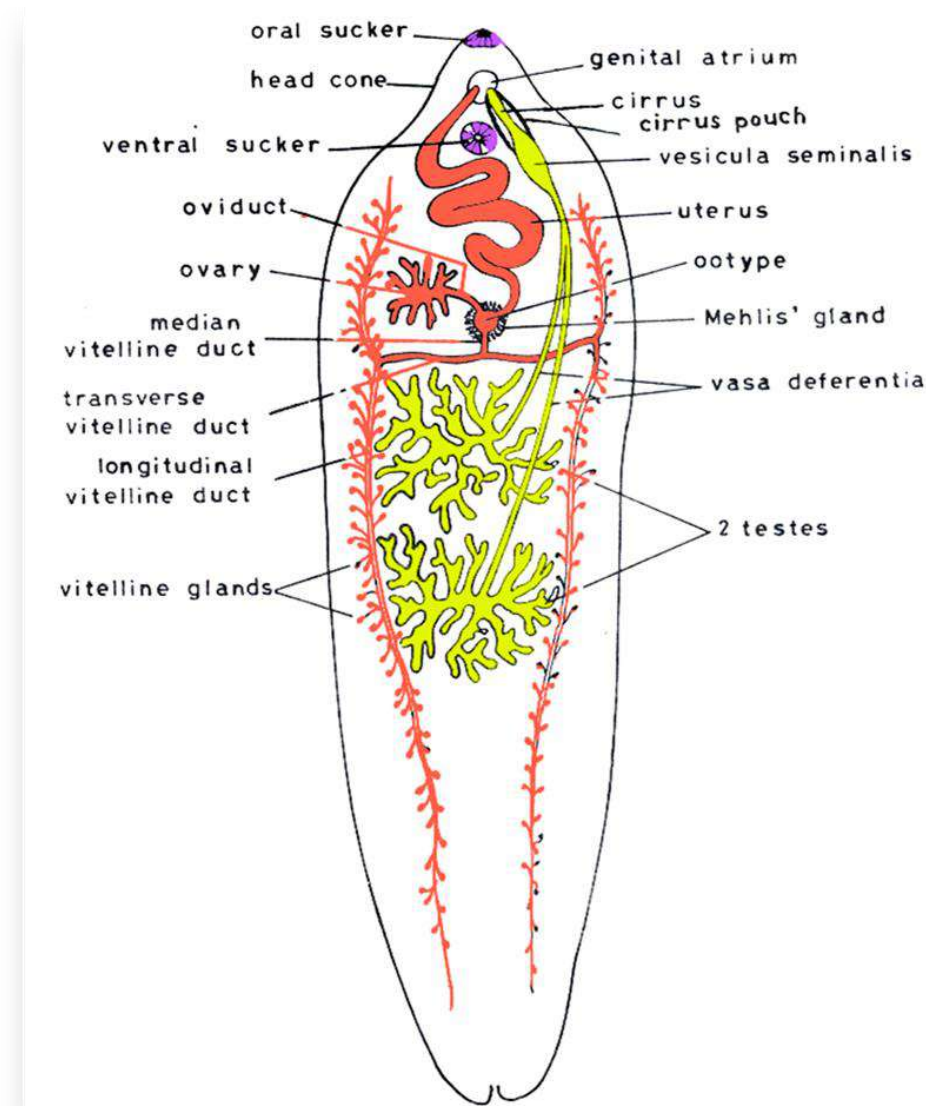


Fig. (6-15): Reproductive system of *Fasciola*.

Male Reproductive system

It consists of:

- **Two Testes:** produce spermatozoa.
- **Two Vasa differentia:** convey sperms from the testes.
- **Vesicula seminalis:** store the sperms.
- **Cirrus pouch and cirrus.** the male copulatory organ that insert sperms into other worm.

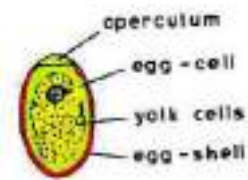
Female Reproductive system:

- **Single Ovary:** produce ova

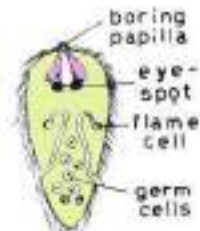
- **Oviduct:** convey ova to the ootype
- **Ootype**³⁸⁸: It is the egg forming apparatus.
- **Vitelline glands** : A large number of vitelline glands are found on both sides of the body. They produce yolk that convey to the ova in the ootype through four *long. vitelline ducts* -----►two *trans. vitelline ducts* -----►one *median vitelline ducts* ----► *ootype*
- **Uterus**³⁸⁹: Inside which fertilization takes place.
- **Genital atrium:** Into which open the male and femal genital pore.
- **Mehlis' gland.** Secrete the egg shell.
- **LIFE CYCLE** (Fig., 6-16)

Life cycle is complicated and requires two hosts: Intermediate host (*Lymnaea* snail) and final host (Sheep).

1. Cross or self-fertilization takes place where the egg is fertilized inside the uterus.
2. The fertilized eggs leave the worm, travel with the bile secretion into the intestine of the host, then they are shed with faeces into water.
3. After two weeks, the egg hatches into a ciliated free – living **Miracidium**.
4. The miracidium swims actively searching its intermediate host (*Lymnaea snail*) and penetrates its tissue by the secretions of its penetration gland.
 - a. Inside the snail tissue, the miracidium loses its ciliary covering, changing into "**Sporocyst**".
 - b. Inside the sporocyst, there are masses of germ cells which develop into other larvae called **Radia**.
 - c. Inside the body of the radia, there are clusters of germ cells which divided to form **Cercaria**.
5. The cercaria leave the body of the radia through the birth pore and penetrate the tissues of the



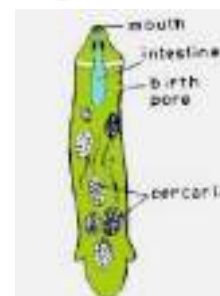
Egg



Miracidium

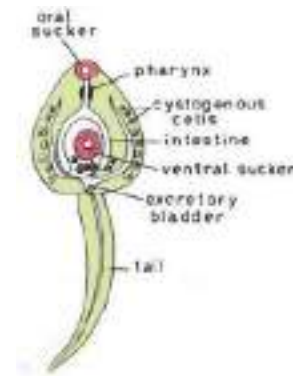


Sporocyst

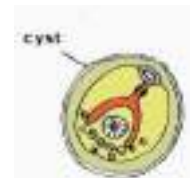


Radia

snail to the surrounding water and swim actively for few days by the aid of their tails. Then they form shell around itself changing into ***Encysted Metacercaria. (Infective stage)***



Cercaria



Encysted metacercaria

6. Grazing animals acquire the infection by eating aquatic vegetation³⁹⁰ infested³⁹¹ with metacercaria.
7. In the duodenum of the final host (cattle, sheep, goats.. etc), the metacercaria lose their protective cyst, penetrate the intestinal wall and migrates into the liver where it becomes mature fluke.

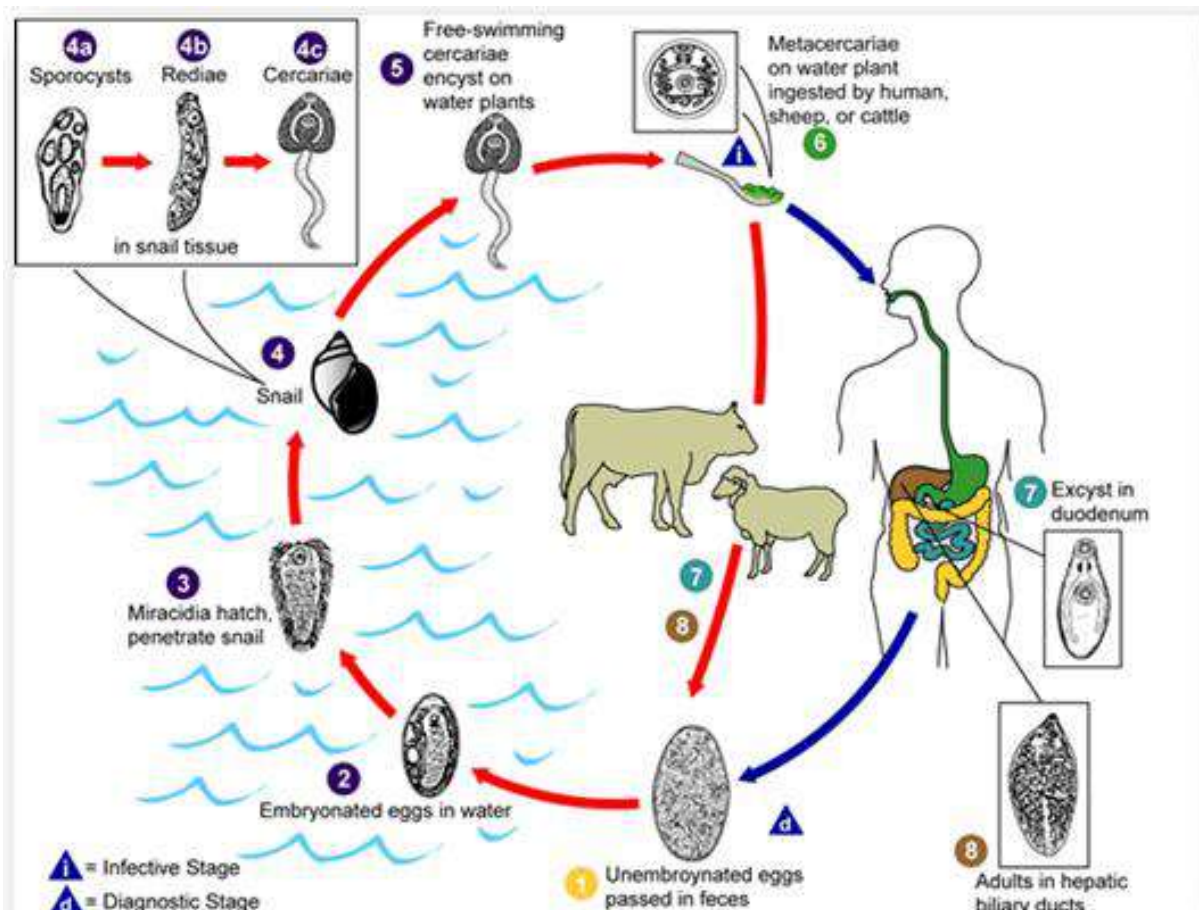


Fig. (6-16):Life cycle of *Fasciola*

HOST PARASITE RELATIONSHIP

1. Effect of parasite on definite (final) host

Fasciola lives in the bile ducts of the liver where it causes:

- a. Hemorrhages³⁹² during its migration from intestinal wall to the liver.

- b. Tissue reactions which leads to the development of fibrous tissues that replace liver cells.
- c. They block³⁹³ the bile ducts causing jaundice³⁹⁴ and disturbances³⁹⁵ in the digestive system.
- d. The secretory products are toxic causing anaemia to the host.

2-Effects of parasite on the intermediate host:

The large number of parasites inside the snail's tissues greatly effect: Viability³⁹⁶ of the snail host and its reproduction capacity and Cause shorter live span.

Parasitic adaptation of *Fasciola*

Liver fluke has undergone great modification, morphological as well as physiological, to suit its existence as an endoparasite in the bile ducts:

1. Outer tegument is thick, permeable to water but enzyme-resistant to protect the parasite from the digestive enzymes.
2. Locomotory organs are absent as not required by the adult.
3. Oral suckers and spines of body serve as organs for attachment in the host's body.
4. Alimentary canal has many modification suited with the ready meal.
 - a. No anus because there is no undigested food
 - b. Suctorial pharynx to suck bile etc.
 - c. Much branched intestine to distribute food in the body.
5. Adult lacks circulatory, respiratory and sensory organs as they are not needed. Respiration is anaerobic as free Oxygen is not available.
6. Reproductive system is highly developed and produce enormous amount of eggs to offset great mortality.
7. Resistent egg shell provides more safety from severe environmental conditions.
8. Hermaphroditism ensure self fertilisation in the absence of other partner.

e.g.2 *Schistosoma* (Blood flukes)

Schistosoma ("Schisto" prefix meaning "split, or cleft": Soma means body) or blood flukes inhabit the blood stream of certain vertebrate hosts (birds and mammals) and produce a disease known as "**Bilharziasis**". Many species of schistosomes are the causative agents of the disease in man. The most common species are: *S. haematobium*, *S. mansoni* and *S. japonicum*.

Schistosoma haematobium

- Commonly known as the bladder³⁹⁷ fluke.
- Adult stage lives in the viens around the urinary bladder and its eggs are passed out in urine. It produces urinary³⁹⁸ schistosomiasis.
- Originally found in Africa, the Near East, and the Mediterranean basin³⁹⁹, and introduced into India during World War II.
- Eggs have terminal spine⁴⁰⁰.
- Freshwater snails of the genus ***Bulinus*** are an important intermediate host for this parasite. Among final hosts humans are most important. Other final hosts are rarely baboons and monkeys.

Schistosoma mansoni

- Commonly known as Manson's blood fluke or swamp fever.
- Adult stage lives in mesentric veins and its eggs are passed out in stool.
- It produces intestinal schistosomiasis.
- Found in Africa, Brazil and Venezuela.
- Eggs have lateral spine.
- Freshwater snails of the ***Biomphalaria*** genus are an important intermediate host for this trematode. Among final hosts humans are most important. Other final hosts are baboons, rodents⁴⁰¹ and raccoons.

Schistoma japonicum

- Its common name is simply blood fluke.
- Found widely spread in Eastern Asia and the southwestern Pacific region. In Taiwan this species only affects animals, not humans. It produces intestinal schistosomiasis.
- Adult stage lives also in mesenric veins and its eggs are passed out in stool.
- Freshwater snails of the ***Oncomelania*** genus are an important intermediate host. Final hosts are humans and other mammals including cats, dogs, goats, horses, pigs, and rats.

MORPHOLOGY

The worm is cylindrical and have two suckers; oral sucker encircling the mouth and ventral sucker. Sexes are separated but usually found in a pairing where the male incubating⁴⁰² the female inside the gynaecophoric canal⁴⁰³. The differences between male and female is summerized in table (6-3).

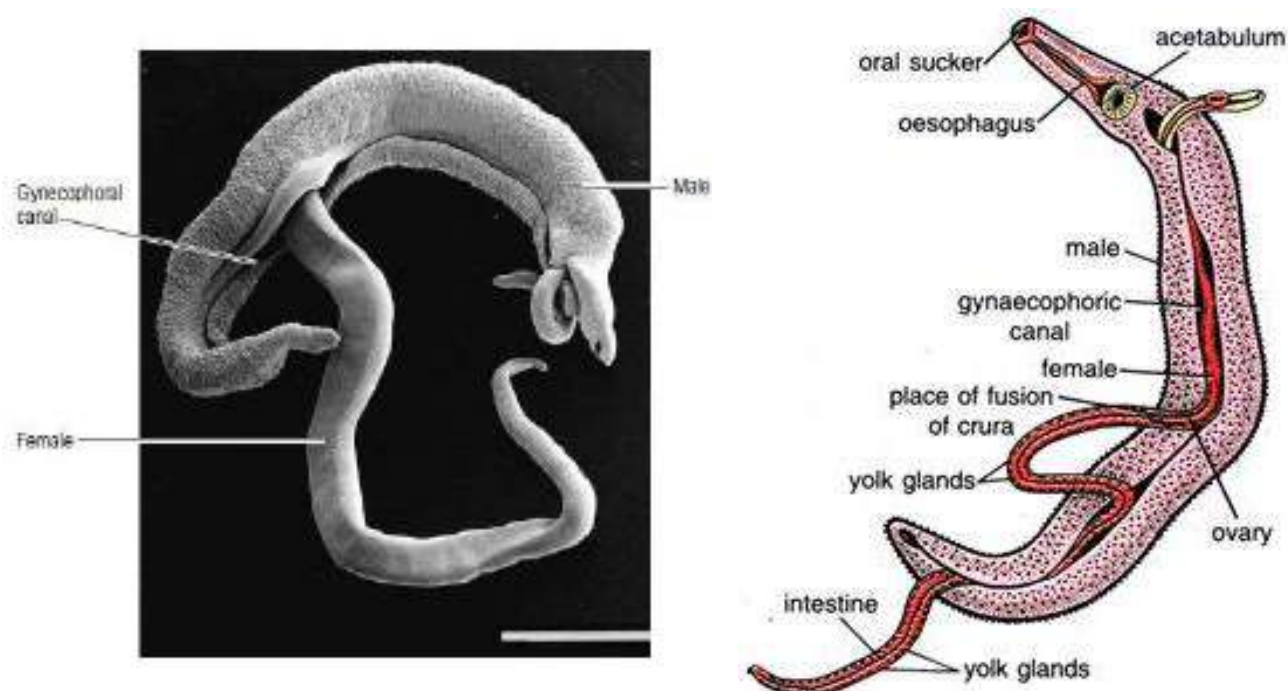


Fig. (6-17): Morphology of *Schistosoma*

DIGESTIVE SYSTEM

The **mouth** leads directly into an oesophagus which surrounded by oesophageal glands and divides into two **intestinal caeca** that reunite in a single caecum. The intestines end blindly, meaning that there is no anus (Fig., 6-18).

Schistosomes feed on blood of the host. Portal blood rich in amino acids and sugars is ingested through the mouth and pass into the intestine where it is digested and absorbed. The remains of haemoglobine form what is known **Bilharsia pigments** which accumulated in the intestine and periodically extruded from the mouth into the blood stream.

Table (6-3): Differences between male and female *Schistosoma*.

	Male	Female
Shape	➤ Short (10- 15 mm) and broad	➤ Longe (16-20mm)r and slim
Colour	➤ White	➤ Dark grey due to the the presence of Hemozoin pigment in the digestive system
Body wall	➤ Covered with numerous tubercles ⁴⁰⁴ (to fix it to the wall of blood vessel) and carrying papillae	➤ Not tuberculated.
Gynaecophoric canal	➤ Found to carry the female	➤ Absent
Suckers	➤ More developed	➤ Simple

REPRODUCTIVE SYSTEM

Male System: The male genital apparatus is composed of six to nine testicular masses, situated dorsally. There is one deferent canal beginning at each testicle which is connected to a single deferent that dilates into a seminal vesicle, located at the beginning of the gynaecophoric canal.

Female System: The ovary is elongated and is located on the anterior half of the body. A short oviduct conducts to the ootype which continues with the uterine tube. In this tube it is possible to find one to two eggs (rarely three to four) but only one egg is observed in the ootype at any one time. The genital pore opens ventrally. The posterior two-thirds of the body contain the vitellogenic glands and their canal, which unites with the oviduct a little before it reaches the ootype.

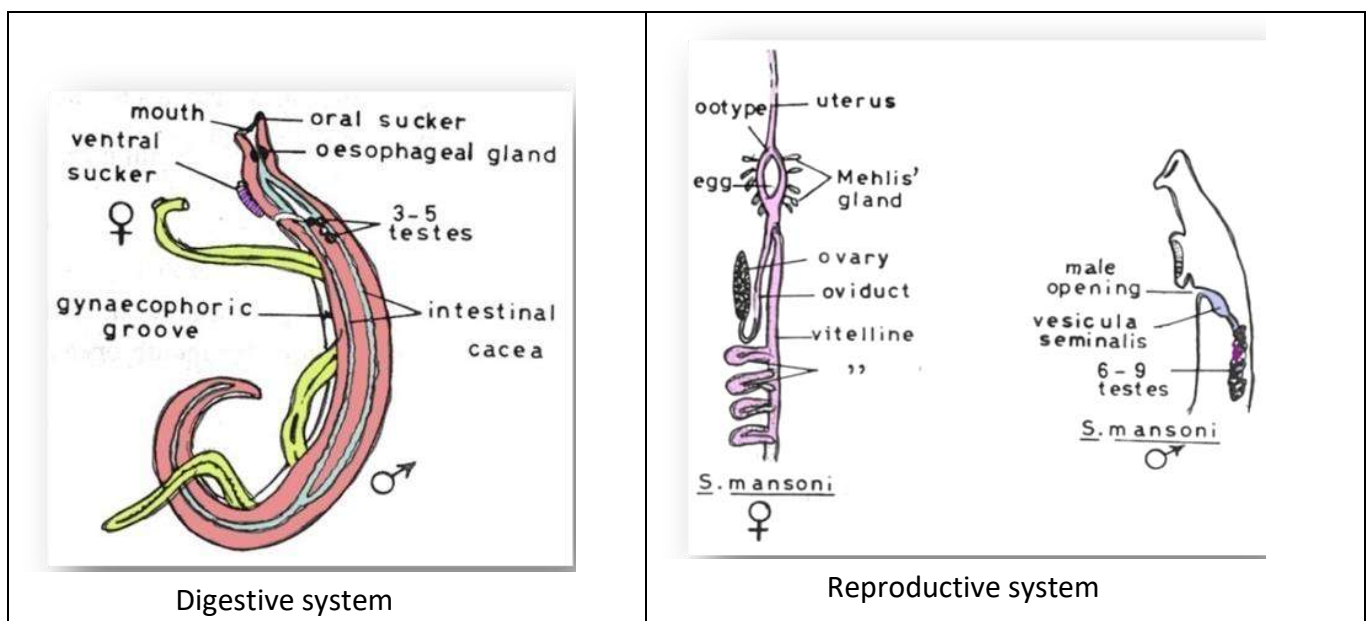


Fig. (6-18): Digestive and Reproductive systems of *Schistosoma*.

LIFE CYCLE

Life cycle of *Schistosoma* illustrates the phenomenon of “Alternation of Generation” as it includes both “Sexual generation” (Adult worms) and “**Asexual generation**” (Miracidium- sporocyst, cercaria) (Fig., 6-19). The following stages are found in the life cycle which is completed within two hosts (Man and Snail).

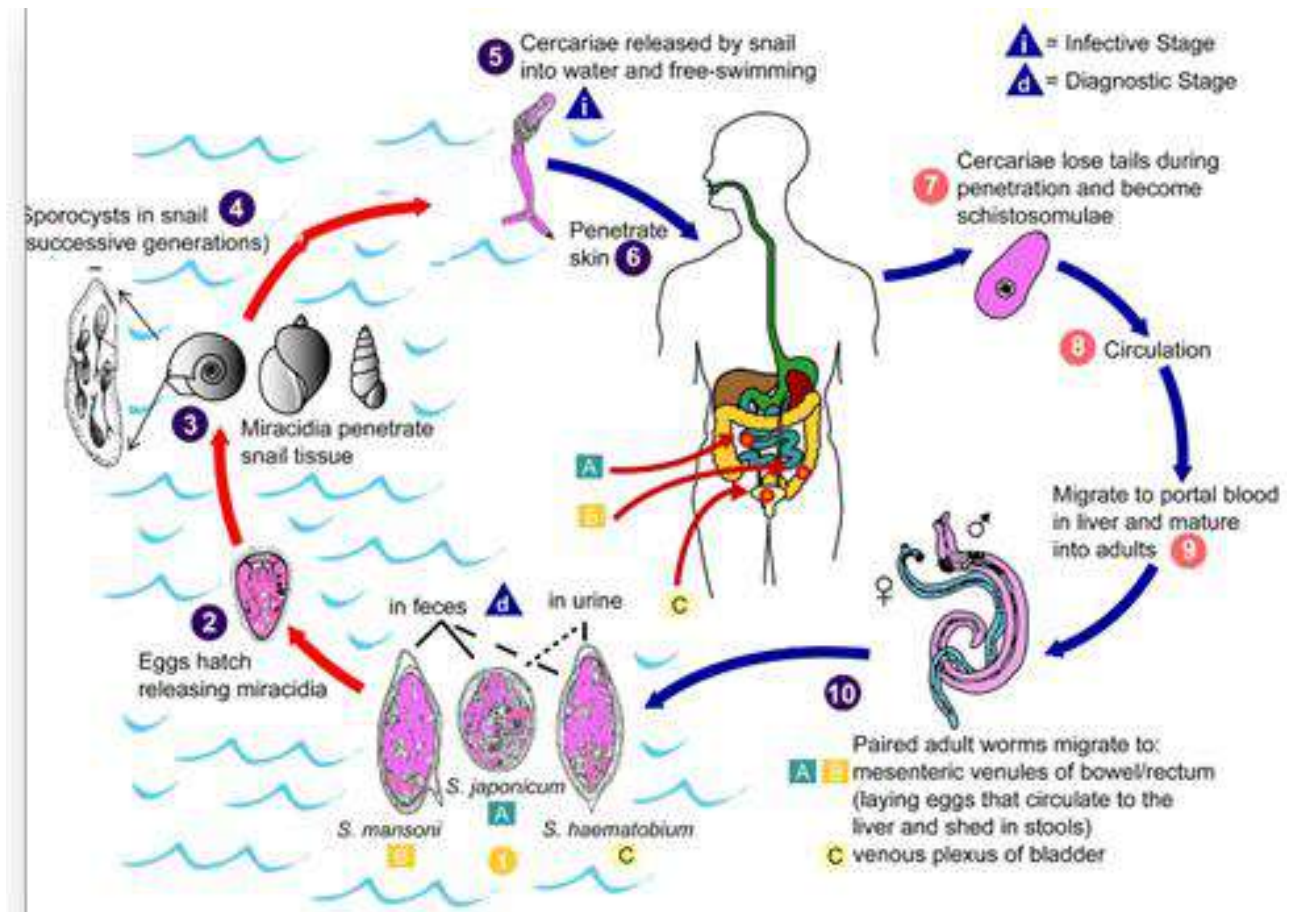
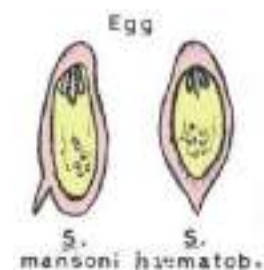


Fig. (6-19): Life cycle of *Schistosoma*

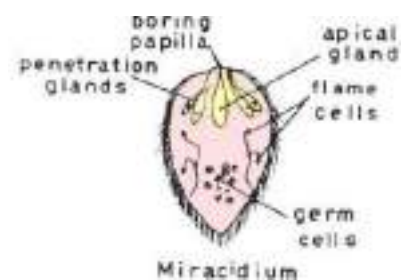
1. Eggs

The female lays fertilized egg in the blood vessels around the urinary bladder⁴⁰⁵ (*S. haematobium*) or around the rectum (*S. mansoni*). The eggs of *S. haematobium* have terminal spine and that of *S. mansoni* have a lateral spine by which they penetrate the wall of urinary bladder or intestine and passed with urine or stools respectively. Upon reaching freshwater, the eggs hatch into miracidium.



2-Miracidium

The miracidium have cilia, boring papilla⁴⁰⁶ but lack eye spot. It swims freely in water for 24-36 h searching the intermediate host (*Bulinus* snail in case of *S. haematobium* and *Biomphalaria* snail in case of *S. mansoni*). It then penetrates the snail's tissue and changes into sporocyst.



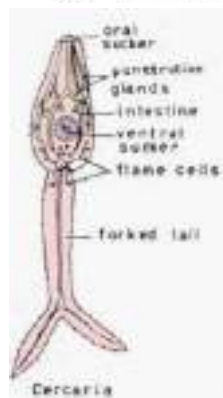
3-Sporocyst

Its germ cells divide parthenogenetically inside the snail tissue to form daughter sporocysts which migrate to the digestive gland then develop into cercariae. About 100,000 cercariae produced from a single miracidium.



4- Cercaria (Infective stage)

Cercariae leave tissues of the snail to reach surrounding water. It is characterised by a forked tail, two suckers and a simple digestive system. Upon finding the human host, a cercaria penetrates the skin of a new host, loses its tail, migrates into the portal circulation and develops into the adult worm.



HOST-PARASITE RELATIONSHIP

Effect of Schistosomes on the intermediate host: The development of a huge number of larval stage (one miracidium produces 100,000 cercariae) affects the biology, feeding and reproduction of the snail host and reduces its lifespan.

Effect of Schistosomes on the final host: Schistosomes produce direct ill effects⁴⁰⁷ to the human host. Schistosomiasis is a chronic⁴⁰⁸ disease. It is one of the greatest parasitic diseases of mankind. The other two being malaria and hook-worms. China and Egypt have maximum cases. Many pathological changes are developed which are:

1. Penetration of the skin by the larvae causes inflammation⁴⁰⁹ at the site of entry.
2. Females rupture smaller blood vessels during migration for egg laying.
3. Passage of eggs through the intestinal wall or urinary tract causes diarrhea, haemorrhage and anaemia.
4. Formation of certain tissue reactions towards the metabolites of the developing worms (mainly the bilharzias pigment).
5. ***Chronic stage (stage of irreversible changes):*** Tissue reaction starts by the formation of fibrous tissue around the eggs, either those which are directly laid by the worms in the urinogenital or intestinal organs, or those which are passively carried by the blood stream to other organs, such as liver, lungs, . . etc. This leads to:
 - Lesions in the urinary bladder, ureters, kidneys and genital organs.
 - Fibrosis and enlargement of liver and spleen.

7.2.3. CLASS: CESTODA (TAPEWORMS)

Cestodes, or tapeworms, are internal parasites (about 5000 species) and with few exceptions the adults inhabit the intestine of a vertebrate. The life cycle almost includes an intermediate host inhabited by a larval stage. Either invertebrates or vertebrates may be intermediate hosts. The intermediate host is usually the prey of the definitive host. The definitive host is a vertebrate.

CHARACTERES:

1. The cestode body is composed of an anterior scolex⁴¹⁰, and a long posterior strobila which is divided into numerous segment-like units known as proglottis⁴¹¹.
2. Most organ systems are reduced or absent except for the reproductive system, which is well developed.
3. There is no gut.
4. The syncytial neodermis (epidermis) bears microvilli.
5. Excretion and osmoregulation are accomplished via protonephridia which empty into two pairs of excretory canals.
6. Cestodes are hermaphroditic with either self- or cross-fertilization.

e.g. *Taenia*

There are two common species of *Taenia*: *T. saginata* and *T. solium*. Table (6-4) summarize the main differences between them.

Table (6-4): Main differences between *T. saginata* and *T. solium*

	<i>T. saginata</i> (beef ⁴¹² – tapeworm)	<i>T. solium</i> (pork ⁴¹³ – tapeworm)
Size	• May reach 25 meters long	• 3-5 meters long
Scolex	• Without <i>Rostellum</i>	• Provided with <i>Rostellum</i> and <i>Hooklets</i>
Intermediate host	• Cattle	• Pig
		

MORPHOLOGY (Fig., 6-20).

The body is composed of an anterior scolex, with which the worm attaches to its host, unsegmented neck and a long posterior strobila which is divided into numerous segment-like units known as proglottis.

1- Scolex

It is the anterior region of *Taenia* which attaches the worm to the gut wall of the host. Scolex is provided with:

-**Four suckers**: work on vacuum principle.

-**Rostellum** armed with two rings of **rostellar hooks** which attach the worm into the intestinal wall (Fig., 6-20).

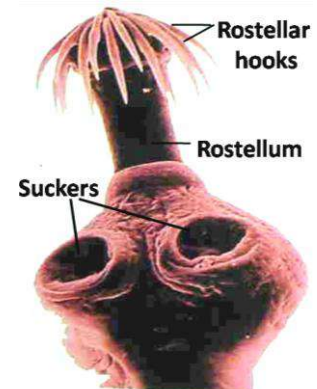


Fig. (6-20): Scolex of *T. solium*

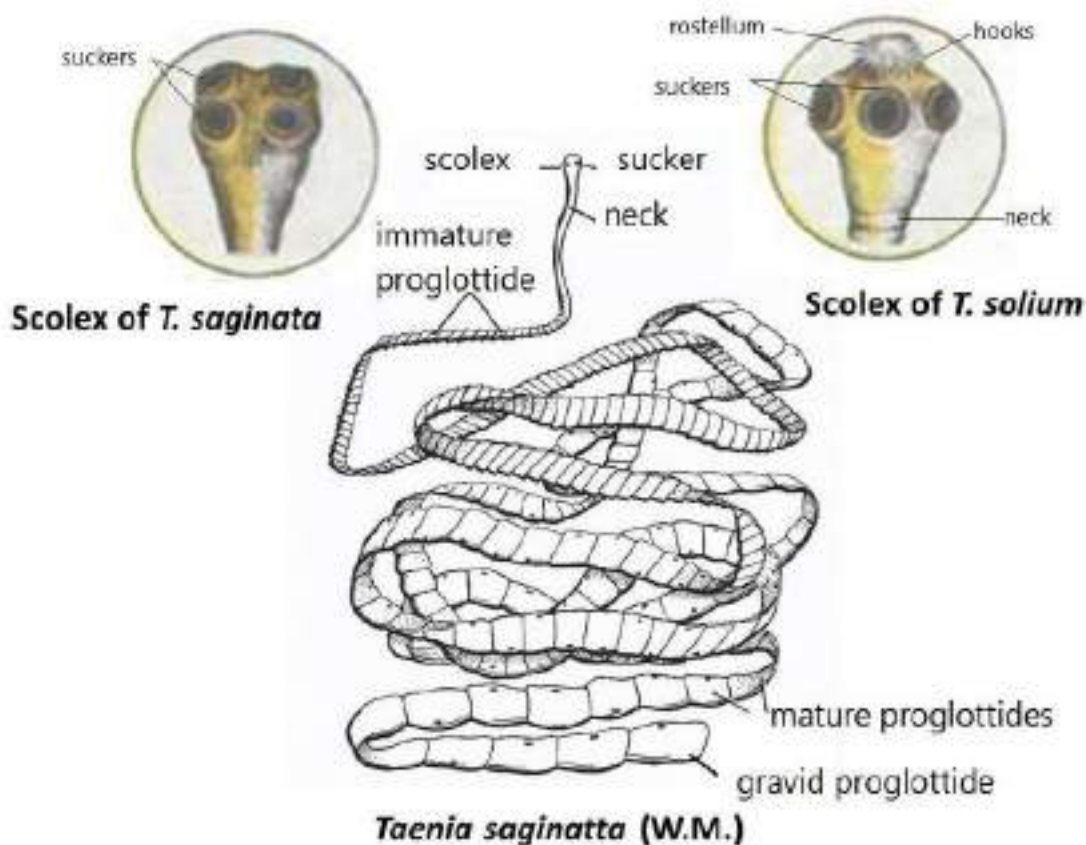


Fig. (6-21): Morphology of *Taenia*

2- Strobila

The strobila is long and wormlike, sometimes reaching 20 or more meters in length. The strobila is strongly flattened dorsoventrally and is composed of a linear series of hundreds or thousands of segment-like proglottis. New proglottis are produced by an area of mitotically active cells just behind the scolex. Proglottis are of three types:

- **Young immature⁴¹⁴ proglottis** at its anterior end. They are short and wide and do not yet contain differentiated cells or organs.
- **Sexually mature proglottis** in the middle. Each mature proglottis contains its own complete hermaphroditic reproductive system as well as its share of the common excretory and nervous systems.
- **Gravid proglottis at the posterior end.** The gravid proglottis contain branched uterus (Fig., 6-22) filled with viable embryonated “ eggs” (about 100,000)

HISTOLOGICAL STRUCTURE

The body wall (Fig., 6-22) consists of :

1. **Tegument:** A syncytial⁴¹⁵, microvilliated, absorptive neodermis. The outer surface of the neodermis is folded into microvilli to facilitate the absorption of food. The nuclei of the syncytium are submerged below the basal lamina and muscle layers into the parenchyma.
2. **A basal lamina,**
3. **Layers of circular and longitudinal muscles.**
4. **Parenchyma:** Inside the body wall is connective tissue consisting of the mesenchymal parenchyma in which the reproductive, excretory, and nervous systems are embedded.

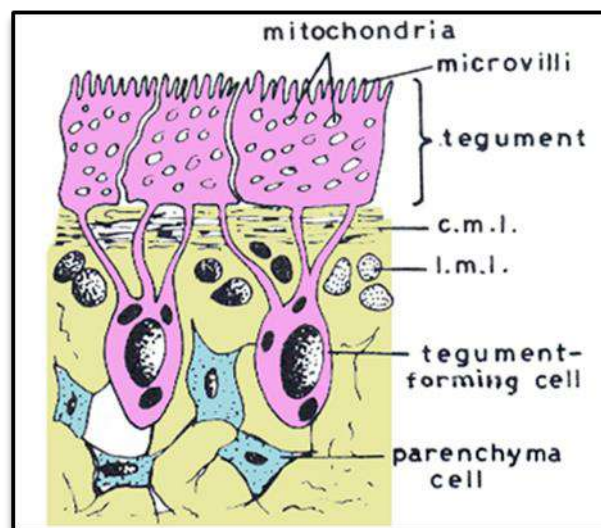


Fig. (6-22): Histological structure of *Taenia*

DIGESTIVE SYSTEM

Tapeworms have no digestive system. Organic molecules, mostly glucose, other sugars and amino acids, are absorbed across the specialized, heavily microvillous neodermis and metabolism is largely anaerobic.

RESPIRATORY AND FLUID TRANSPORT SYSTEMS

There is no need for a gas exchange mechanism and there is none. Food and waste molecules diffuse to and from the body surface and there is no fluid transport system. The microvilli of the neodermis absorb food molecules directly from the environment.

EXCRETORY SYSTEM

The excretory system consists of numerous flame bulb **protonephridia** scattered throughout the parenchyma of each proglottis. Individual protonephridia drain into an elaborate system of nephridial canals which ultimately open to the exterior at the posterior end of the last proglottis of the strobila. Dorsal and ventral lateral nephridial canals on each side of each proglottis extend the length of the worm. These longitudinal canals are jointed at the posterior end of each proglottis by a transverse excretory canal.

NERVOUS SYSTEM

The right and left lateral longitudinal nerve cords arise from nerve rings in the scolex and pass posteriorly in the sides of the proglottis. Nerves extend from this system to the muscles and internal organs.

THE REPRODUCTIVE SYSTEM

Tapeworms are hermaphroditic. The reproductive systems of the youngest, anteriormost proglottis are not yet formed but a mature proglottis possesses complete reproductive system of both sexes (Fig.,6-23).

- **The male organs:** Consists of numerous small spherical testes (about 500 in number), scattered within the parenchyma. The vas efferens comes out from each testis. All vasa efferentia join together to form a convoluted tube, the vas deferens, which dilates to form the vesicula seminalis and ends by a muscular cirrus (penis) enclosed in a cirrus pouch. The cirrus opens by the male genital opening in the genital atrium.
- **The female organs:** Include a single ovary composed of two lobes. From each lobe arises a short duct which leads into the median oviduct that opens into ootype, which is surrounded by Mehlis' gland (which secretes egg shell). There is a single vitelline gland whose secretions are carried through the vitelline duct which opens into the ootype. Two other canals arise from the ootype: the uterus which acts as a reservoir for the fertilized eggs produced in the ootype, and the vagina which opens by the female genital pore in the genital atrium. The

proximal part of the vagina may be slightly swollen to form the receptaculum seminis⁴¹⁶ (which store sperms received from male system).

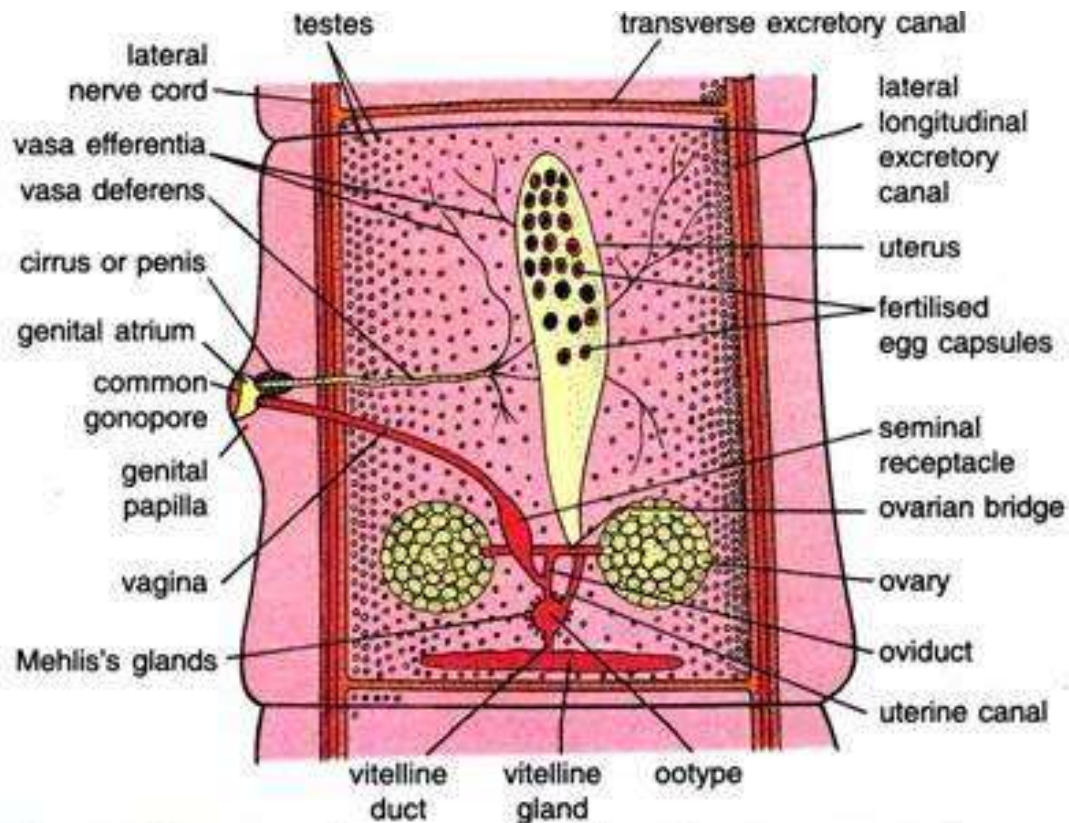


Fig. (6-23): Mature proglottide

Fertilization and Development

Commonly self-fertilize, a convenience⁴¹⁷ for an animal that lives in a habitat where it may be the only member of its species. Cross-fertilization may occur if more than one worm is present in the host. Fertilization of ova by sperms (from the seminal receptacle) occurs in the oviduct. The fertilized egg moves in the oviduct to the ootype where it receives yolk from the vitellain gland and become enclosed with a shell or embryophore. Shelled embryonated eggs move anteriorly into the uterus where they accumulate and



Fig. (6-24): Gravid proglottide

stored. The uterus become enlarged and fill most of the proglottis which changed into gravid proglottis (Fig., 6-24).

LIFE CYCLE (Fig., 6-25)

1. The gravid proglottis (full of fertilized eggs) are detached⁴¹⁸ and passed with the stool to the exterior where they degenerates and extrudes⁴¹⁹ the eggs on

- moist earth. The egg contains **Onchosphore (hexacanth embryo)** which has six hooklets and surrounded by shell or *embryophore* (Fig., 6-26).
- When the eggs are ingested by cattle (intermediate host of *T. saginata*) or pigs, (intermediate host *T. solium*), the embryophores is digested by the action of the digestive enzymes and the onchosphore is liberated in the intestinal lumen.
 - The onchosphore bores the intestinal wall by the secretion of histolytic enzymes and reach to the blood circulation.
 - The onchosphore is carried to a skeletal or cardiac muscle⁴²⁰ where it loses its hooks and develops (within 60 - 70 days) into a **bladder worm** or **cysticercus**, (Fig., 6-27). This is the infective stage which occur in the muscles of heart, tongue, shoulder, diaphragm..etc. Man becomes infected through eating under cooked meat infected with these Cysticerc
 - The wall of the cysticercus digested in the stomach and the liberated larva migrates into the intestine where it develops into the adult worm.

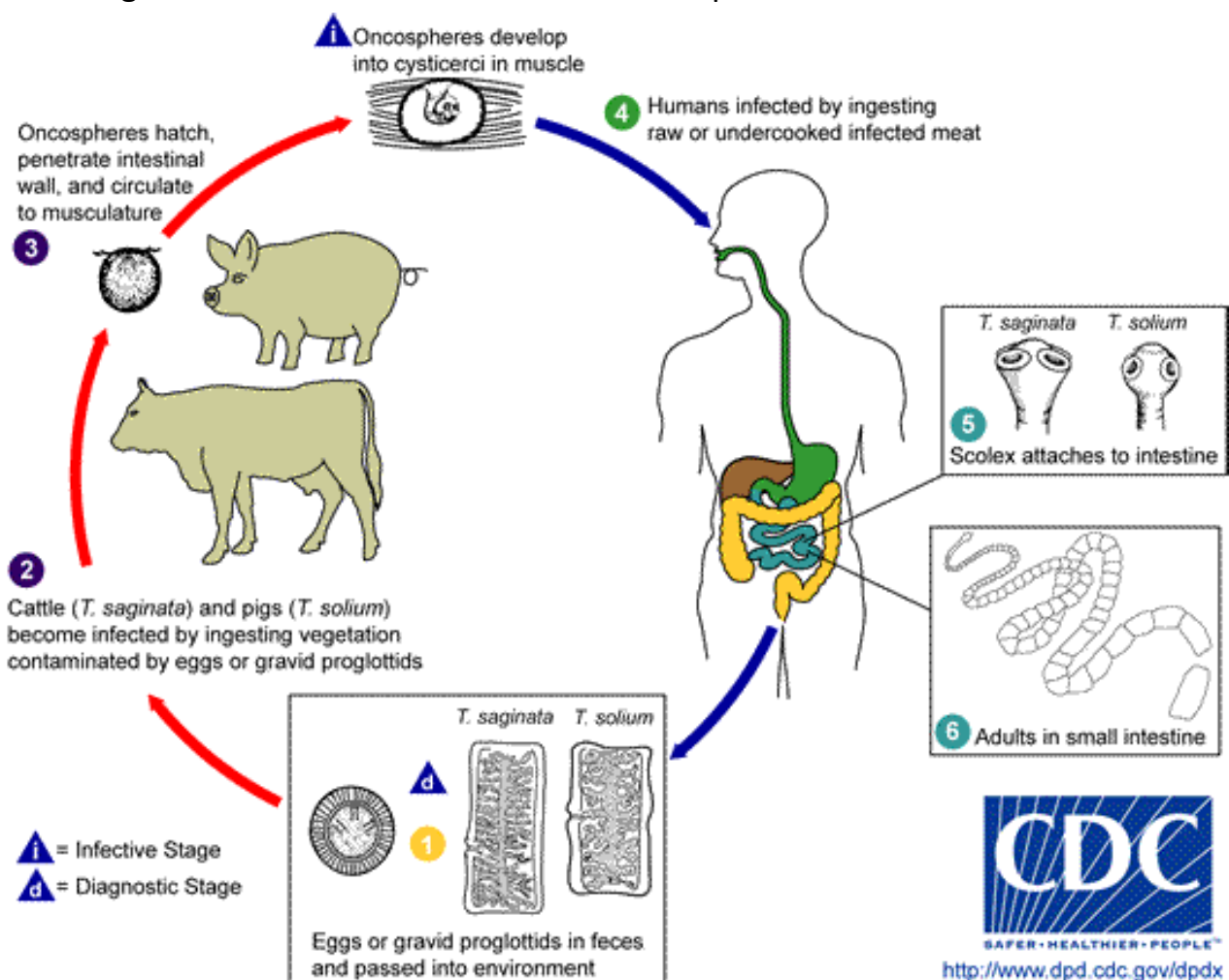


Fig. (6-25): Life cycle of *T. saginata*

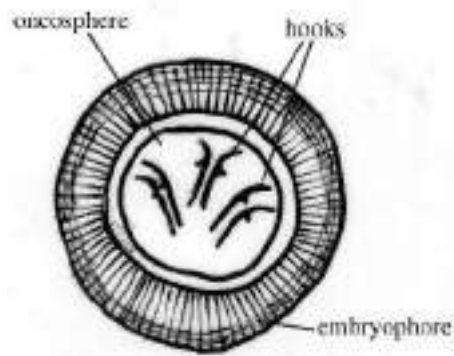


Fig., (6-26): Hexacanth embryo

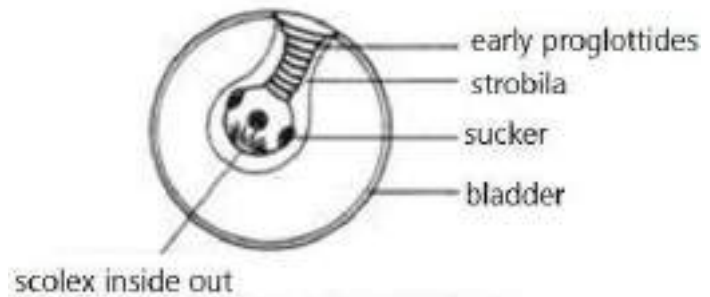


Fig., (6-27): Bladder worm (Cysticercus)

HOST-PARASITE RELATIONSHIP

Effect of cysticerci on the intermediate host

The presence of cysticerci in the muscle of the intermediate host (Fig., 6-28) usually produce little reaction except when they occur in a large numbers in some vital organs as the heart and diaphragm.



Fig. (6-28): Bladder worm in muscles

Effect of adult worms on the final host

1. The worm is volumetric; its size may reach one litre and may occupy most of the lumen of the intestine causing intestinal obstruction and disturbance in the digestion and absorption processes.
2. The worms absorb a large amount of the digested food found in the intestine and this usually leads to weakness and loss of weight.
3. The worms excrete poisonous metabolites which may be absorbed in the blood and cause certain systemic complications.

PARASITIC ADATATIONS OF TAENIA

1. External body covering is freely permeable of water and nutrients by resist digestion by the host 's alkaline digestive juices
2. Internal osmotic pressure is higher than that of the surrounding fluid and pH tolerance is high.
3. Adult as well as larvae lack cilia and any other locomotory orans, which are not needed.
4. Scolex, with suckers and spines serves for attachment to the intestinal mucosa.
5. Alimentary canal is totally absent as the parasite absorb digested food directly through the skin.
6. Adult lacks circulatory, respiratory and sensory organsas they are not needed.

7. Respiration is anaerobic as free Oxygen is not available.
8. Reproductive system is highly developed and produce enormous amount of eggs to offset great mortality.
9. Resistent egg shell provides more saftey from severe environmental conditions.
10. Hermaphroditism and prglottids ensure sefl fertilisation in the absence of other partner.

Table (6-5):Comparison between *Fasciola* and *Taenia*

	<i>Fasciola</i> (Sheep liver fluke)	<i>Taenia</i> (Pork or beef – tapeworm)
Class	• Trematoda.	• Cestoda.
Final host	• Man.	• Man.
Intermediate host	• <i>Lymnaea</i> snail.	• Cattle (for <i>T. saginata</i>). • Pig (for <i>T. solium</i>).
Shape	• Leaf -like , unsegmented. • With two suckers. • Live inside bile ducts.	• Ribbon – like , segmented • With 4 suckers. • Live inside the intestine.
Adult worm	• 10 cm • Several worms can live inside one host.	• May reach 25 m. • Only one worm usually occur in one host.
Digestive system	• Incomplete • Holozoic Nutrition. • Egg with operculum. It passes from the genital atrium.	• Absent • Saprozoic Nutrition. • Egg without operculum. It sets free by disintegration of gravid proglottis.
Life Cycle	• Zygote produces ciliated miracidium, with a single wall. • Larval multiplication occurs inside intermediate host. • There is alternation of generation	• Zygote produces a spherical six-hooked hexacanth with two protective walls. • No larval multiplication occurs inside intermediate host. • There is no alternation of generation
Infective stage	• Metacercaria (on aquatic plants).	• Cysticercus (in musle of intermediate host)

ii- Subgrade: Pseudocoelomata

In contrast to acoelomate bilateral animals (flat worms and nemerteans), in which the space between the digestive tract and body wall musculature is filled with mesenchyme, all other bilateral animals have a fluid-filled space, the body cavity. The fluid within the body cavity can function as a hydraulic skeleton and maintaining the turgidity⁴²¹ of the body. It can also aid in the translocation of gases, food and waste materials, particularly in the absence of circulatory system. Through the Animal Kingdom, there are two types of body cavities, the pseudocoel and coelom. The pseudocoel is a derivative of the embryonic blastocoel, arising between the mesoderm and endoderm (Fig., 8-1). During early development, the blastocoel, after the formation of archaentron, is not obliterated⁴²² but persist as a cavity surrounding the internal organs. Since it does not form within the mesoderm, as does the coelom, the pseudocoel has neither peritoneal lines nor mesenteries, characteristics of coelomates.

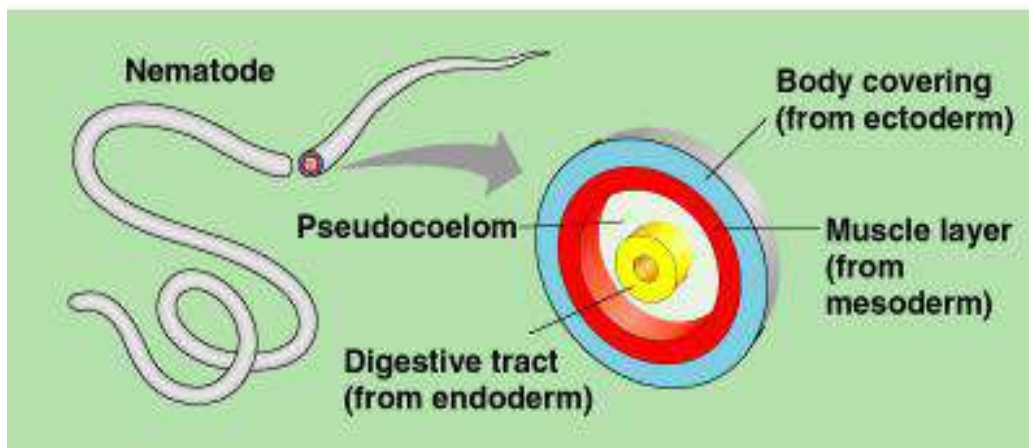


Fig. (8-1): Pseudocoelomate body

We are going to study the two common phyla of pseudocoelomates: Rotifera and Nemata (Nematoda).

7- PHYLUM : NEMATATA (NEMATODA) **(Round worms)**

Roundworms or eel worms are unsegmented pseudocoelomate cylindrical worms which have been able to adapt to almost all habitat available to animal life. The 20,000 known nematode species inhabit terrestrial, marine, and freshwater environments and are found in almost all moist habitats. The taxon includes numerous plant and animal parasites, many of which are of medical or agricultural importance, but most are free-living (non-parasitic). The human body harbour more

than 50 parasitic species of these worms. Most nematodes, or roundworms, are long, slender, almost featureless externally, tapered at both ends, and round in cross section.

7.1. GENERAL CHARACTERS

1. Bilateral symmetrical pseudocoelomates.
2. They have elongate, cylindrical, unsegmented body.
3. The body is covered with thick cuticle which moulted⁴²³ during growth.
4. With well – developed *longitudinal* muscles.
5. They have a complete digestive system with a mouth and an anus.
6. Most nematodes lack cilia or flagella, even in the sperm.
7. The respiratory and circulatory systems are lacking.
8. The excretory system consists of two longitudinal excretory canals.
9. The nervous system is composed of a circumoesophageal ring from which arises six anterior cords and six posterior cords.
10. Sexes are separate and with direct life cycle.

7.2. CLASSIFICATION OF NEMATODA

Nematodes are classified into two classes:

7.2.1. Class: Aphasmidia

- Most primitive forms of nematoda including nearly marine members, beside other freshwater, terrestrial and parasitic forms.
- Without caudal phasmids.

7.2.2. Class : Phasmidia

- Includes free living terrestrial and the majority of nematodes parasites of plants (about 2000 species) and animals (about 3,000 species).
- With a pair of caudal phasmids.

e.g.₁ *Ascaris lumbricoides*
(Intestinal fluck)

Ascaris lumbricoides , common saying “round worm of man”, is the largest and the most common of the intestinal nematodes parasitizing humans. Distribution of *Ascaris* is worldwide, but most prevalence in areas of warmer climates, moist and poor sanitation⁴²⁴.

MORPHOLOGY

The adults are cylindrical in shape and creamy-white in colour. The female averages

20-35 cm in length. The male is smaller, averaging 15-31 cm in length and distinctly more slender than the female. Male is also distinguished from female by a curved posterior end bearing cloacal opening⁴²⁵ from which protrude a pair of copulatory spicules (Fig., 7-1).

BODY WALL:

The body wall (Fig., 7-2) consists of:

1-Epidermis: of thin syncytial layer and covered with a thick proteinaceous cuticle which plays an important role, in the absence of circular muscles, in containing the high hydrostatic pressure of the hemocoel. It has:



Female male

Fig. (7-1): Posterior end of *Ascaris*

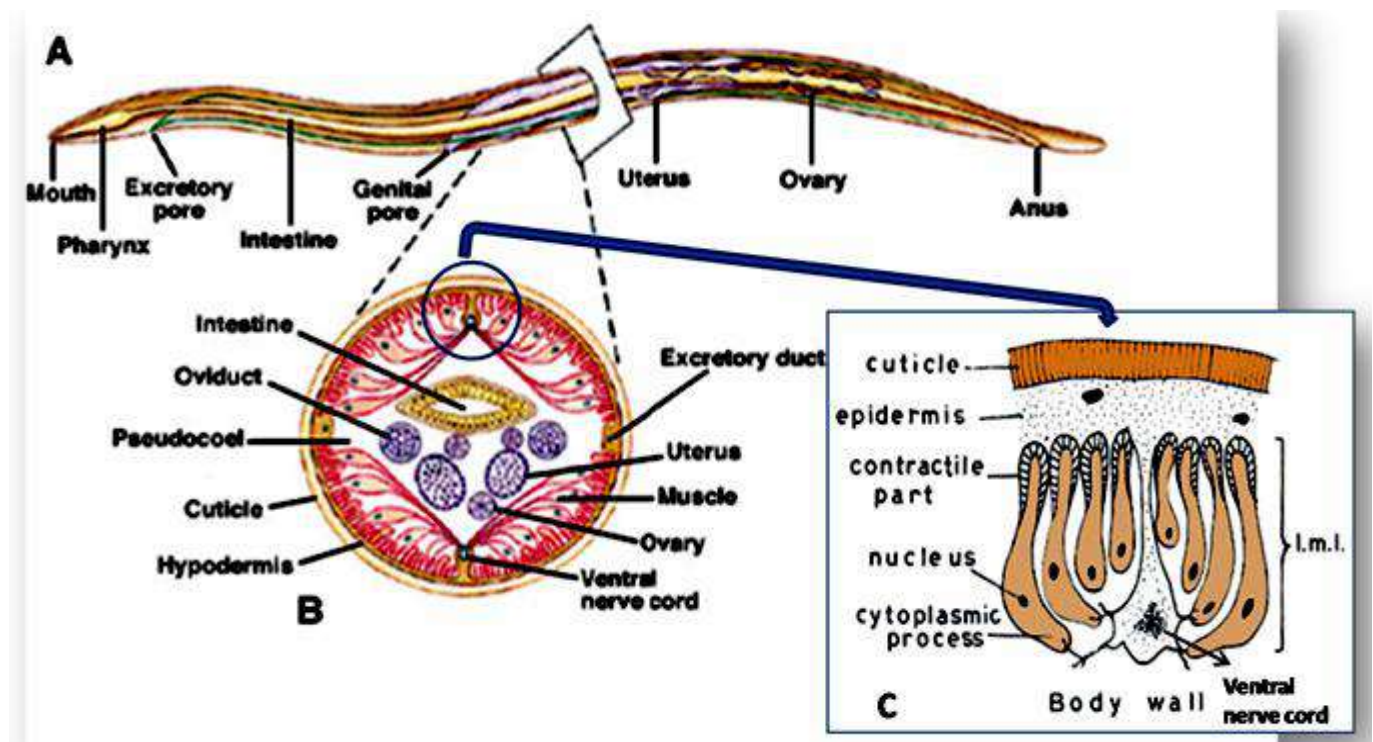


Fig. (7-2): Body wall of *Ascaris*.

- *Dorsal ridge* (enclosing dorsal nerve cord).
- *Ventral ridge* (enclosing ventral nerve cord).
- *Two lateral ridges* (enclosing two excretory canals).

2-Longitudinal muscle layer: each fiber is differentiated into:

- Outer contractile portion.
- Inner cytoplasmic portion.

3-Pseudocoelom: vacuoles containing paraenchyma cells. It is filled with fluid under exceptionally high pressure (higher than that of any other animal). The pressure maintains the body shape and acts as a hydrostatic skeleton against which the body wall muscles act to accomplish locomotion. **DIGESTIVE SYSTEM**

The gut is complete with terminal anterior mouth and subterminal posterior anus. It comprises ectodermal foregut and hindgut and an endodermal midgut (Fig., 7-4).

a- Foregut (stomodaeum): It is ectodermal and lined with cuticle. It begins with the mouth, provided with three lips lined with minute teeth (Fig., 7-3).

The mouth opens into thin-walled buccal cavity⁴²⁶.

Immediately posterior to the buccal cavity is the longer, thicker-walled pharynx whose heavily muscularized walls are used to suck food into the gut in opposition to the high hydrostatic pressure of the hemocoel.



Fig. (7-3): Lips of *Ascaris*

b- Midgut (intestine). It is a long dorsoventrally flattened tube that extends posteriorly. Unlike the ectodermal foregut, its wall consists solely of a simple columnar epithelium.

c- Hindgut or Proctodaeum. In females, the rectum is difficult to differentiate from the intestine but in males the rectum is a cloaca which receives the male gonoduct and the intestine before opening to the exterior via the anus. Being ectodermal, the rectum is lined with cuticle.

Adult *Ascaris* feed on semi-digested food found in the intestine of the host. Nutrition takes place as following:

- **Ingestion:** food enters the mouth through the pharynx.
- **Digestion:** food is passed into the intestine where nutrients are broken down and absorbed.
- **Elimination**⁴²⁷: undigested food wastes leave through the anus.

RESPIRATORY SYSTEM

Energy metabolism is anaerobic⁴²⁸ and there are no special gas exchange structures.

EXCRETORY/OSMOREGULATORY SYSTEM

The excretory system consists of an enormous H-shaped canal system contained within a single cell. The uprights of the “H” are longitudinal canals located in the lateral epidermal cords and extend over the entire length of the

worm. The two longitudinal canals connect with each other via a transverse canal near the anterior end of the worm. A short excretory duct leads from the transverse canal to the excretory pore on the anterior ventral midline. The system is thought to be chiefly osmoregulatory. The excretory pore is located immediately posterior to the mouth on the ventral midline but it is difficult to find.

REPRODUCTIVE SYSTEM

Reproductive organs (Fig., 7-4). are tubular. Male has a single reproductive tubule. The female has double reproductive tubules and the vulva is ventrally located at the posterior part of the anterior third of the body.

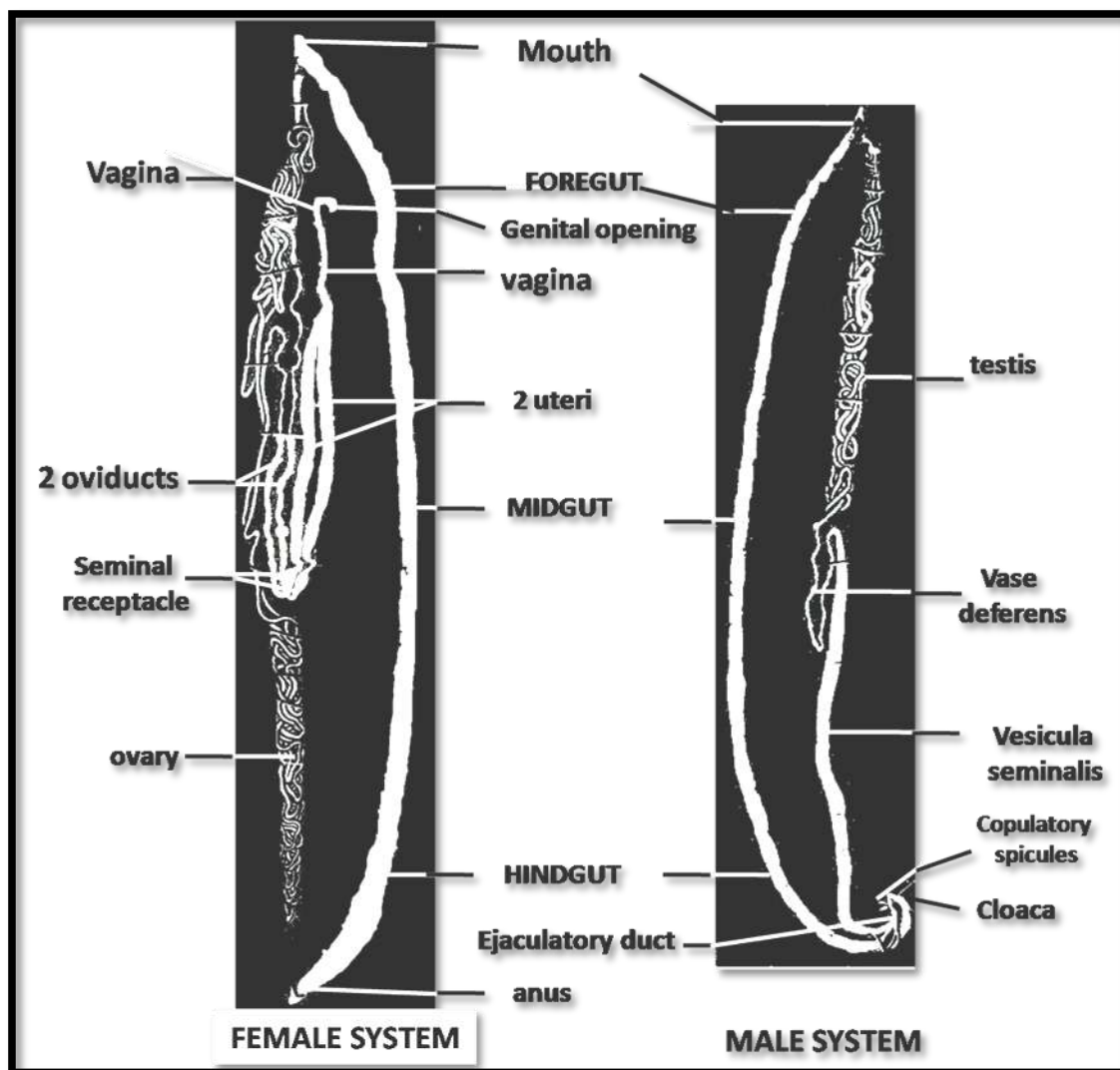


Fig. (7-4): Digestive and reproductive systems of *Ascaris*.

A- Male System

The male system consists of a single thread – like coiled testis. It leads into vasa deferentia and then to a wider tube, the vesicula seminalis. This ends in an ejaculatory tube, which joins the proctodaeum to the anus and has a pair of penial sacs containing two copulatory spicules.

B- Female system

The female system consists of two long coiled thread – like ovaries found in both ends. Each ovary leads into an oviduct which passes into a wider tube, the uterus. The two uteri join to form the vagina that open into the exterior by a gonopore. A seminal receptacle is found at the base of either uterus to store the sperms received during copulation.

During copulation the male introduces the amoeboid sperms into the vagina. The sperms travel to the lower part of the uteri to fertilize the eggs.

The produced zygote is then enveloped⁴²⁹ by a vitelline membrane and a mammillated coat.

LIFE CYCLE (Fig., 7-5).

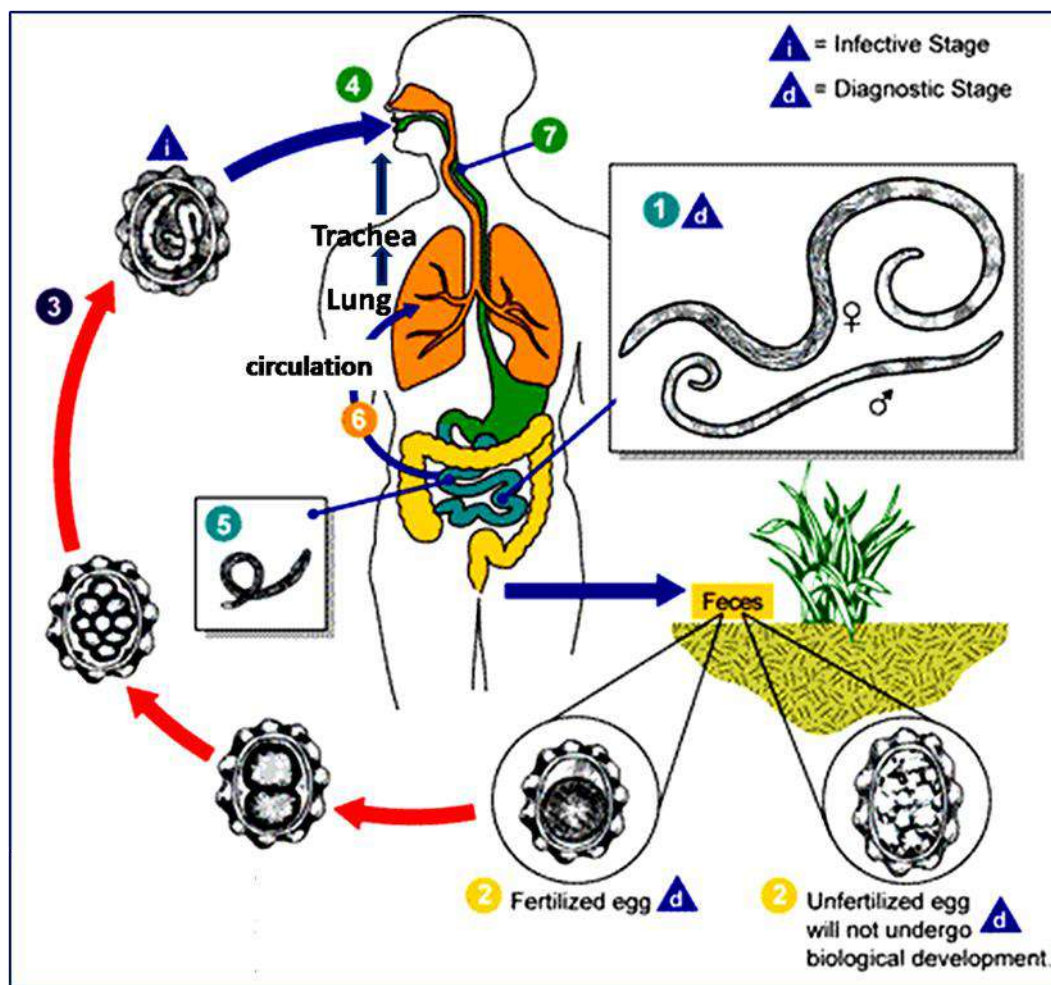


Fig. (7-5): Life cycle of *Ascaris*.

- Eggs** Fertilized egg is enveloped with a vitelline membrane (secreted by the zygote) and a mammillated coat (secreted by gland cells in the wall of the uterus). Eggs passed in faeces of human host including an uncleaved zygote.
 - In unsuitable condition: The eggs may remain inactive for 6 years.

- In suitable condition: (22 – 35 C°, O₂ and humidity) the zygote develops into ***rhabidiform larvae* (the infective stage)** which moult and remain in the egg envelop.
- 2. Man acquires the infection by the ingestion of the infective stage.
- 3. In the intestine, the egg envelope rupture, larvae are liberated and penetrate the intestinal wall and enter into the blood stream.
- 4. They then travel into liver ►► heart ►► lungs ►► trachea⁴³⁰ ►► pharynx and finally swallowed to the intestine where they moult and become mature worms.

PATHOGENESIS⁴³¹

- A. Effect of migrating larvae on the host** The presence of larvae in the lung initiates some tissue reactions and hemorrhages and this may allow secondary infection. The larvae may also cause a pneumonia⁴³². These clinical manifestation is also called **Loeffler's syndrome**.
- B. Effect of the adult worms on the host:**
 - 1. The nutritional demands⁴³³ and the space requirement of the parasite may lead to serious problems.
 - 2. They secrete certain substance which inactivate trypsin⁴³⁴. Thus, host's food protein remains undigested. This causes the school children infected with *Ascaris* to become shorter and have less memory and thinking capacity.
 - 3. They may entangled⁴³⁵ in masses which completely block the intestine.
 - 4. They may invade the bile or pancreatic ducts and obstructing these passages.
 - 5. The excretory products are toxic.

PARASITIC ADAPTATIONS OF ASCARIS

- 1. The mouth is bounded by three lips which help the parasite to attach with mucous membrane of the host's intestine.
- 2. The parasite is devoid of locomotory organs as the parasite lives in the intestine where protection from enemies and food supply are ensured.
- 3. The body wall of *Ascaris* is covered with cuticle, resistant to the digestive enzymes of the host.
- 4. The pharynx is muscular that facilitates ingestion of food by sucking action. There are no digestive glands.
- 5. Sense organs are ill-developed, being found only on lips papillae papillae.

6. Ingested food of this parasite is pre- digested, so the digestive tract is simple without provision for storage, as there is constant supply of food.
7. The body wall is covered with tough, thick and resistant cuticle, shields against the digestive enzymes of the host and antitoxins.
8. The respiration is almost entirely anaerobic. Extremely low metabolic rate and anaerobic respiration enable the worm to live inside the host's intestine, where the free oxygen is negligible.
9. Reproductive system of *Ascaris* is well- developed and numerous eggs are produced to make up for the poor chances of the right host being reached.
10. The eggs are covered with resistant covering or chitinous shell which provide safety to the zygote and embryonated eggs from unfavourable environmental factors.
11. Infection of new host is direct and fast and need no intermediate host.

e.g.-2 *Ancylostoma duodenale* (Hookworm⁴³⁶)

Ancylostoma duodenale (ancylo-Ankylo a combining form meaning "hook," "joint has head slightly bent in relation to the rest of the body. This bend forms a definitive hook shape at the anterior end for which hookworms are named. This nematode parasite of man is much more dangerous than *Ascaris*. Adult hookworm lives in enormous number in the small intestine of man attached by their buccal capsules to the mucosa of the intestine which they bite to suck plentiful of blood for nutrition.

MORPHOLOGY

Ancylostoma duodenale is an S-shaped worm because of its flexure⁴³⁷ at the frontal end (Fig., 7-7). The worm is pinkish-white. Adult male hookworms range in size from 8-11 mm long , whereas adult females range in size from 10-13 mm long. This species is dimorphic, with the males having posterior copulatory bursa.

Females have a vulva located approximately one-third of the body length from the posterior end. Both male and female hookworms have two powerful ventral teeth in the adult forms of the parasite, one along each side of the buccal capsule and a smaller pair of teeth are located deeper in the capsule. The genital opening and anus are separated in female, while they are united into cloaca in case of male.

DIGESTIVE SYSTEM AND NUTRITION

The mouth leads into an cup-like buccal cavity which is lined with cuticle, thus forming a buccal capsule (Fig., 7-6). This capsule is armed with 2 pairs of ventral teeth and one pair of smaller dorsal teeth.

Two more saw-like teeth project from the floor of the buccal capsule.

The capsule is followed by a long muscular oesophagus, both forming the STOMODAEUM. This is followed by a simple tubular intestine, then a short PROCTODAEUM or rectum (Fig., 7-7). Connected with the digestive system are two large cephalic glands ⁴³⁸ which extend along the anterior third of the body and open in the buccal capsule.



Fig. (9-6): Buccal capsule

Their secretion prevents coagulation ⁴³⁹ of the host's blood. Hook -worms hold on to the mucosa ⁴⁴⁰ of the intestine with their buccal capsule and cut bits of the mucosa with their teeth causing haemorrhage. They feed on the blood and bits of the mucosa which they suck by their muscular oesophagus. The wound continues to bleed for a short time after the worm leaves it.

EXCRETORY AND NERVOUS SYSTEMS

Ankylostoma has an H-shaped excretory cell or **renette** with a canal system similar to that of *Ascaris*, in addition to two cervical glands of excretory function which connect with the transverse canal.

The nervous system resembles that of *Ascaris*.

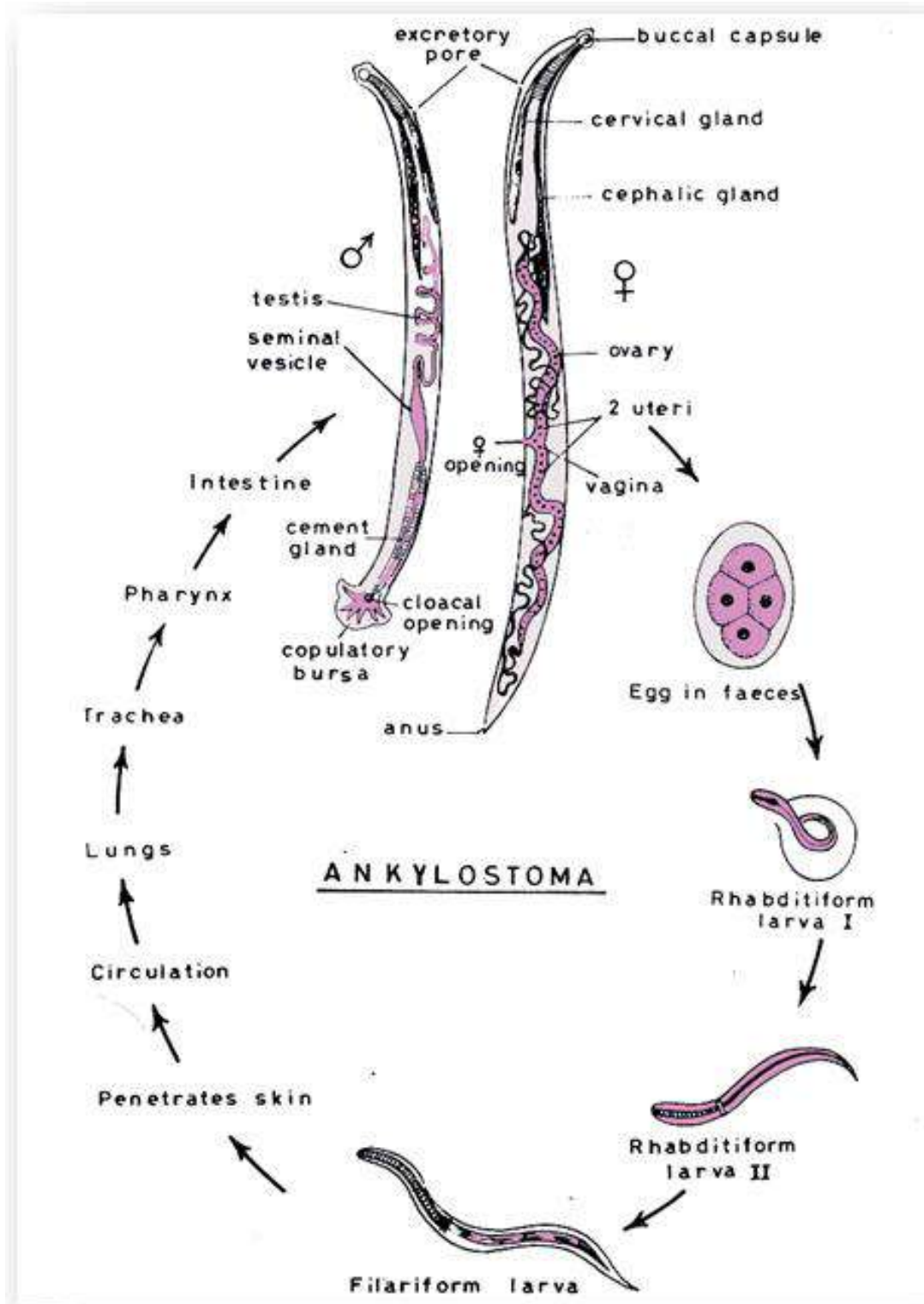
REPRODUCTIVE SYSTEM

The male has a single tubular coiled testis which leads into a narrow vasa deferentia, then into a dilated vesicula seminalis. This is followed by a long ejaculatory duct ⁴⁴¹, which is surrounded by a large cement gland and opens into the rectum, both leading to the outside by the cloacal opening. Two long copulatory spicules lie in pouches dorsal to the ejaculatory duct. The posterior end of the male is expanded into a copulatory bursa which curves about the genital opening of the female during copulation. It has three lobes supported by fleshy rays. The female has two coiled ovaries which lead by narrow oviducts into two dilated and coiled uteri. These join in a very short vagina which opens to the exterior by the genital opening.

LIFE CYCLE (Fig., 7-7).

1. **Eggs:** Female worms can lay 25,000 eggs per day. The eggs are released with the feces into the soil. Within two days, the eggs hatch in warm, moist soil. The larvae live in the soil, waiting for contact with a host.

2. **Rhabditiform Larval Stage (non-infective stage):** The first form of the larval stage is called rhabditiform larva and exists in contaminated feces or soil. Within five to ten days, the larva will grow and moult twice.



3. Fig. (7-7): Life cycle of *Ankylostoma*

4. **Filariform Stage (Infective stage):** After the last molt, larvae will enter a filariform stage and can then infect a host. Filariform larvae can survive for up to thirty days in the soil. If a host touches the contaminated area, the larva enters through its skin. It then enters the circulatory system and is carried to the lungs. The host will eventually cough up the larva and swallow it. The larva will then pass through the digestive tract to the small intestine where it will grow into an adult.
5. **Adult Stage:** In a definitive host, adult hookworms attach themselves to the wall of the small intestine, feeding on the blood of the host and reproduce. Females will then lay eggs in the digestive tract to start the life cycle again. Adult hookworms can live for as long as two years in the intestine of the host.
6. **PATHOGENESIS**
7. When the hook-worms reach the small intestine of man, they will attach to the villi⁴⁴² with their buccal capsules. The tips of the villi become eroded⁴⁴³, a haemorrhage is produced and the worms start to suck the flowing blood. It has been recently demonstrated that each worm is capable of removing 0.67 ml of blood per day. In light infections the blood loss can be compensated⁴⁴⁴ by new supplies from blood-producing organs. However, in heavy infections, severe blood loss leads to anaemia. Heavy infections in children may cause considerable retardation⁴⁴⁵ in their physical and mental growth, as well as an increase in their susceptibility to other diseases.

Table (7-1): Comparison between *Ascaris* and *Ankylostoma*

	<i>Ascaris</i>	<i>Ankylostoma</i>
Size	• Large, may reach 35 mm	• Small, up to 14 mm
Habitat	• Live in the intestinal lumen and feed on semi-digested food	• Found attached to the intestinal mucosa of the intestine by its buccal capsule.
Mouth	• Surrounded by three lips	• Have buccal capsule provided with teeth
The posterior end of male	• Curved and provided with two copulatory spicules	• Expanded and modified into copulatory bursa
Infective stage	• Second stage Rhabdiform larva inside the egg envelope.	• Filariform larva
Mode of Infection	• By ingestion	• by penetration of the skin

SELECTED REFERENCES

1. Al-Hussaini, A.H. and Demian, E.S. (1994): "Practical Animal Biology". Vol. II: Systematic Zoology. 13th ed., Dar Al-Maaref, Cairo.
2. Al-Hussaini, A.H. and Demian, E.S. (1994): "Practical Animal Biology". Vol. III: Coelomate Invertebrates. 13th ed., Dar Al-Maaref, Cairo.
3. Brusca, R.C., Brusca, G.J. and Haver, N.J. (2003): Invertebrates" 2nd ed. Sinauer Associates.
4. Campbell, N.A. and Reece, J.B., (2015): "Biology" 8th ed. Pearson Education Inc.
5. El-Benhawy, M., Demian, E.S., Shalaby, A.A. and Roshdy, M.A. (1994): "Text Book of Zoology". 9th ed., Dar Al-Maaref, Cairo.
6. Gamil, M. Soliman (2004): Invertebrate Zoology: The Mideastern Invertebrate Fauna. Part I: The Noncoelomate. 2nd ed.,. The Palm press, Cairo.
7. Hyman, L.H. (1992): "Invertebrates: Protozoa Through Ctenophra". Vol. 1. International Books and Periodicals Supply Services, Delhi.
8. Hyman, L.H. (1992): "Invertebrates: Echinodermata, The Coelomate Bilateria". Vol.4. International Books and Periodicals Supply Services, Delhi.
9. Kaestner, A. (1970): "Invertebrate Zoology". Vol. 3. Interscience Publishers, New York.
10. Kotbal, R.L. (2016): "Modern Text Book of Zoology. Invertebrates. 11th ed., Rakesh & Rastogi, Meerut, India.
11. Macalister, A. (2010): "Zoology of the invertebrate animals". Goldstein Press .
12. Macalister, A. (2009): "An Introduction to Animal Morphology and Systematic Zoology". Part I. "Invertebrata". BiblioLife. Pp, 348.
13. Pechenik, J. (2009): "Biology of the Invertebrates". 6th ed. McGraw-Hill.
14. **Randall, T. Schuh, R.T. and Andrew V.Z. Brower, A.V.Z.** (2009): "Biological Systematics: Principles and Applications". 2nd ed. Comstock Publishing Associates.
15. Ruppert, E.E., Fox, R.S. and Barnes R.D. (2004): "Invertebrate Zoology". 7th edition. Saunders College Publishing.
16. Wallace, R.L. and Taylor, W.K. (2003): "Invertebrate Zoology Lab Manual", 6th Edition. Benjamin Cummings.

WEB PAGES

1. http://en.wikipedia.org/wiki/Invertebrate_zoology
2. <http://www.marietta.edu/~mcshaffd/invert/>
3. http://www.mhhe.com/biosci/pae/zoology/hickman11/?bcsi_scan_53A23A8130582379=1
4. http://en.wikibooks.org/wiki/Invertebrate_Zoology
5. <http://webs.lander.edu/rsfox/invertebrates/>

DICTIONARY

- | | |
|---|---|
| <p>٣٢. اخصاب fertilization</p> <p>٣٣. حيوي viable</p> <p>٣٤. أدلة مستقلة independent evidence</p> <p>٣٥. ملوث contaminated</p> <p>٣٦. متناقض inconsistent</p> <p>٣٧. السابقين – الأسلاف predecessors</p> <p>٣٨. تدرجي hierarchical</p> <p>٣٩. نظام التسمية الثنائية binomial nomenclature</p> <p>٤٠. شعبة Phylum</p> <p>٤١. طائفة Class</p> <p>٤٢. رتبة Order</p> <p>٤٣. ابن عرس weasels</p> <p>٤٤. المرتبة العليا top rank</p> <p>٤٥. بدائي primitive</p> <p>٤٦. خيوط متعددة الأنوية multinucleate filaments</p> <p>٤٧. تأكيد emphasis</p> <p>٤٨. المستوى الجزيئي molecular level</p> <p>٤٩. يؤسس establish</p> <p>٥٠. مزج blending</p> <p>٥١. معيار standard</p> <p>٥٢. فراشة butterfly</p> <p>٥٣. علم التصنيف الجزيئي molecular taxonomy</p> <p>٥٤. الطب الشرعي الجنائي criminal forensics</p> <p>٥٥. غالباً predominately</p> <p>٥٦. وُصفت described</p> <p>٥٧. يُحدِّد restricts</p> <p>٥٨. انتشار – مرور diffusion</p> <p>٥٩. فجوة غذائية food vacuole</p> <p>٦٠. فجوة منقبضة contractile vacuole</p> <p>٦١. التنظيم الأسموزي osmotic regulation</p> <p>٦٢. التكيس encystment</p> | <p>١. متنوع diverse</p> <p>٢. متفرد unique</p> <p>٣. مَهْمَة task</p> <p>٤. رُتبت arranged</p> <p>٥. تطبيقي applied</p> <p>٦. الآفات pests</p> <p>٧. ناقلات الأمراض disease vectors</p> <p>٨. مسببات الأمراض pathogens</p> <p>٩. النظام البيئي ecosystem</p> <p>١٠. قاعدة base</p> <p>١١. تطور development</p> <p>١٢. دليل evidence</p> <p>١٣. أساسي elementary</p> <p>١٤. شامل inclusive</p> <p>١٥. من حيث الشكل الظاهري morphological</p> <p>١٦. بيئي ecological</p> <p>١٧. علاقات تطورية phylogenetics</p> <p>١٨. علم التصنيف taxonomy</p> <p>١٩. المستهل – البداية outset</p> <p>٢٠. تقديرات estimates</p> <p>٢١. المنطقة الاستوائية tropical regions</p> <p>٢٢. منقرض extinct</p> <p>٢٣. التغذية nutrition</p> <p>٢٤. الدب bear</p> <p>٢٥. افترض assumed</p> <p>٢٦. اختصر – لخص abridged</p> <p>٢٧. عرّف define</p> <p>٢٨. تتزاوج interbreed</p> <p>٢٩. خصيبة fertile</p> <p>٣٠. عقيمة sterile</p> <p>٣١. البغل mule</p> |
|---|---|

٩٤. قطيرات صغيرة minute droplets	٦٣. بدائية primitive
٩٥. تنفجر bursts	٦٤. تؤدي - تقوم perform
٩٦. تخلي - تفرغ evacuate	٦٥. منفردة solitary
٩٧. الانتشار البسيط simple diffusion	٦٦. مستعمرات colonies
٩٨. النواتج الإخراجية excretory products	٦٧. عضيات الحركة locomotary organelles
٩٩. يستخدم utilized	٦٨. الأقدام الكاذبة (sing., pseudopodia)
١٠٠. التكاثر reproduction	٦٩. الأسواط (sing. flagellum)
١٠١. الانشطار الثنائي الطولي longitudinal binary fission	٧٠. الأهداب (sing., cilium)
١٠٢. الظروف المناسبة (العادية) suitable conditions	٧١. طفيلي parasitic
١٠٣. الظروف غير العادية (الصعبة) unsuitable condition	٧٢. الانشطار الثنائي binary fission
١٠٤. تفرز secrets	٧٣. الانشطار المتعدد multiple fission
١٠٥. كيس - حوصلة cyst	٧٤. الانتشار dispersion
١٠٦. تتحمل withstand	٧٥. تشتمل - تحوي comprising
١٠٧. الصعبة adverse	٧٦. حساسة للضوء photosensitive
١٠٨. تتحرر liberated	٧٧. البرك ponds
١٠٩. علماء الطحالب phycologists	٧٨. البيئة habitat
١١٠. تُعتبر considered	٧٩. الشكل الظاهري (المظهر الخارجي)
١١١. تمتلك possesses	٨٠. حركة دودية worm - like movement
١١٢. مقدرة ability	٨١. انقباض contraction
١١٣. العامل المسبب causative agent	٨٢. انبساط relaxation
١١٤. التقدم الاقتصادي والاجتماعي economic and social progress	٨٣. تمكّن enables
١١٥. العائل الأساسي definite host	٨٤. مائلاً obliquely
١١٦. العائل الوسيط intermediate host	٨٥. بطريقة حلزونية spiral manner
١١٧. غشاء متموج undulating membrane	٨٦. التغذية nutrition
١١٨. العائل host	٨٧. تصنع - تركيب synthesize
١١٩. العدوى - الإصابة infection	٨٨. بمساعدة by the aid of
١٢٠. الطفيل parasite	٨٩. الوسط المحيط surrounding medium
١٢١. اللعاب saliva	٩٠. الارتشاف أو الشرب الخلوي (امتصاص المواد)
١٢٢. التكاثر multiplication	السائلة عن طريق الغشاء الخلوي pinnocytosis
١٢٣. فترة الحضانة (الفترة التي تتقضي منذ دخول	٩١. شبه منفذ semi - permeable
الطفيل جسم العائل حتى ظهور اعراض المرض)	٩٢. تميل tends
incubation period	٩٣. الزائد excess
١٢٤. أعراض المرض symptomes	

١٥٥. تعمل acts
 ١٥٦. تُفَرَز secreted
 ١٥٧. التمثيل - الاستيعاب assimilation
 ١٥٨. التغوط (التخلص من الفضلات) egestion
 ١٥٩. أكثر تركيزاً more concentrated
 ١٦٠. يطرد expelled
 ١٦١. الإخراج excretion
 ١٦٢. ضارة harmful
 ١٦٣. تسحب withdraw
 ١٦٤. التجدد regeneration
 ١٦٥. كيس مقاوم resistant cyst
 ١٦٦. تتحسن improved
 ١٦٧. التجرثم sporulation
 ١٦٨. بدلاً من ذلك instead
 ١٦٩. الطور المغتذي trophozoite
 ١٧٠. تتميز differentiated
 ١٧١. محبب granular
 ١٧٢. محاط bounded
 ١٧٣. صغير minute
 ١٧٤. تجويف الأمعاء lumen of the intestine
 ١٧٥. تهاجم invade
 ١٧٦. الطبقة المخاطية (الطبقة المبطننة للأمعاء)
 mucosal layer
 ١٧٧. مخزون reserve
 ١٧٨. الغائط - الفضلات faeces
 ١٧٩. تبقى حية survive
 ١٨٠. يكتسب acquires
 ١٨١. طعام ملوث contaminated food
 ١٨٢. تحول transformation
 ١٨٣. يذوب dissolved
 ١٨٤. غير ضار harmless
 ١٨٥. إصابة مرضية pathological infection
 ١٨٦. تخترق penetrates
 ١٨٧. نزف bleeding

١٢٥. المعوي المتوسط (أحد أجزاء القناة الهضمية للذبابة)
 midgut
 ١٢٦. الطور غير الناضج immature stages
 ١٢٧. الغدد اللعابية salivary glands
 ١٢٨. يهاجر migrate
 ١٢٩. الطور المعدي infective stage
 ١٣٠. العلاقة بين العائل والطفيل host-parasite relationship
 ١٣١. يستهلك consumes
 ١٣٢. سام toxic
 ١٣٣. تهاجم invade
 ١٣٤. إغماء coma
 ١٣٥. الفقاريات vertebrates
 ١٣٦. الخلايا الملتزمة (إحدى أنواع كريات الدم البيضاء)
 phagocytes
 ١٣٧. مغزلي الشكل (مدبب الطرفين) spindle
 ١٣٨. يدخل introduced
 ١٣٩. يتمزق - ينفجر rupture
 ١٤٠. يتحرر - ينطلق released
 ١٤١. يبتلع - يزدرد ingest
 ١٤٢. مرض الليشمانيا الحشوي (مرض كالاآزار)
 visceral leishmaniasis (Kala- Azar)
 ١٤٣. تضخم enlargement
 ١٤٤. مرض الليشمانيا الجلدي cutaneous
 leishmaniasis
 ١٤٥. مرض القرحة الشرقية oriental sore
 ١٤٦. يشفى heal
 ١٤٧. يتحول progress
 ١٤٨. تصطاد capture
 ١٤٩. بروز protrusion
 ١٥٠. الحالة الغروية (حالة وسط بين السوائل والجوامد)
 colloidal state
 ١٥١. ينسحب drawn
 ١٥٢. جزيئات particles
 ١٥٣. تحيط تدريجياً gradually encloses
 ١٥٤. الهضم digestion

٢٢٠. غذائي trophic
٢٢١. القناة الهضمية alimentary canal
٢٢٢. أعراض symptoms
٢٢٣. رعشة rigor
٢٢٤. تعرق sweating
٢٢٥. تقيؤ vomiting
٢٢٦. أضرار شبكية العين retinal damage
٢٢٧. مميت fatal
٢٢٨. مفيدة beneficial
٢٢٩. تمد furnish
٢٣٠. القشريات (مجموعة من الحيوانات مفصلية الأرجل crustaceans مثل الجمبري)
٢٣١. الصناعة industry
٢٣٢. خصوبة التربة soil fertility
٢٣٣. تلوث pollution
٢٣٤. الإجهاض abortion
٢٣٥. الابتلاع- التغذية على كائنات أخرى ingestion
٢٣٦. تسود dominating
٢٣٧. التفلج (انقسام الخلايا في المراحل الجنينية المبكرة) cleavage
٢٣٨. التعضي - تكوين الأعضاء organization
٢٣٩. تماثل الجسم body symmetry
٢٤٠. شعبة المثقبات (المساميات) Phylum: Porifera
٢٤١. عديمة التماثل asymmetrical
٢٤٢. التماثل الشعاعي radial symmetry
٢٤٣. متماثلة الجانبين bilateral symmetry
٢٤٤. ثنائية الطبقة Diploblastica
٢٤٥. ثلاثية الطبقة Triploblastica
٢٤٦. جالسة (ملتصقة بقاع البحر) sessile
٢٤٧. المواد الإخراجية wastes
٢٤٨. التنسيق - التآزر بين الخلايا coordination
٢٤٩. نسيج حقيقي proper tissue
٢٥٠. مثقبة perforated
٢٥١. حجرات chambers
١٨٨. تقرحات ulcers
١٨٩. الدوسنتاريا الأميبية amoebic dysentery
١٩٠. بحري (يعيش في المياه المالحة) marine
١٩١. صدفة shells
١٩٢. المكون الرئيسي للمحيطات the major constituents of the ocean
١٩٣. تشبه resembles
١٩٤. شبكة network
١٩٥. ظاهرة phenomena
١٩٦. ظاهرة تبادل الأجيال alternation of generation
١٩٧. ناضج mature
١٩٨. شبيه بالنعل slipper-shaped
١٩٩. محدب convex
٢٠٠. زوائد processes
٢٠١. تشبه الكلية kidney-shaped
٢٠٢. تضرب stricks
٢٠٣. المحور الطولي longitudinal axis
٢٠٤. تدفع propels
٢٠٥. الميزاب الفمي oral groove
٢٠٦. الشرج anus
٢٠٧. الإقتران conjugation
٢٠٨. أقل حيوية less viable
٢٠٩. التزاوج الذاتي autogamy
٢١٠. فريدة unique
٢١١. خبيث malignant
٢١٢. الثدييات mammals
٢١٣. بعوضة الأنوفيليس anopheline mosquitoes
٢١٤. رحيق الأزهار nectar
٢١٥. غير كاف insufficient
٢١٦. الطور النسيجي tissue phase
٢١٧. طور كريات الدم الحمراء erythrocytic phase
٢١٨. طور العائل اللاقاري invertebrate phase
٢١٩. ينشأ initiated

٢٨٦. invaginate تنغمد
 ٢٨٧. mops المماسح (لأغراض النظافة)
 ٢٨٨. reputed مزعوم
 ٢٨٩. therapeutic value قيمة علاجية
 ٢٩٠. crafts الحِرَف
 ٢٩١. pottery الفخار
 ٢٩٢. jewelry making صناعة المجوهرات
 ٢٩٣. crustaceans الحيوانات القشرية
 ٢٩٤. molluscs الرخويات
 ٢٩٥. nudibranchs عاريات الخياشيم
 ٢٩٦. commensals شريك في علاقة نافعة مع الكائنات الأخرى
 ٢٩٧. anti-inflammatory مضادة للالتهاب
 ٢٩٨. intriguing غريب
 ٢٩٩. harnessed مُسَخَّر
 ٣٠٠. together for eternity معا للأبد
 ٣٠١. Phylum: Cnidaria شعبة: اللاسعات
 ٣٠٢. nettle شوكة
 ٣٠٣. advance تقدم - تطور
 ٣٠٤. sea anemones شقائق النعمان
 ٣٠٥. corals الشعاب المرجانية
 ٣٠٦. jelly fishes قناديل البحر
 ٣٠٧. stinging cells الخلايا اللاسعة
 ٣٠٨. defense الدفاع عن النفس
 ٣٠٩. anus الشرج
 ٣١٠. extracellular خارج الخلية
 ٣١١. intracellular داخل الخلية
 ٣١٢. suppression اخماد - اختزال
 ٣١٣. habitat البيئة - طبيعة المعيشة
 ٣١٤. cylindrical اسطوانية الشكل
 ٣١٥. lakes بحيرات
 ٣١٦. stream الجداول - المستنقعات
 ٣١٧. submerged مغمورة
 ٣١٨. abundant وفير
 ٣١٩. adhesive لاصق

٢٥٢. intracellular داخل الخلية
 ٢٥٣. skeleton هيكل
 ٢٥٤. طور يرقى (طور في دورة الحياة يختلف عن الأبوين)
 ٢٥٥. larval stage hollow مفرد
 ٢٥٦. aggregation تجمع
 ٢٥٧. independent مستقلة
 ٢٥٨. embedded مغمورة
 ٢٥٩. supported مدعمة
 ٢٦٠. osculum الفتحة الزفيرية
 ٢٦١. ostia ثقب شهيقي
 ٢٦٢. dermal layer طبقة الأدمة
 ٢٦٣. gastric layer طبقة معوية
 ٢٦٤. wonder تتجول
 ٢٦٥. differentiate تتمايز - تتحول
 ٢٦٦. choanocytes الخلايا الطوقية
 ٢٦٧. lining تبطن - تغلف
 ٢٦٨. water current تيار الماء
 ٢٦٩. drawing سحب
 ٢٧٠. ejecting يطرد - يخرج
 ٢٧١. provides تمدد
 ٢٧٢. waste removal التخلص من الفضلات
 ٢٧٣. trap تمسك - تصطاد
 ٢٧٤. less efficient أقل كفاءة
 ٢٧٥. harbour تستضيف - تحوي
 ٢٧٦. symbiotic تعايشي (صورة من صور تبادل المنفعة بين الكائنات الحية)
 ٢٧٧. instead بدلا من ذلك
 ٢٧٨. pump يضخ
 ٢٧٩. deprived of خالية من
 ٢٨٠. capacity المقدرة
 ٢٨١. blended تُقَرَّم
 ٢٨٢. gather تتجمع
 ٢٨٣. withstand تتحمل
 ٢٨٤. hermaphrodite مُخَنَّث
 ٢٨٥. disposing تنتشر

٣٢٠. basal disc قرص قاعدي
 ٣٢١. tentacles لوامس
 ٣٢٢. gonads (الخصية أو المبيض) المناسل
 ٣٢٣. the interstitial cells الخلايا البينية
 ٣٢٤. الأمشاج (الحيوانات المنوية أو البويضات) gametes
 ٣٢٥. nerve – net شبكة عصبية
 ٣٢٦. sensory cells خلايا حسية
 ٣٢٧. mucous cells الخلايا المخاطية
 ٣٢٨. cnidocytes الخلايا اللاسعة
 ٣٢٩. homogenous متجانسة
 ٣٣٠. basement membrane غشاء قاعدي
 ٣٣١. glandular cells الخلايا الغدية
 ٣٣٢. trigger الزناد
 ٣٣٣. prey الفريسة
 ٣٣٤. discharged تنطلق
 ٣٣٥. dart-like thread خيط شبيه بالسهم
 ٣٣٦. paralyse يشل
 ٣٣٧. penetrant المخترقة
 ٣٣٨. stimulated تُستثار
 ٣٣٩. pierces تخترق
 ٣٤٠. solvent الملتقة
 ٣٤١. wrapped around يلتف حول
 ٣٤٢. processes زوائد
 ٣٤٣. occassionly من حين لآخر - عرضيا
 ٣٤٤. gliding التزحلق
 ٣٤٥. bends over ينثني
 ٣٤٦. somersaulting الشقلبة
 ٣٤٧. swing يتأرجح
 ٣٤٨. detaches تنفصل
 ٣٤٩. cooperate تتعاون
 ٣٥٠. swallows تبتلع
 ٣٥١. engulfed تلتهم
 ٣٥٢. expelled تطرد
 ٣٥٣. budding التبرعم
 ٣٥٤. improved تتحسن
 ٣٥٥. modified متحور
 ٣٥٦. benefiting مستفيد
 ٣٥٧. mutualism تبادل المنفعة
 ٣٥٨. uncomfortable غير مريح
 ٣٥٩. inflict يوقع
 ٣٦٠. unconsciousness اغماء
 ٣٦١. masked - يَخْتَفِي - يُعْطَى
 ٣٦٢. Echinodermates شوكيات الجلد
 ٣٦٣. Platyhelminthes الديدان المفلطحة
 ٣٦٤. cephalization وجود منطقة رأس واضحة
 ٣٦٥. flame cell خلية لهبية
 ٣٦٦. excretory ducts قنوات إخراجية
 ٣٦٧. cerebral ganglia عقد عصبية مخية
 ٣٦٨. nerve cords أحبال عصبية
 ٣٦٩. accessory genital glands الغدد التناسلية المُساعدة
 ٣٧٠. cuticle (طبقة جلدية سميكة) الجليد
 ٣٧١. suckers الممصات
 ٣٧٢. turbellae دوامات
 ٣٧٣. humid رطبة
 ٣٧٤. مستقبلات ضوئية (خلايا حساسة للضوء)
 photoreceptors
 ٣٧٥. wedge-shaped وتدي الشكل
 ٣٧٦. veterenary بيطري
 ٣٧٧. demostic animals الحيوانات الأليفة
 ٣٧٨. oral sucker ممص فمي
 ٣٧٩. Monogenea وحيدة العائل
 ٣٨٠. Digenia ثنائية العائل
 ٣٨١. dioecious منفصلة الأجناس
 ٣٨٢. تتكاثر بالتوالد البكري (من بويضة غير مخصبة
 parthenogenetically بحيوان منوي)
 ٣٨٣. liver fluck الدودة الكبدية

٤١٥. مدمج خلوي (تركيب متعدد الأنوية ينشأ من اندماج العديد من الخلايا) syncytial

٤١٦. المستقبل المنوي (كيس يقوم بتخزين المنى في الجهاز الأنثوي بعد استقباله من الذكر) receptaculum seminis

٤١٧. مناسب - مريح convenience

٤١٨. تتفصل detached

٤١٩. تقذف - تخرج extrude

٤٢٠. العضلة القلبية cardiac muscle

٤٢١. صلابة turgidity

٤٢٢. يُزال obliterated

٤٢٣. ينسلخ moulted

٤٢٤. أنظمة الصرف الصحي sanitation

٤٢٥. فتحة المذرق (فتحة تجمع فتحة الشرج والفتحة cloacal opening التناسلية البولية)

٤٢٦. التجويف الفمي buccal cavity

٤٢٧. إزالة الفضلات elimination

٤٢٨. لاهوائي anaerobic

٤٢٩. يُغلف enveloped

٤٣٠. القصبة الهوائية trachea

٤٣١. التأثيرات المرضية pathogenesis

٤٣٢. التهاب رئوي pneumonia

٤٣٣. الاحتياجات الغذائية nutritional demands

٤٣٤. انزيم التريسين (انزيم مسئول عن هضم البروتين في الأمعاء) trypsin

٤٣٥. يتشابك entangled

٤٣٦. الدودة الخطافية (الأنكلستوما) hookworm

٤٣٧. انحناء flexure

٤٣٨. غدد رأسية cephalic glands

٤٣٩. تجلُط - تخثر coagulation

٤٤٠. الطبقة المخاطية للأمعاء mucosa

٤٤١. قناة قاذفة ejaculatory duct

٤٤٢. خملات (زوائد تبرز من جدار الأمعاء) villi

٤٤٣. مُتآكل eroded

٤٤٤. يُعوض compensated

٤٤٥. تأخر retardation

٣٨٤. القنوات الصفراوية bile ducts

٣٨٥. حويصلات ارتشافية (تقوم بإدخال الغذاء السائل بطريقة الارتشاف) pinocytotic vesicles

٣٨٦. شويكات spinules

٣٨٧. مريء oesophagus

٣٨٨. مكان إعداد البيض ootype

٣٨٩. الرحم uterus

٣٩٠. النباتات المائية aquatic vegetation

٣٩١. المصابة infested

٣٩٢. نزف hemorrhages

٣٩٣. تسد block

٣٩٤. مرض الصفراء jaundice

٣٩٥. اضطرابات disturbances

٣٩٦. حيوية viability

٣٩٧. المثانة bladder

٣٩٨. بولي urinary

٣٩٩. حوض البحر المتوسط Mediterranean basin

٤٠٠. شوكة طرفية terminal spine

٤٠١. القوارض rodents

٤٠٢. يحتضن incubating

٤٠٣. قناة الإحتضان gynaecophoric canal

٤٠٤. حلماة tubercles

٤٠٥. المثانة البولية urinary bladder

٤٠٦. حلمة ثاقبة boring papilla

٤٠٧. تأثيرات مَرَضِيَّة ill effects

٤٠٨. مُزمن chronic

٤٠٩. التهابات inflammations

٤١٠. منطقة الرأس scolex

٤١١. قطعة لسانية proglottids

٤١٢. لحم البقر beef

٤١٣. لحم الخنزير pork

٤١٤. غير ناضجة immature



Zagazig University
Faculty of Science
Zoology Department



Practical Notes On Systematic Zoology





قسم علم الحيوان
كلية العلوم
جامعة الزقازيق



علم تصنيف الحيوان (المذكرة العملية)



Student Name:	
Socialization	
Section:	
ID	

Weeks	Date	Lesson	Instructor's Signature
1			
2			
3			
4			
5			
6			

Kingdom: Protista
Subkingdom: Protozoa
Phylum: Sarcomastigophora
Subphylum Mastigophora
Class: Phytomastigophora
e. g. *Euglena sp.*

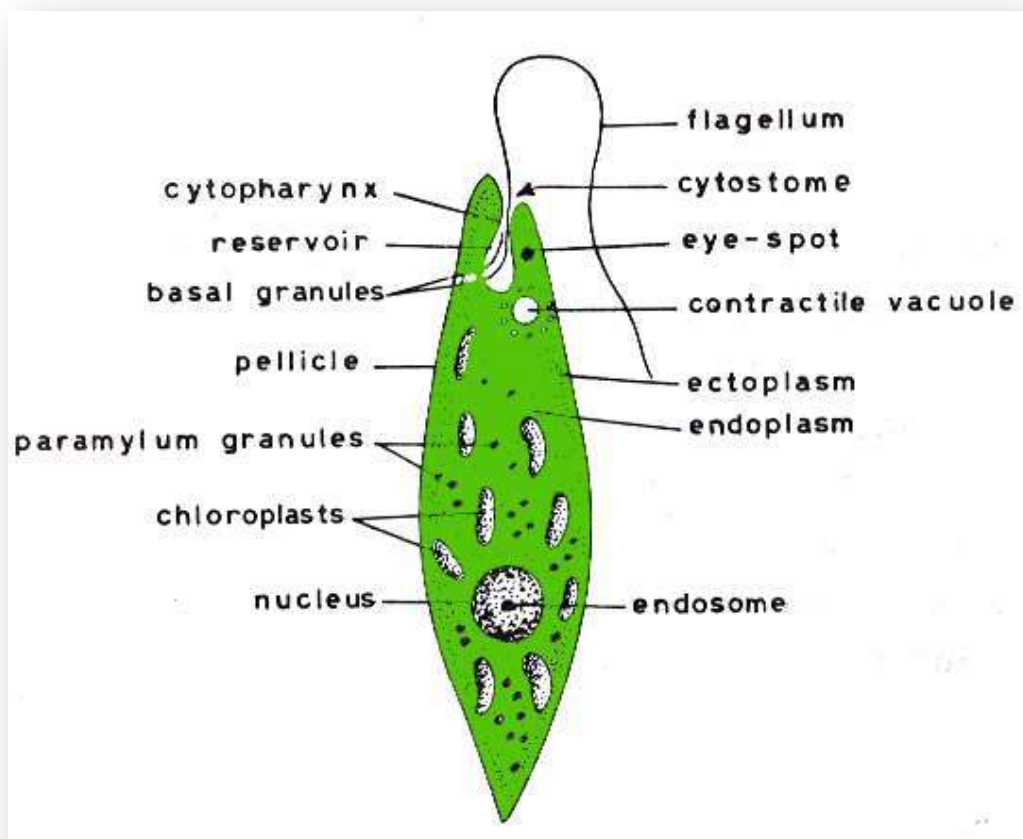


Fig. (1): *Euglena sp.*

Kingdom: Protista
Subkingdom: Protozoa
Phylum: Sarcomastigophora
Subphylum Mastigophora
Class: Zoomastigophora
e.g. Trypanosoma sp.

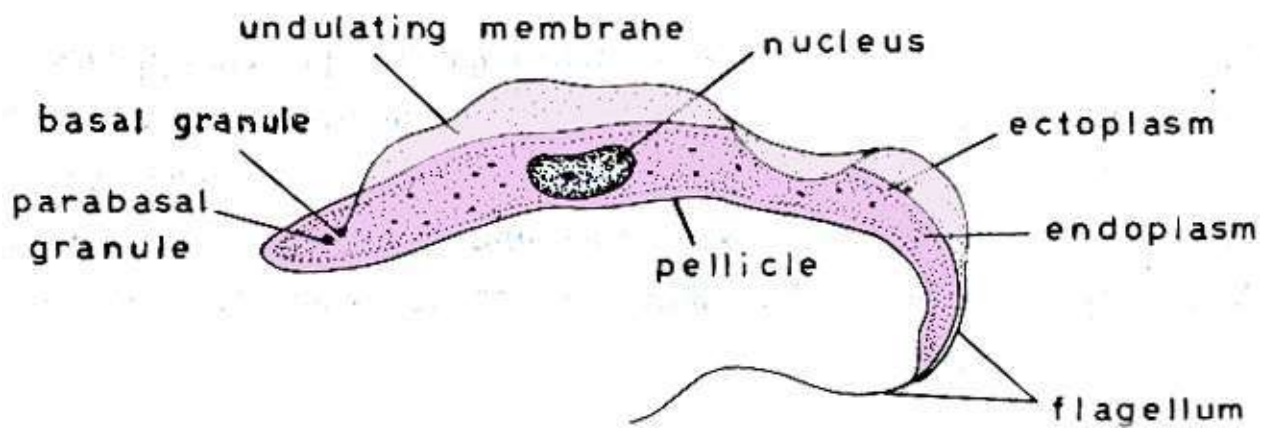


Fig. (2): *Trypanosoma sp*

Kingdom: Protista
Subkingdom: Protozoa
Phylum: Sarcomastigophora
Supylum: Sarcodina

e.g. *Amoeba sp.*

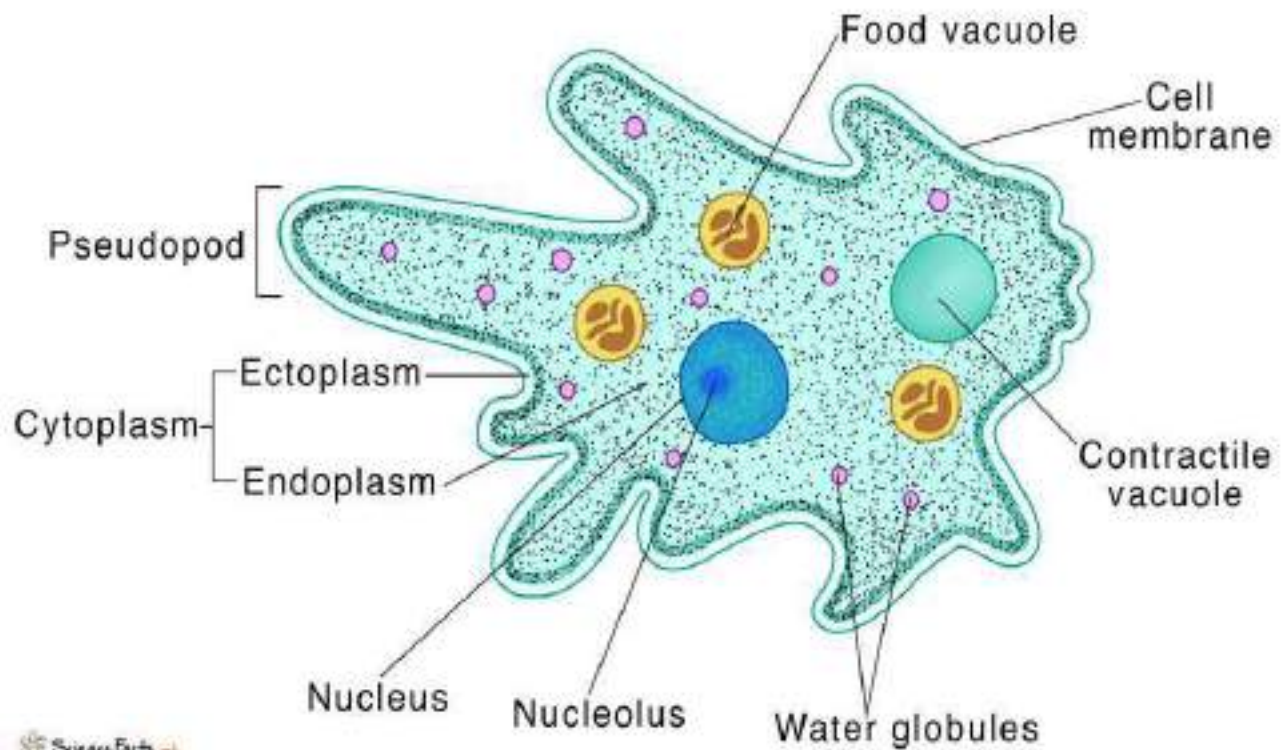


Fig. (3): *Amoeba sp*

Kingdom: Protista

Subkingdom: Protozoa

Phylum: Ciliophora

e.g. *Paramecium sp.*

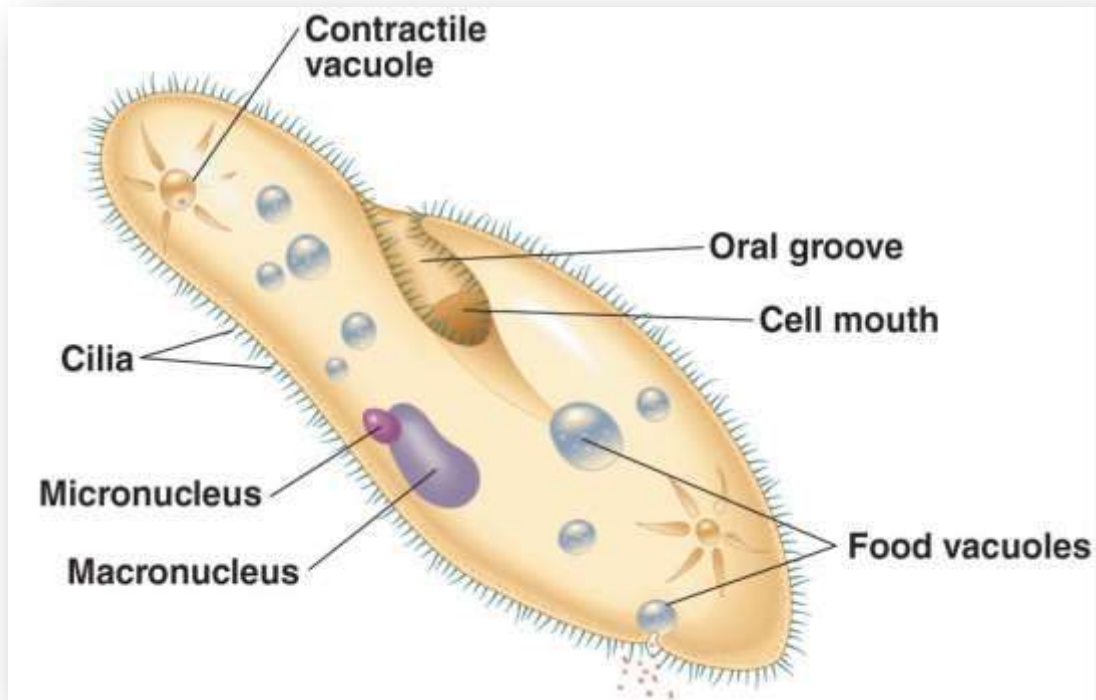


Fig. (4): *Paramecium sp.*

Kingdom: Animalia
Subkingdom: Parazoa
Phylum: Porifera (Sponges)
e.g. Sponges

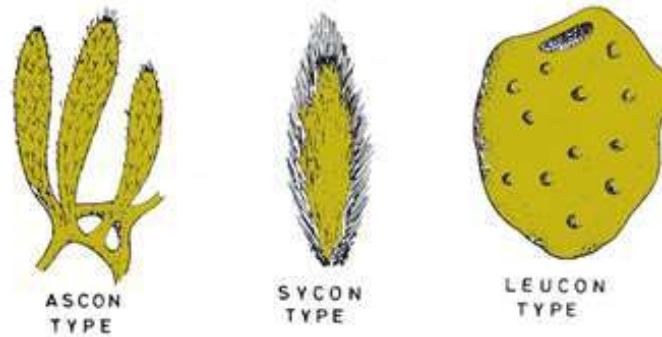


Fig. (5): Grades of sponges



Fig. (6): Types of skeleton in sponges of sponges

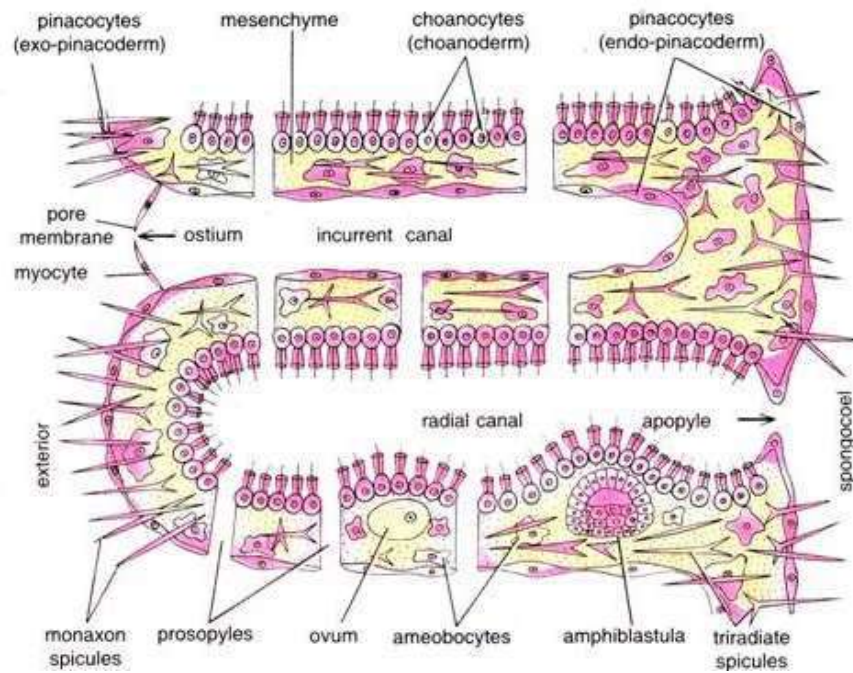


Fig. (7): Diagrammatic sectional view of *Grantia*

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Radiata
Phylum : Cnidaria
Class: Hydrozoa
e.g. Hydra

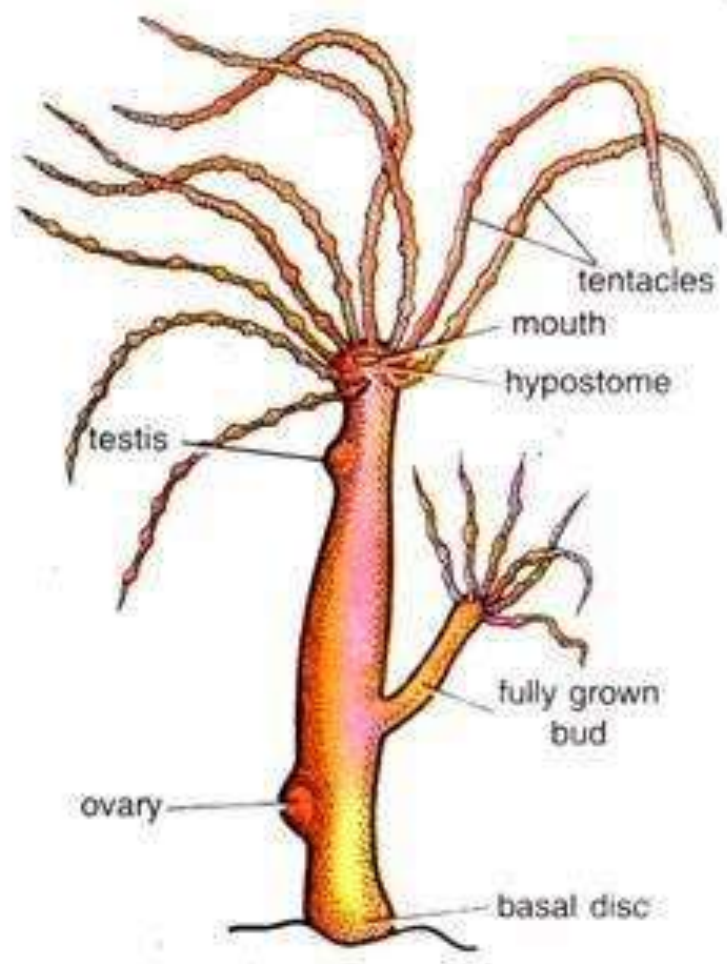


Fig. (8): *Hydra sp* (W.M.)

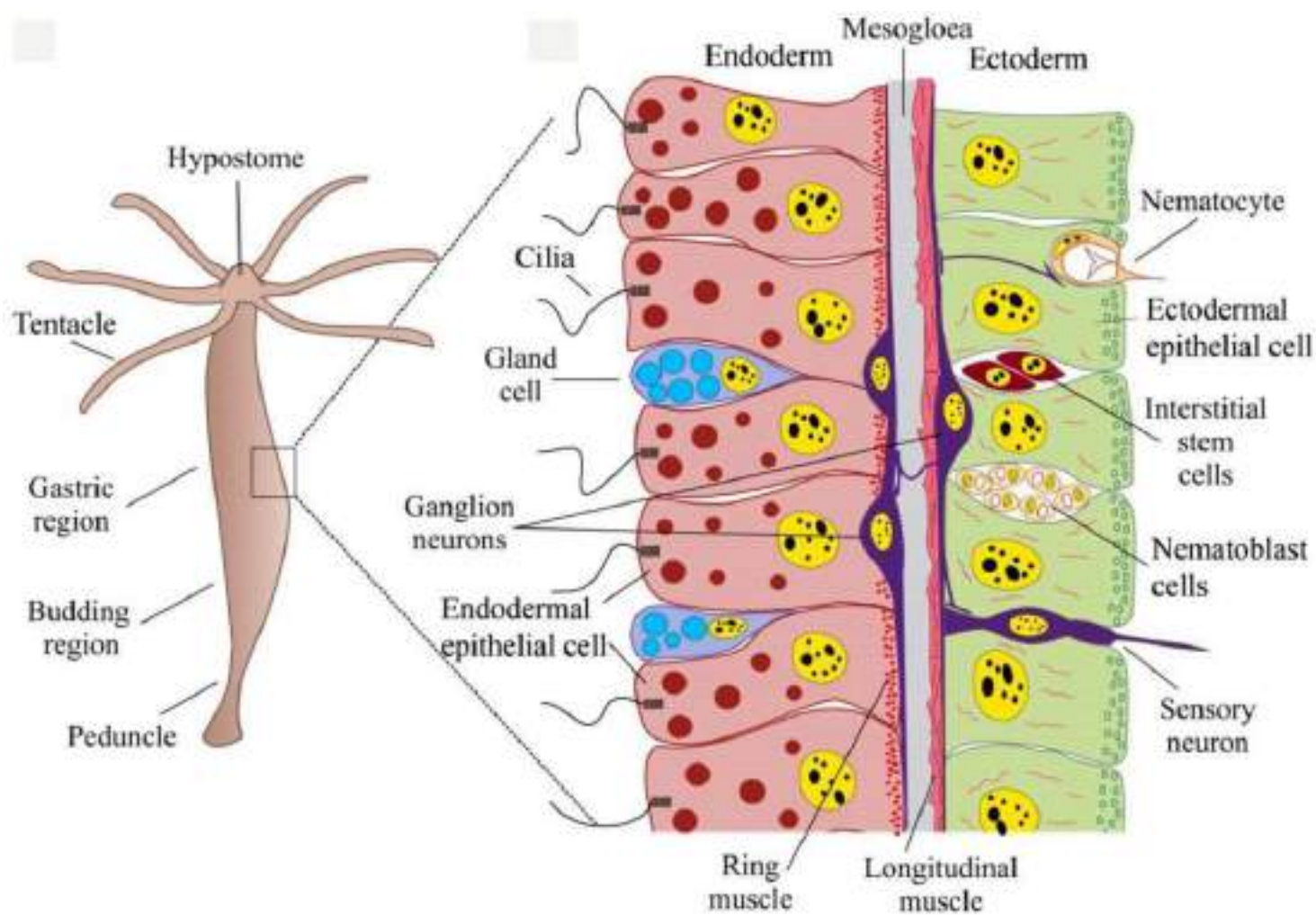


Fig. (9): T.S. of *Hydra*

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Radiata
Phylum : Cnidaria
Class: Hydrozoa
e.g. Obelia

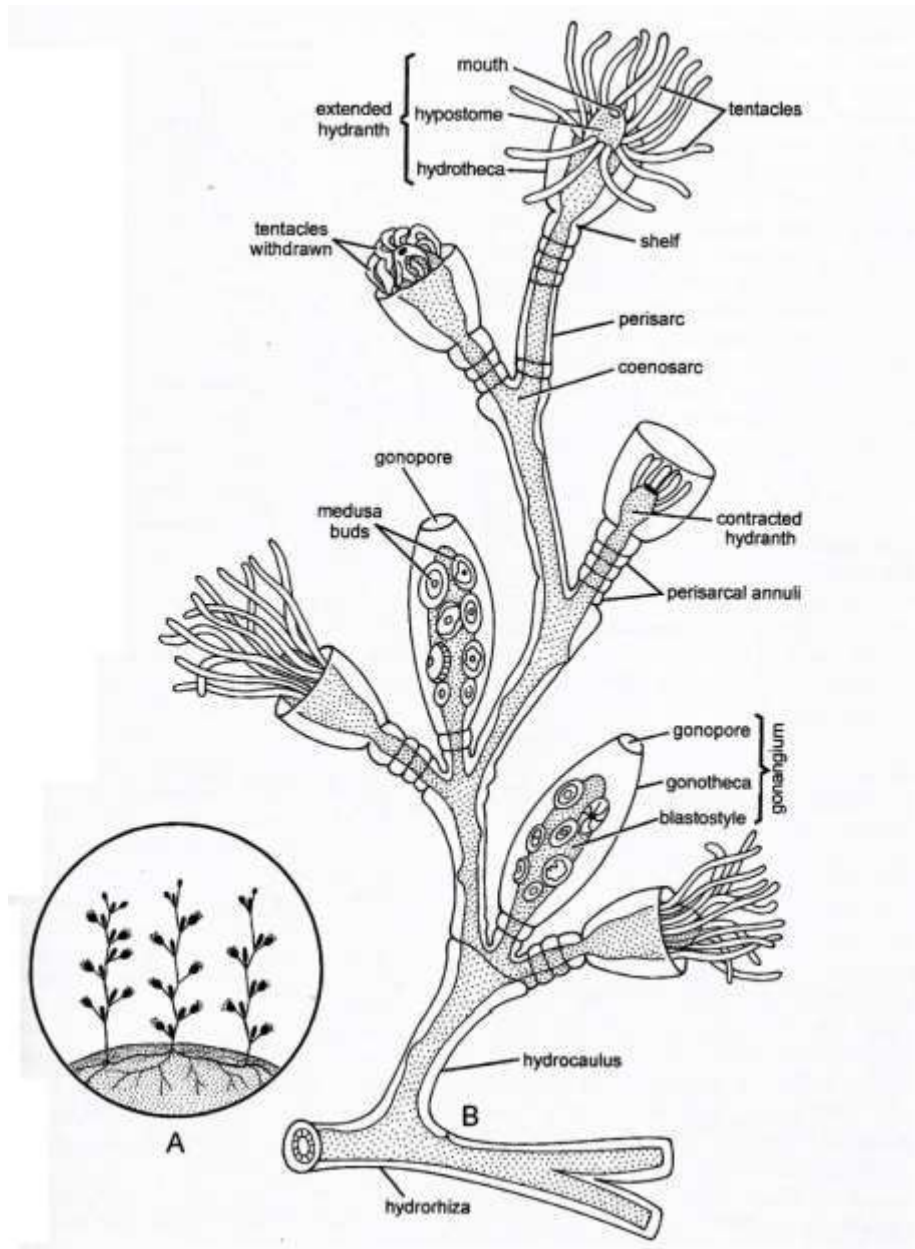


Fig. (10): Colony of *Obelia*

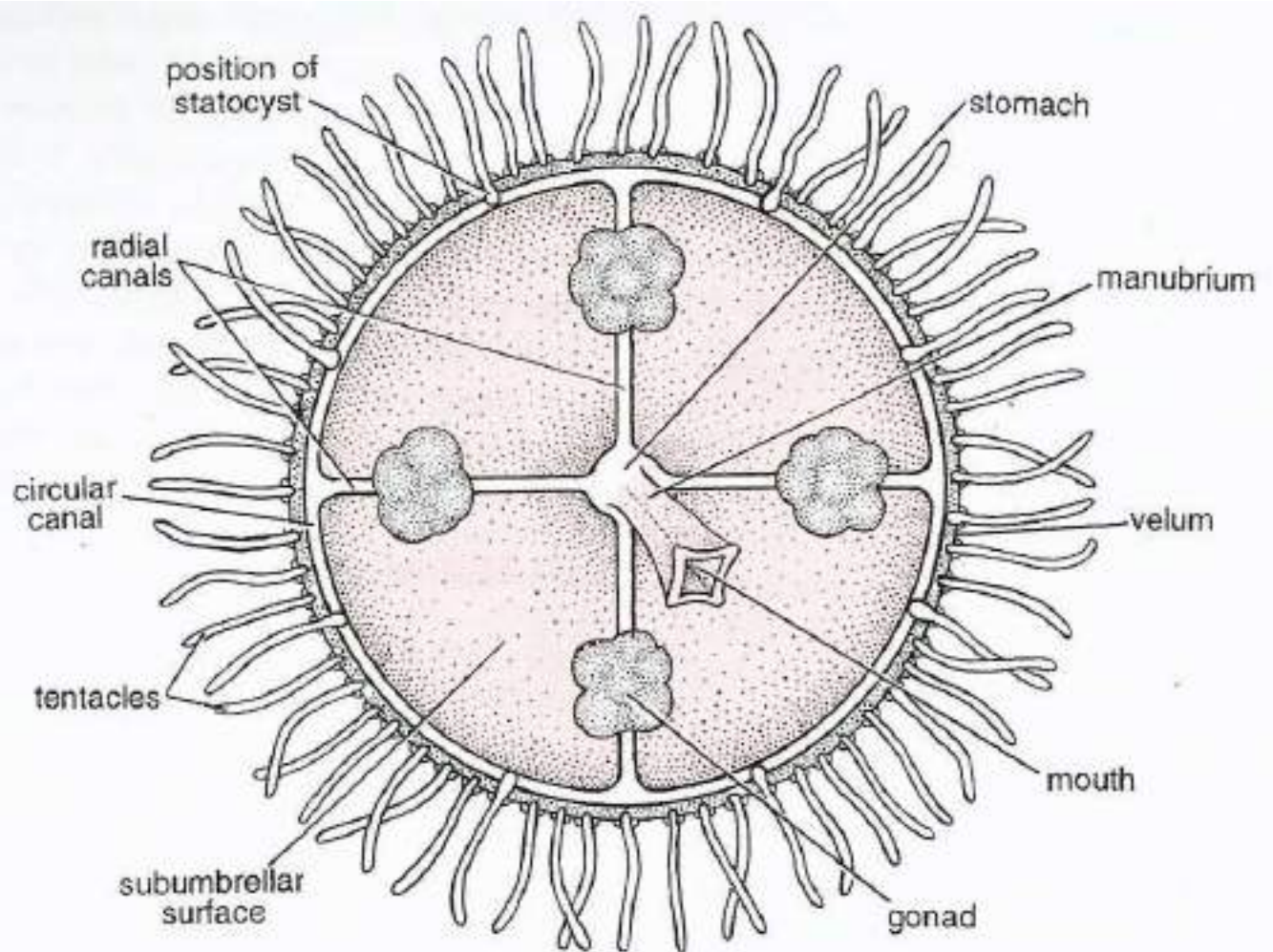


Fig. (11): Medusa of *Obelia*

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Bilateria
Subgrade Acoelomata
Phylum: Platyhelminthes (Flat worm)
Class: Trematoda
Order: Digenea

e.g. *Fasciola hepatica*
(Liver Fluke)

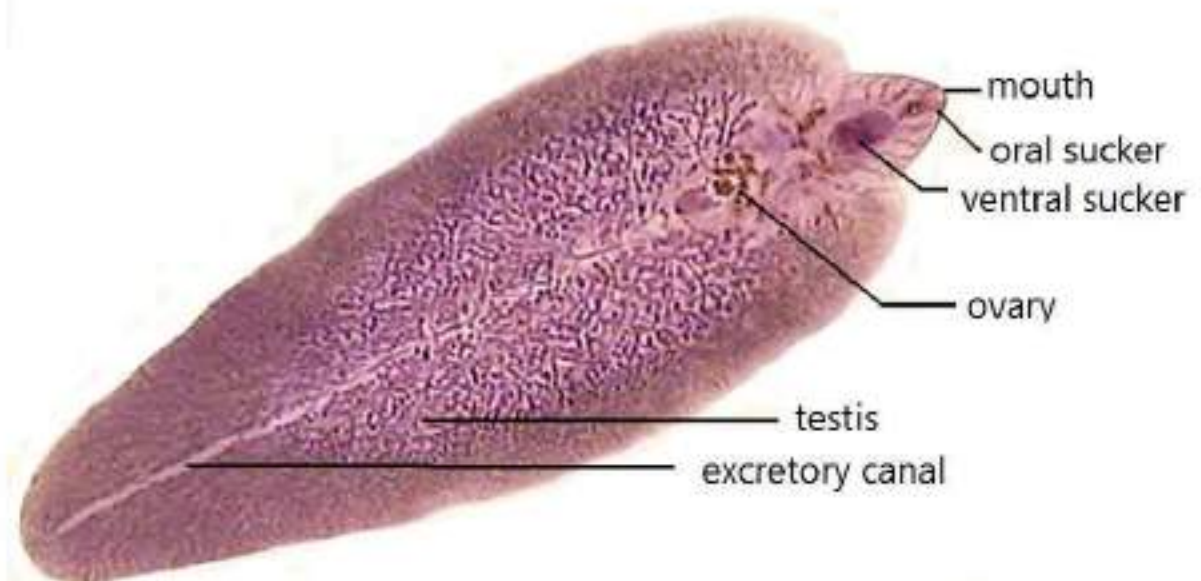
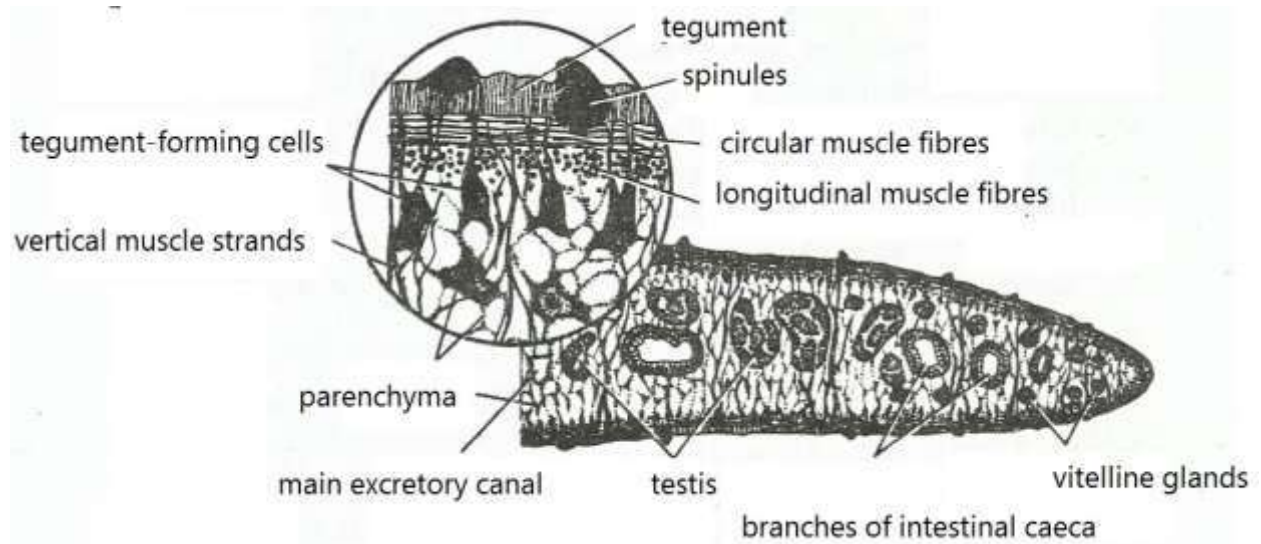


Fig. (12): *Fasciola* sp



(13a):T.S. of *Fasciola*

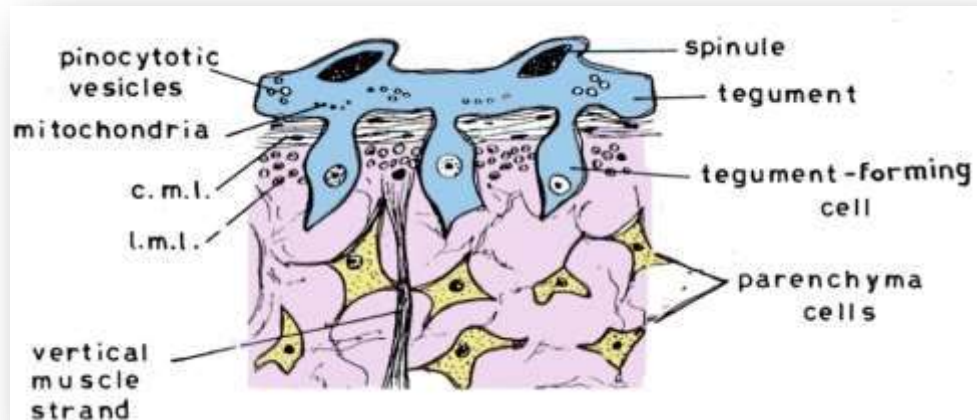
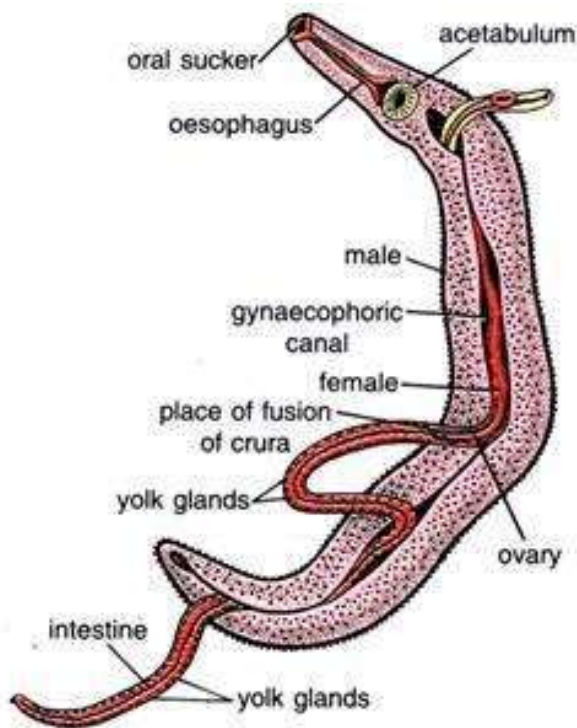


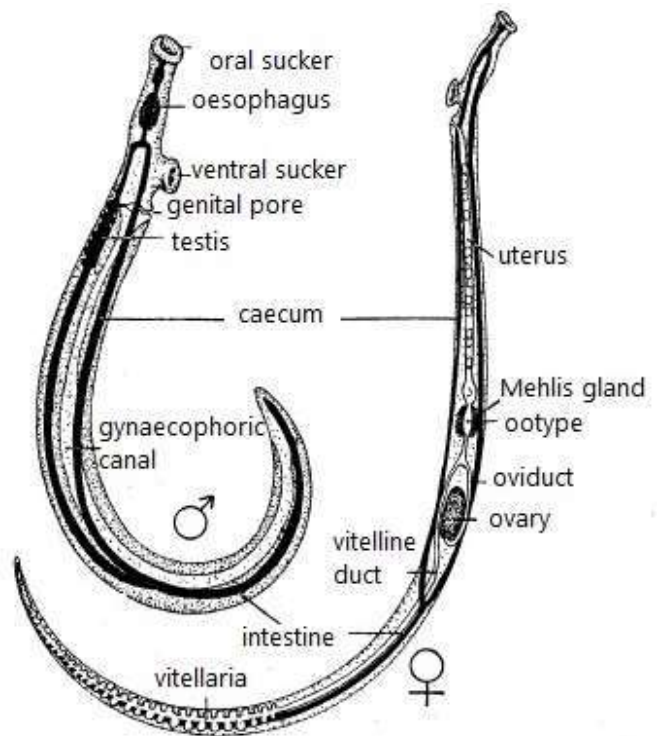
Fig. (13 b): Histological structure of body wall of *Fasciola*.

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Bilateria
Subgrade Acoelomata
Phylum: Platyhelminthes (Flat worm)
Class: Trematoda
Order: Digenea

e.g. *Schistosoma sp.* (Liver fluck)

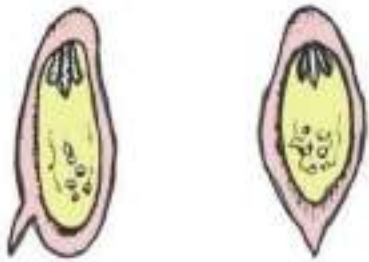


Conjugated male and female



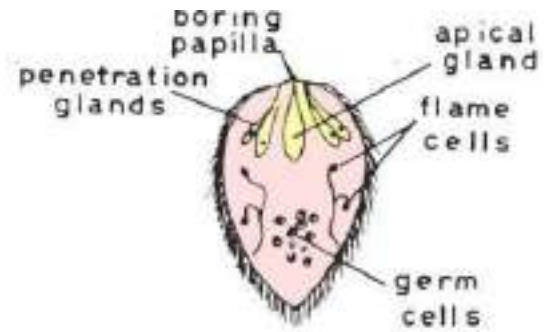
Separated male and female

Fig. (14 a): *Schistosoma sp.* (W.M.)

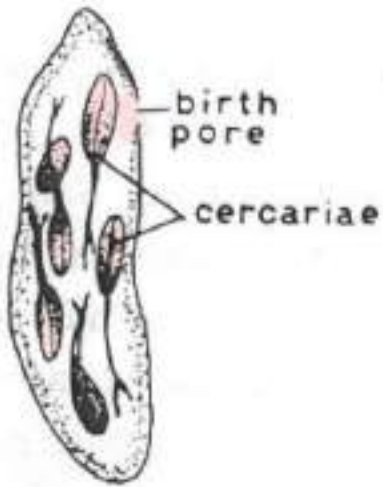


S. haematobium *S. mansoni*

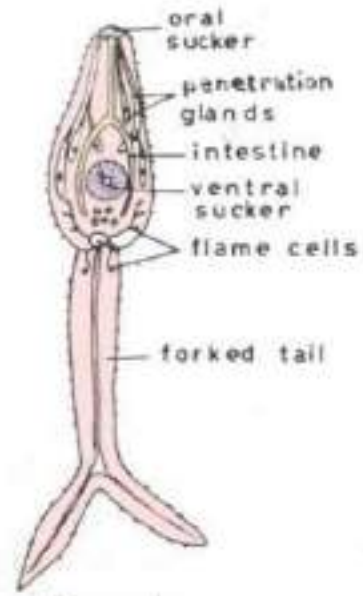
A. Eggs



B. Miracidium



C. Sporocysts



D. Cercaria (infective stage)

Fig. (14 b): Different stages of life cycle of *Schistosoma* sp. (W.M.)

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Bilateria
Subgrade Acoelomata
Phylum: Platyhelminthes (Flat worm)
Class: Cestoda

e.g. *Taenia sp.*

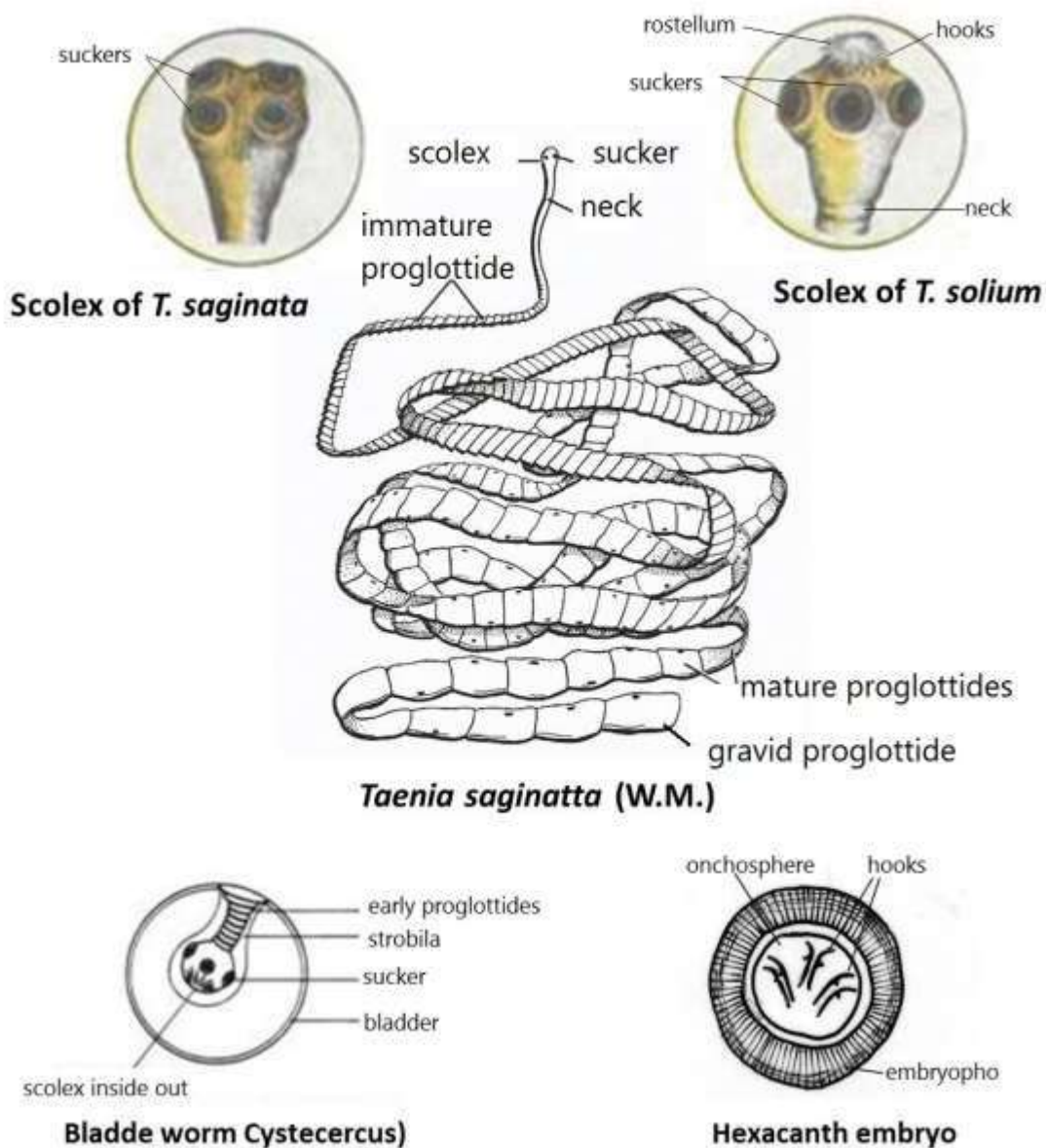


Fig. (15 a): *Taenia sp*

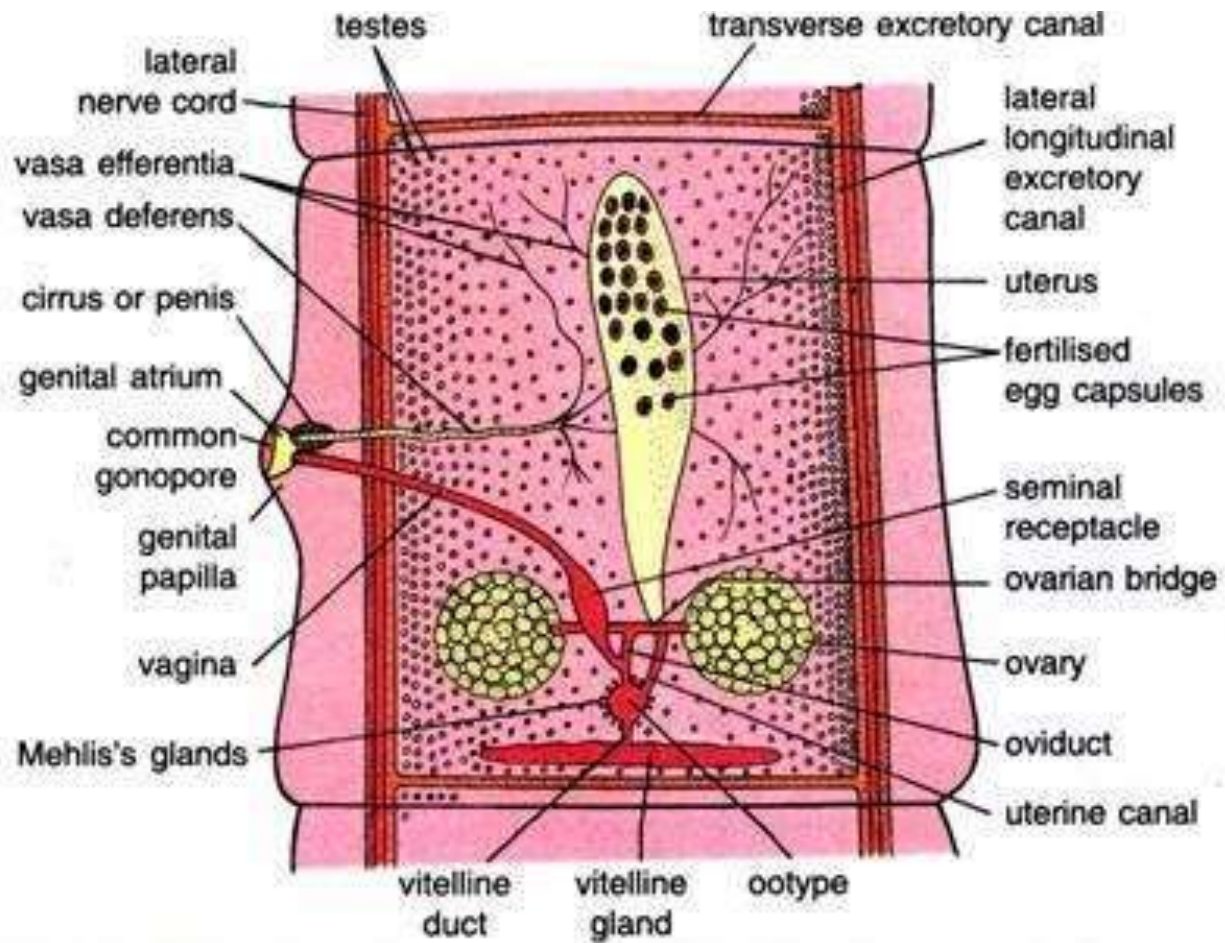


Fig. (15 b) : Mature proglottide of *Taenia*

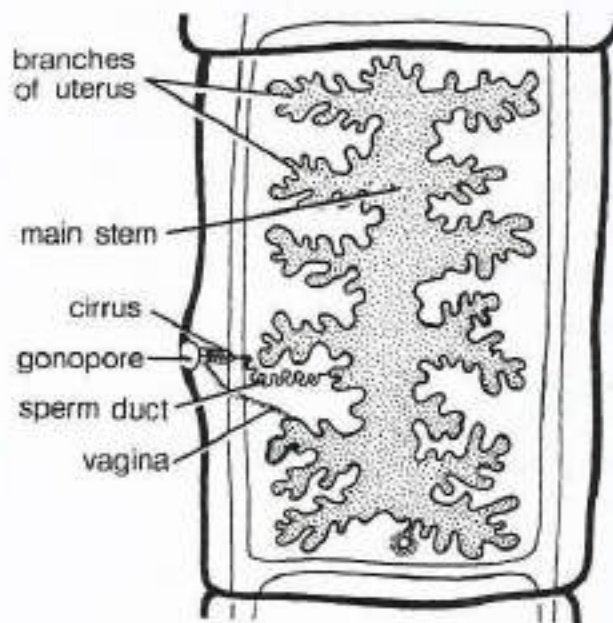


Fig. (15 c): Gravid proglottide of *Taenia*

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Bilateria
Subgrade Pseudocoelomata
Phylum: Nematoda
Class Phasmida
e.g. *Ascaris lumbricoides*

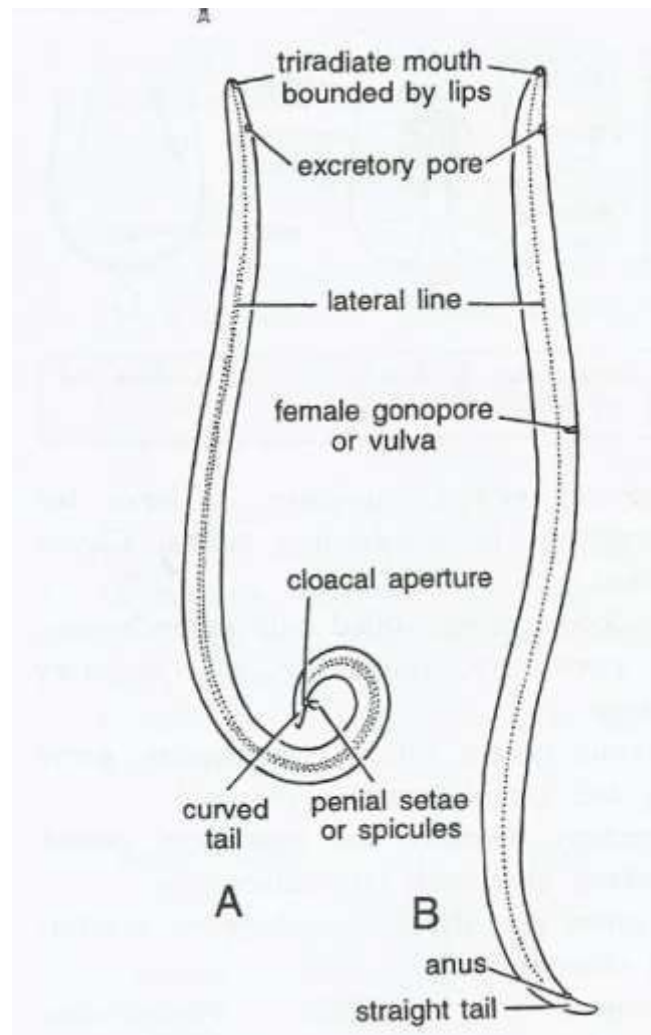


Fig. (16 a): *Ascaris*. A: Male B: Female

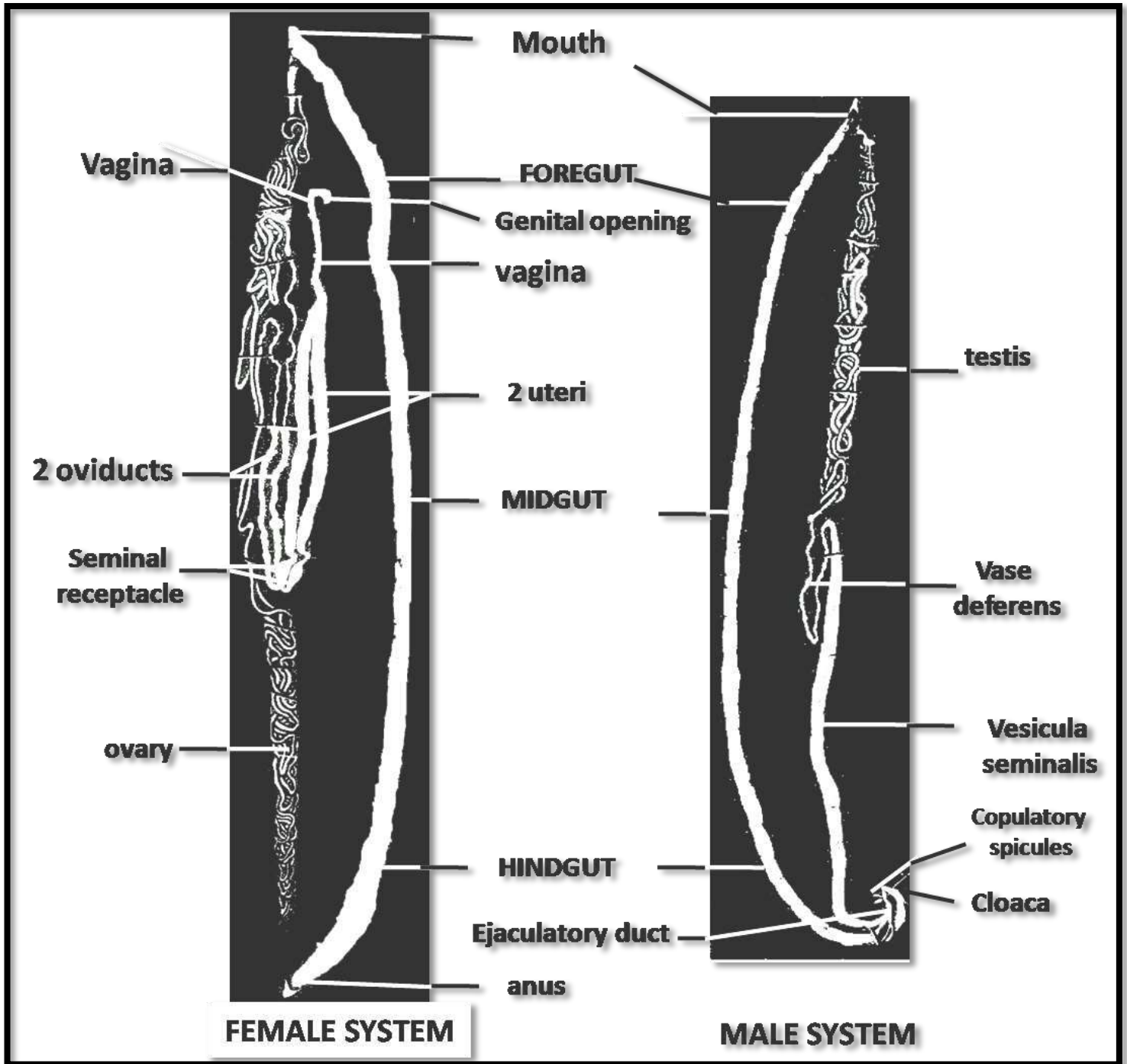


Fig. (16 b): Digestive and reproductive systems of *Ascaris*.

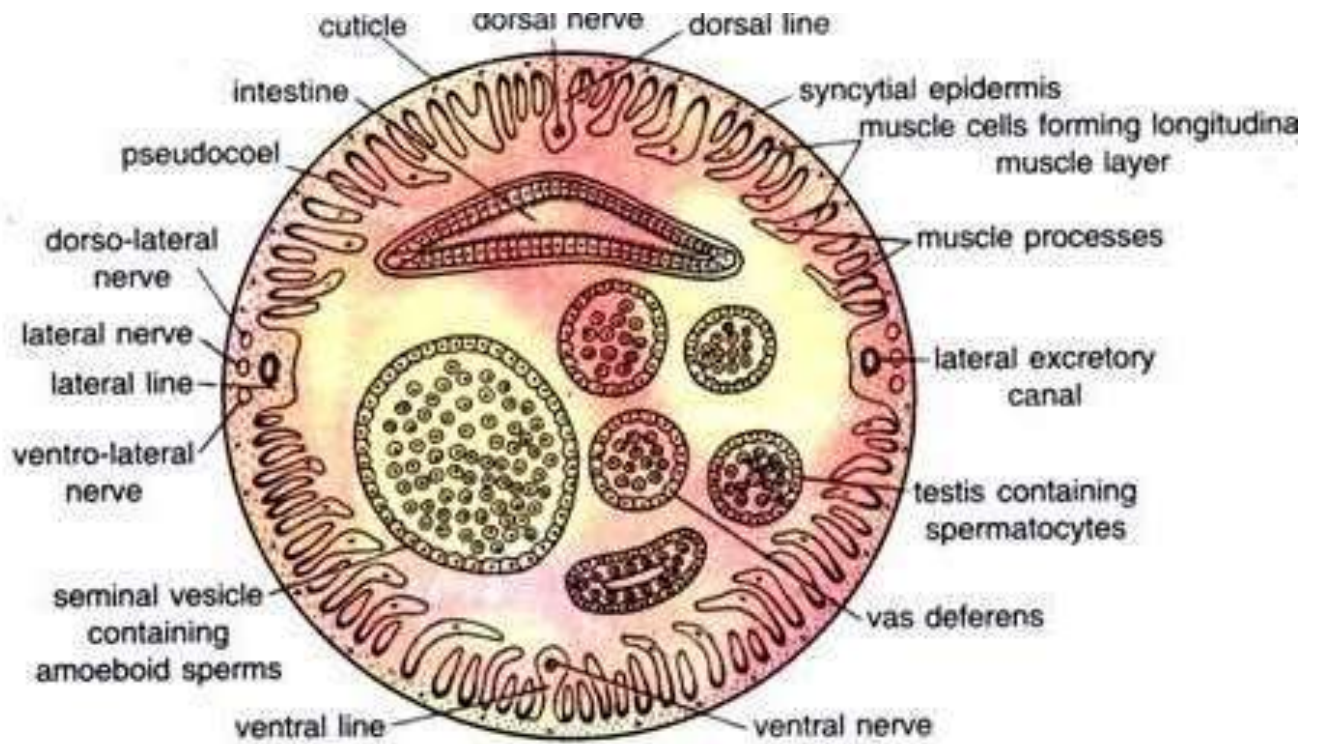


Fig. (16 c): T.S. of mature male *Ascaris*

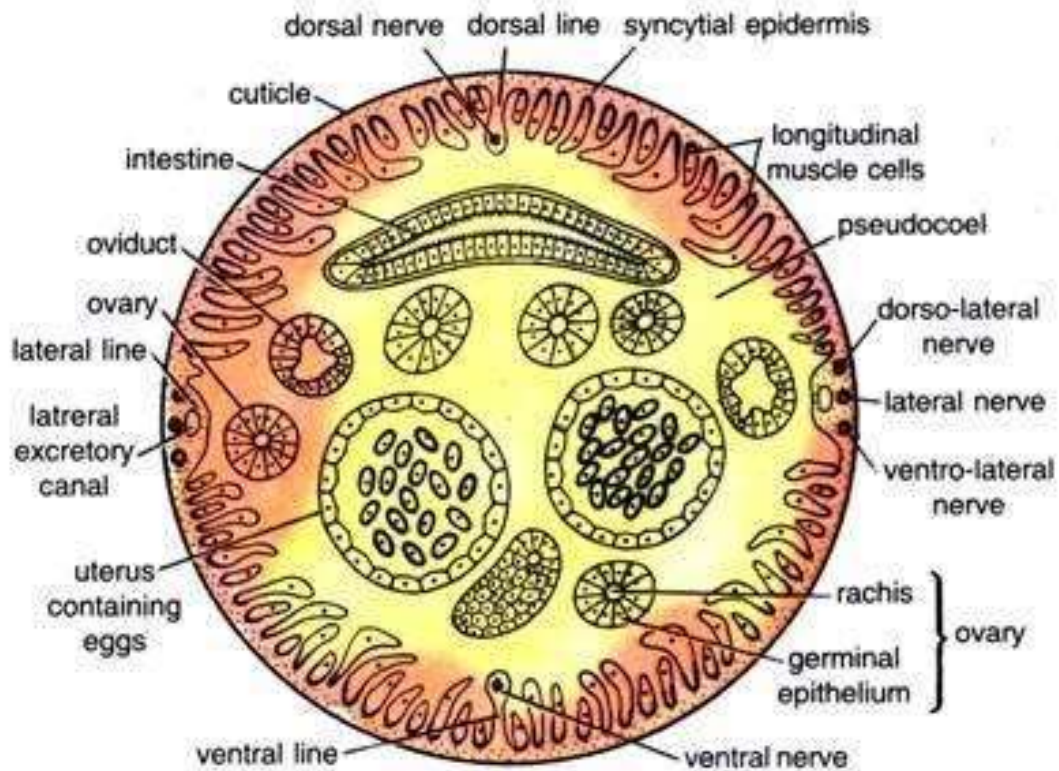


Fig. (16 d): T.S. of mature female *Ascaris*

Kingdom: Animalia
Subkingdom: Eumetazoa
Grade Bilateria
Subgrade Pseudocoelomata
Phylum: Cestoda
e.g. *Ankylostoma*

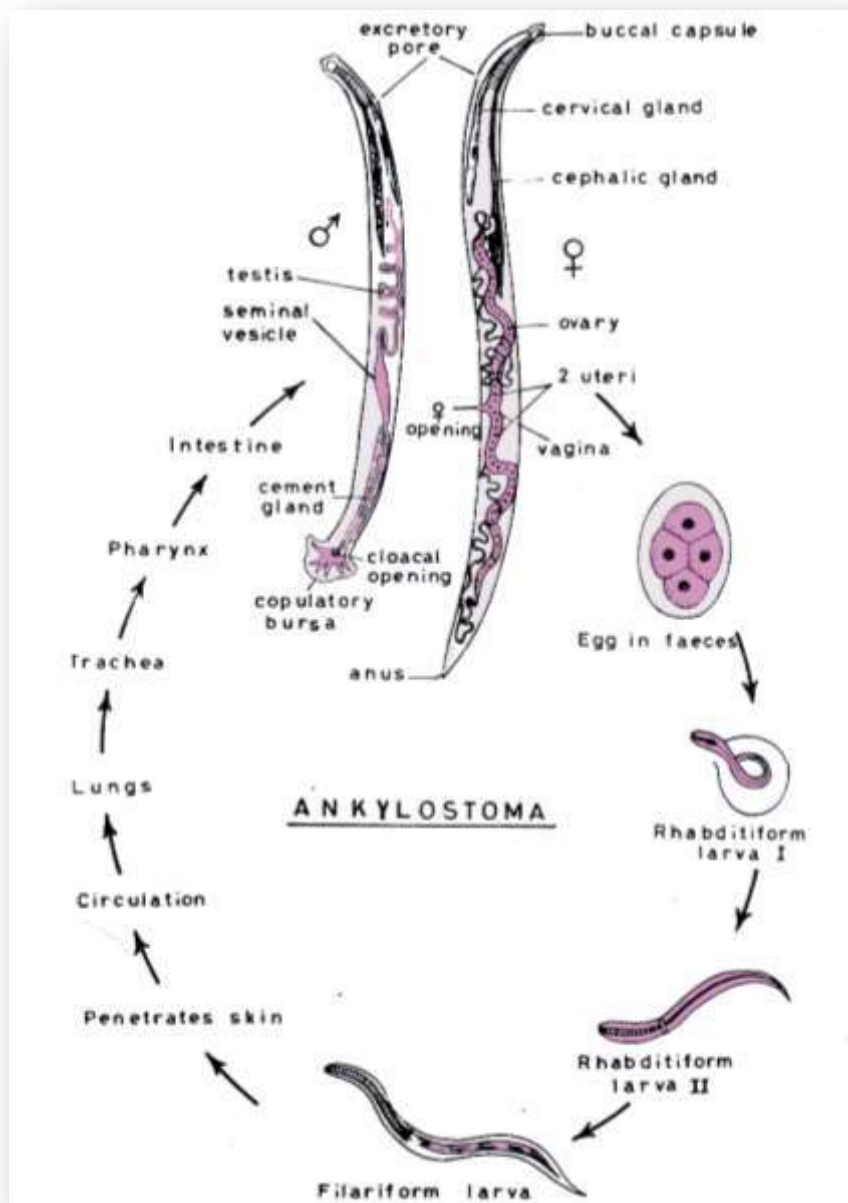


Fig. (17): Life cycle of *Ankylostoma*



Zagazig University
Faculty of Science
Zoology Department



Practical skills
On
Dissection of Maculated Toad
(*Bufo regularis*)



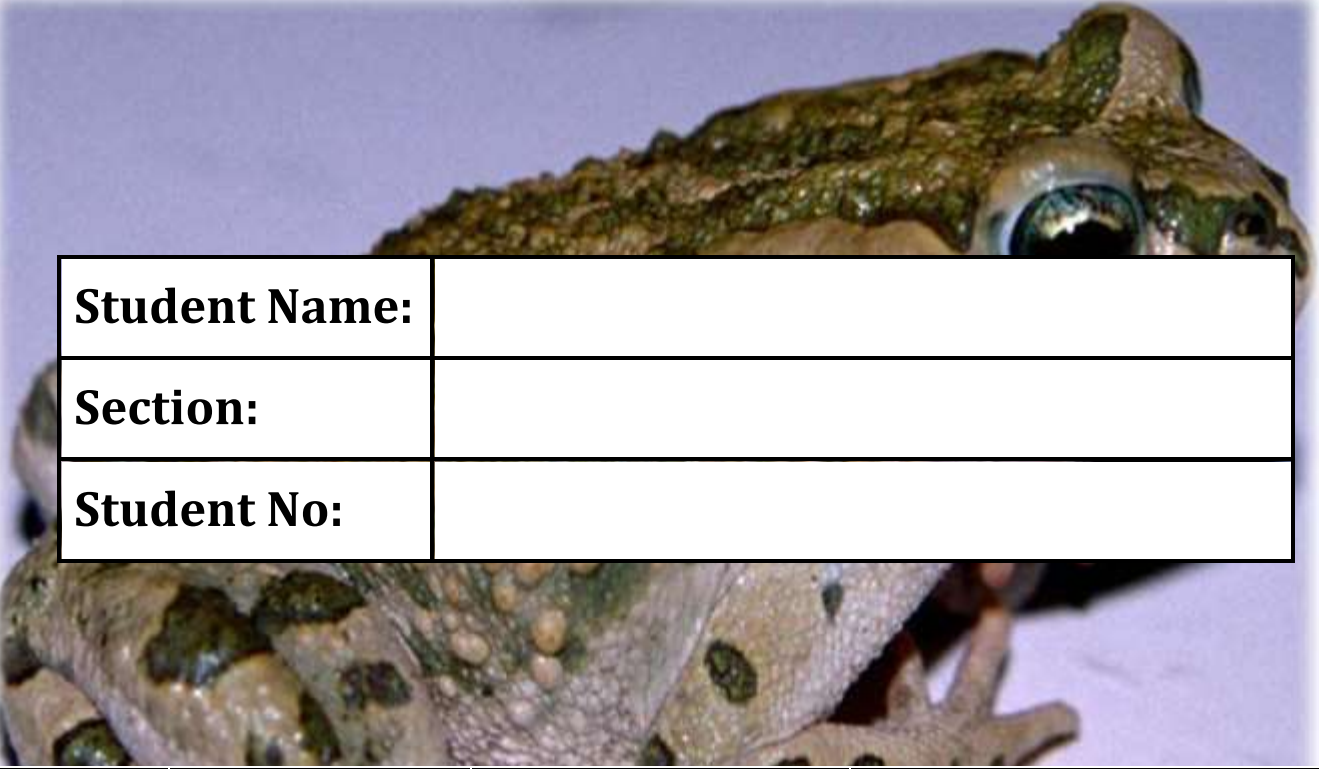


قسم علم الحيوان
كلية العلوم
جامعة الزقازيق



المهارات العملية في تشريح الضفدعة الرقطاء (*Bufo regularis*)





Student Name:	
Section:	
Student No:	

Weeks	Date	Lesson	Instructor's Signature
1			
2			
3			
4			
5			
6			
7			

Systematic Position

PHYLUM : Chordata
SUB-PHYLUM : Vertebrata
CLASS : Amphibia
ORDER : Anura
FAMILY : Bufonidae
e.g. : *Bufo regularis*
(The maculated toad)

Morphological adaptations

Examine the provided specimen and noticed the following morphological adaptations:

1. **Stream-like body** to reduce the resistance of water during swimming.
2. **Colouration:** The general body colouration and pattern of pigments patches help in camouflaging.
3. **Skin** is wet and slippery to help in cutaneous respiration on land and underwater.
4. The skin is provided with poisonous gland. The parotid glands are aggregations of these glands. They secrete poisonous white secretion for protection against predators.
5. The Z-shape hind limb is large, powerful and provided with webbed toes for jumping and to propel the animal in water.
6. Short forelimb provided with two horny pads to absorb the shock of jumping.
7. Transparent nictating membrane protects the eye and enable the toad to see under water.
8. The protruded eyes enable the toad to see in all directions to compensate the absence of neck.
9. Anteriorly fixed slimy tongue enables it to catch the insects.
10. Up and down movement of the floor of the buccal cavity is a respiratory movement.

How we can differentiate between Male and Female Toad

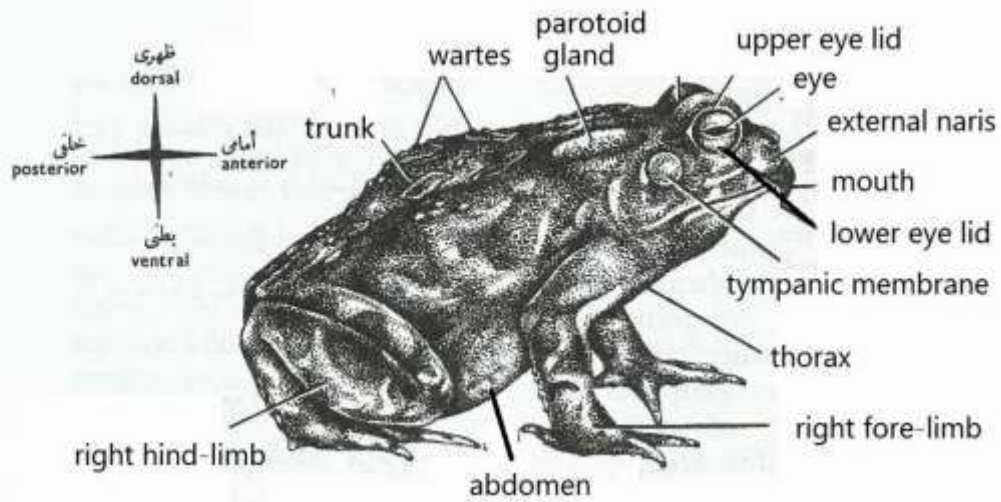
By the colour of subgular area being black (represent the vocal sac) in the male, whitish in the female (secondary sexual character)

For dissection instructions follow the video in the link

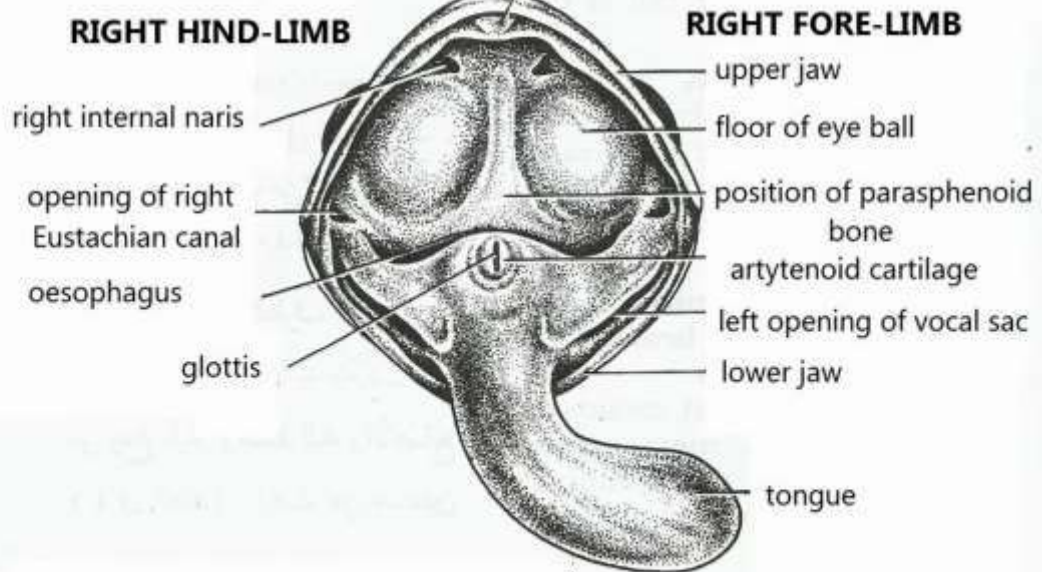
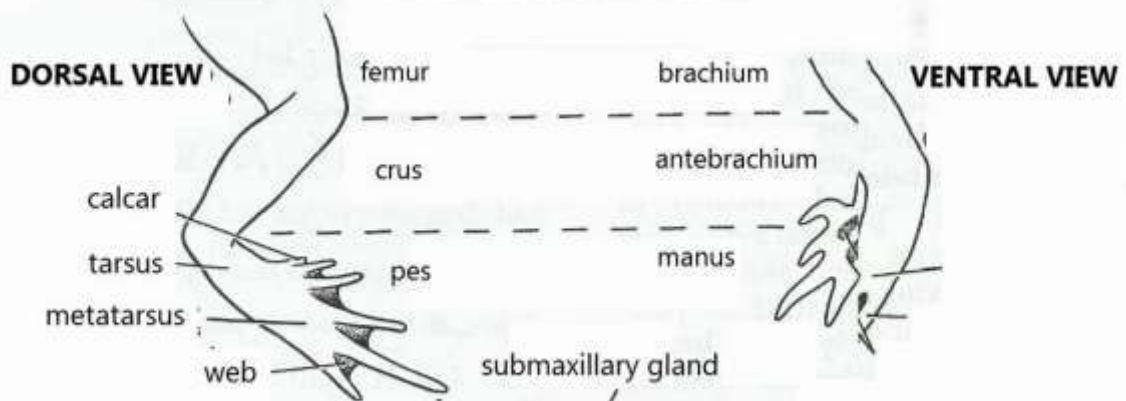
<https://www.youtube.com/watch?v=3Ambj0Y-8qQ&t=162s>

1. Morphology

- ✚ For dissection instructions follow the video in the link:
<https://www.youtube.com/watch?v=K3WJ2APNyik&t=121s>
- ✚ Draw



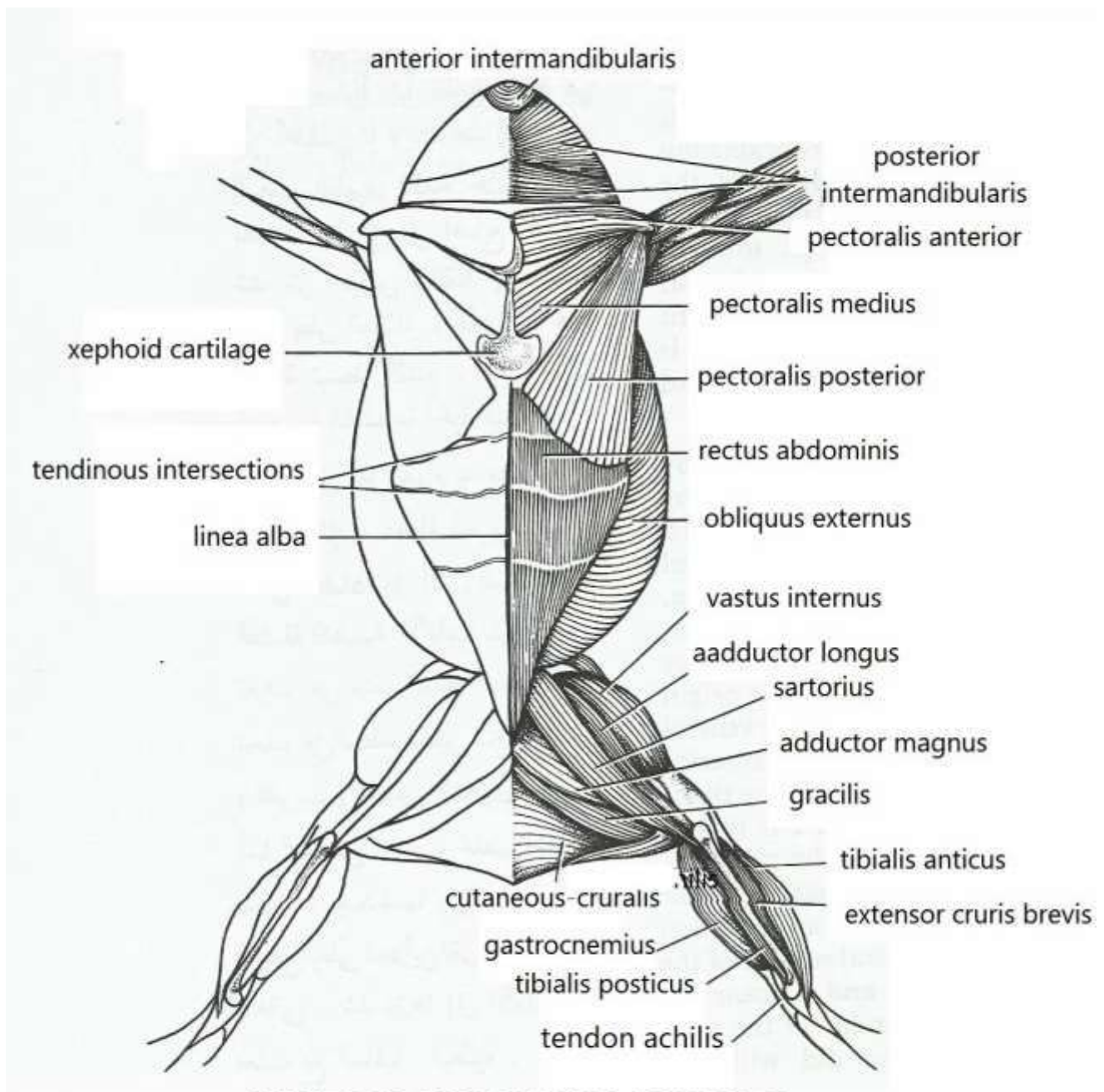
EXTERNAL FEATURES



BUCCOPHARYNGEAL CAVITY

2. Superficial Muscles

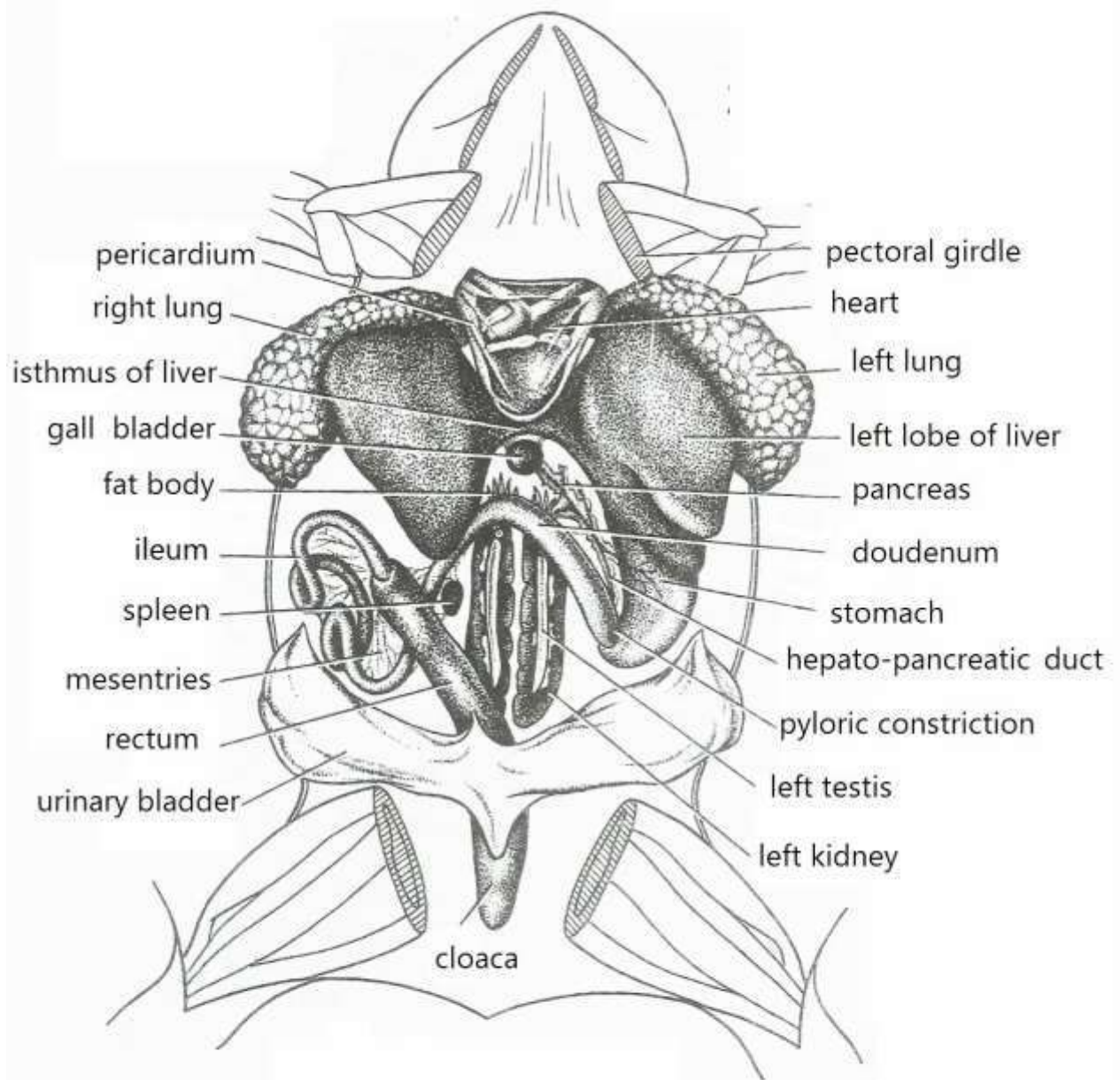
- A. For Dissection instructions follow the video in the link:
https://www.youtube.com/watch?v=4KQ_yjQLKGE&t=39s
- B. Draw a labelled diagrams



VENTRAL SUPERFICIAL MUSCLES

3. General Viscera

- ✚ For Dissection instructions follow the video in the link:
<https://www.youtube.com/watch?v=6189Ns8doUU&t=16s>
- ✚ Draw a labelled diagram:

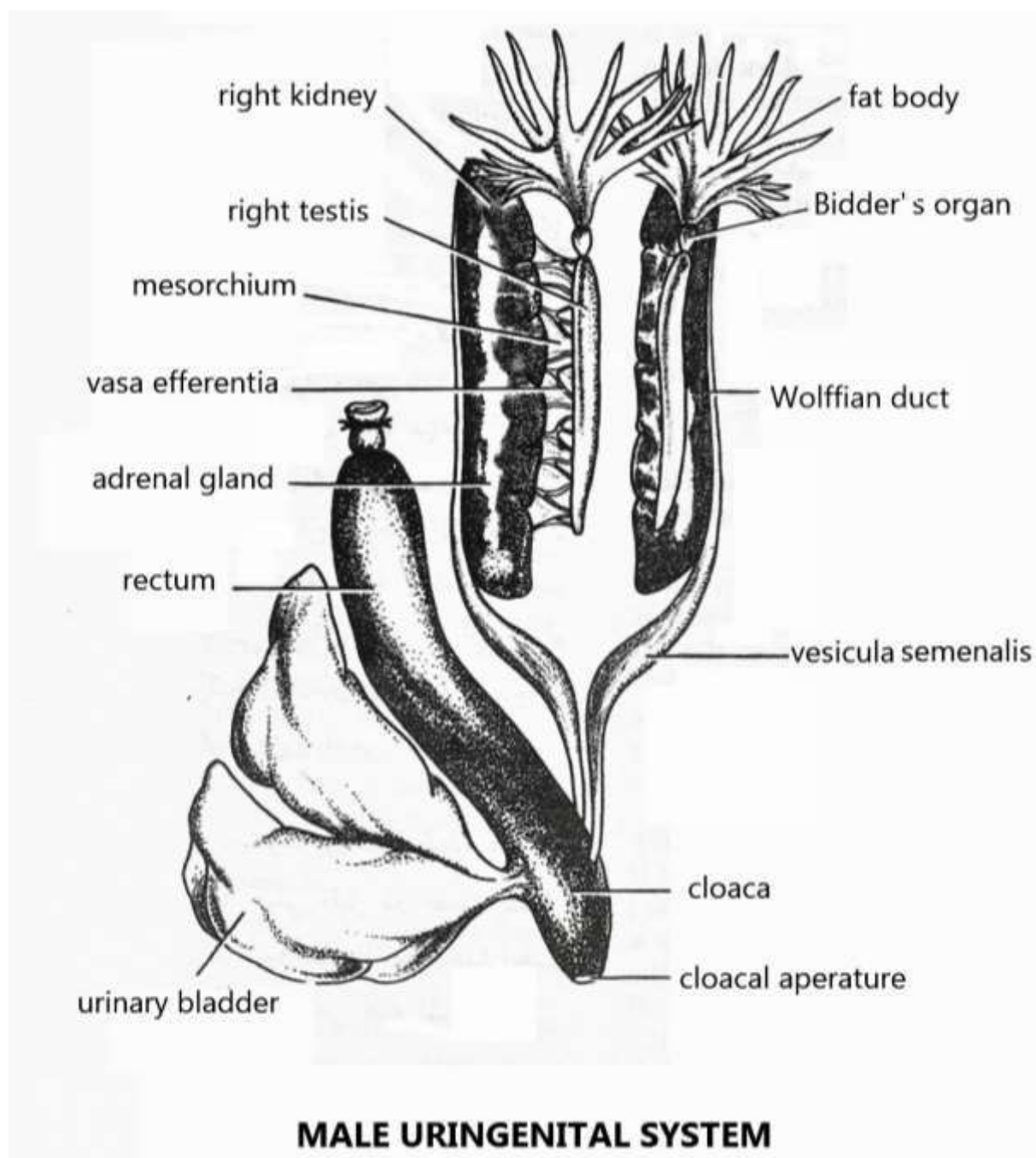


GENERAL VISCERA

4. A. Male Urinogenital System

✚ For Dissection instructions follow the video in the link:
<https://www.youtube.com/watch?v=2xaBbCSgmgs&t=8s>

✚ Draw a labelled diagram

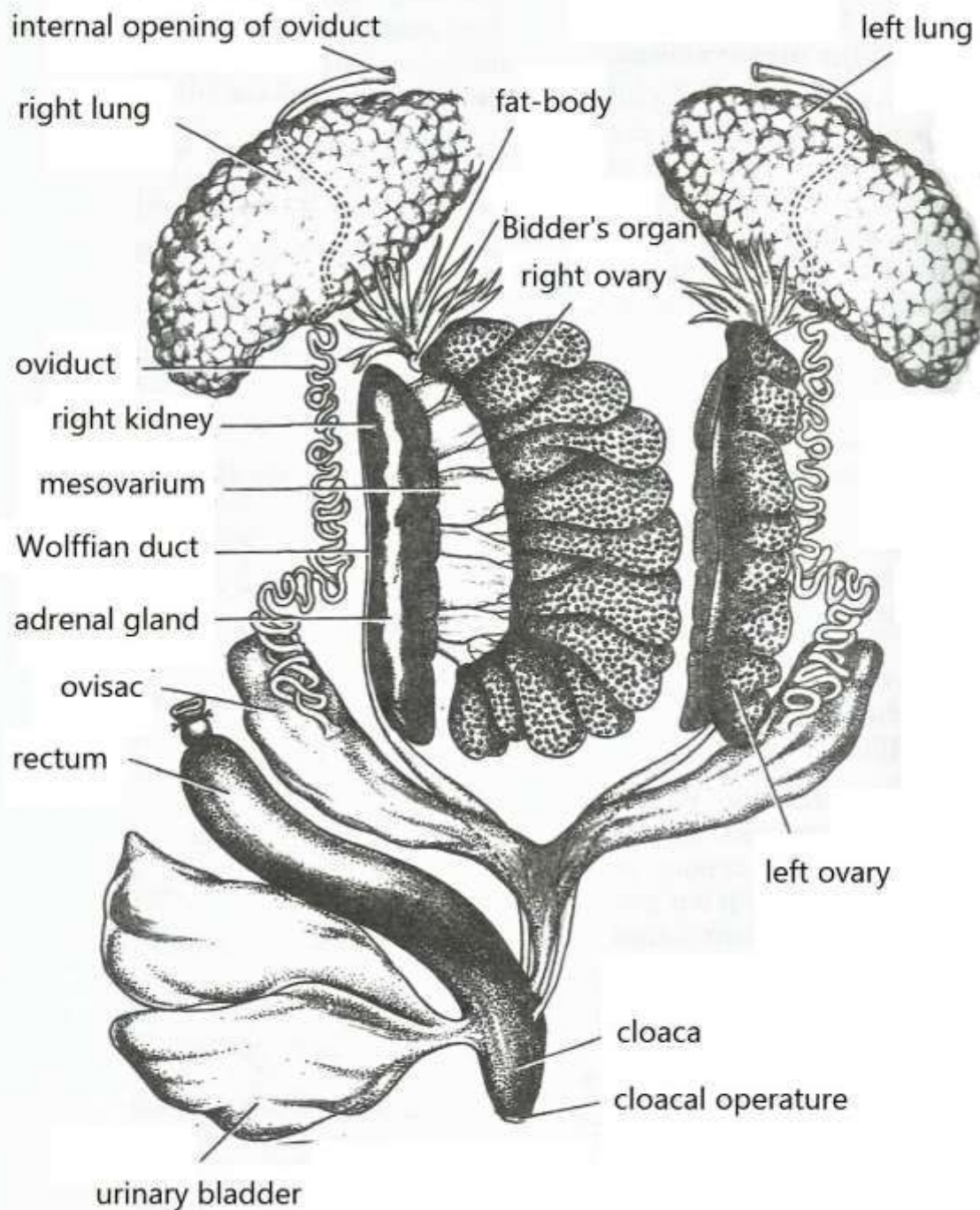


4. B Female Urogenital System

 For Dissection instructions follow the video in the link:

<https://www.youtube.com/watch?v=2xaBbCSgmgs&t=8s>

 Draw a labelled diagram

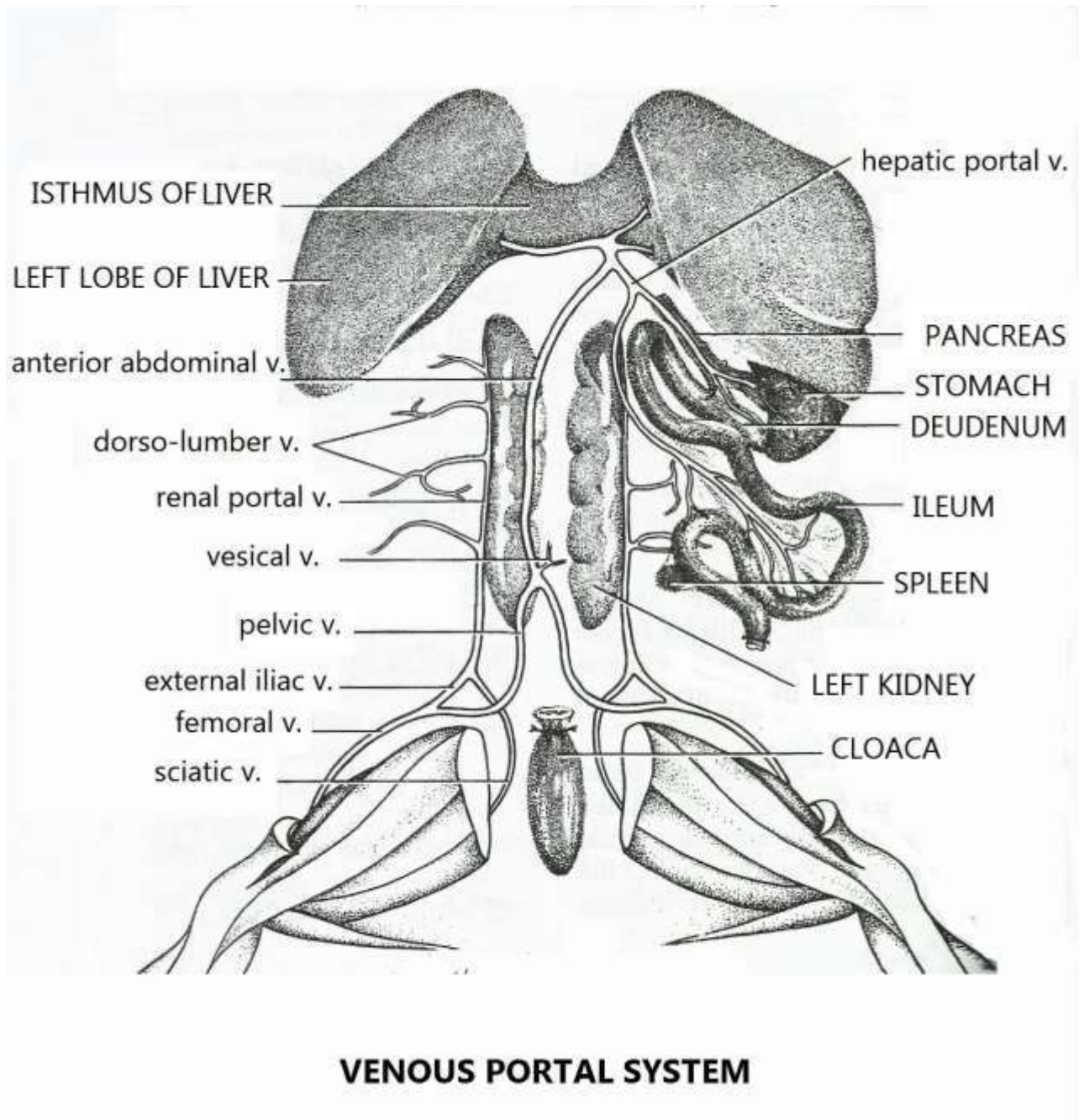


FEMALE URINOGENITAL SYSTEM

5. Venous Portal System

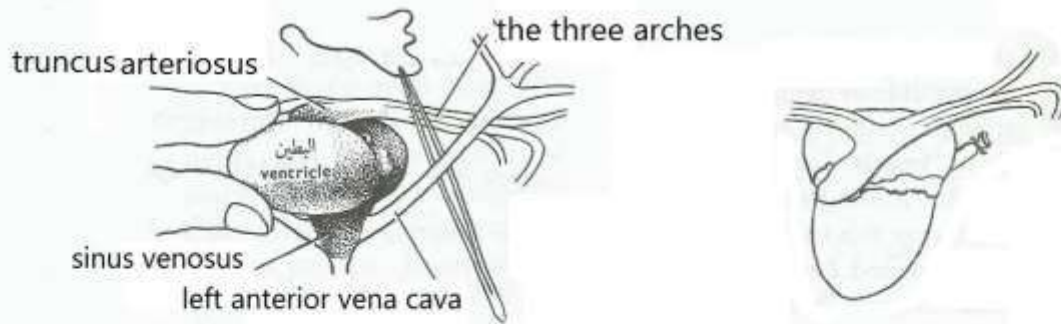
✚ For Dissection instructions follow the video in the link:
<https://www.youtube.com/watch?v=QkHyJirvwJQ&t=684s>

✚ Draw a labelled diagram

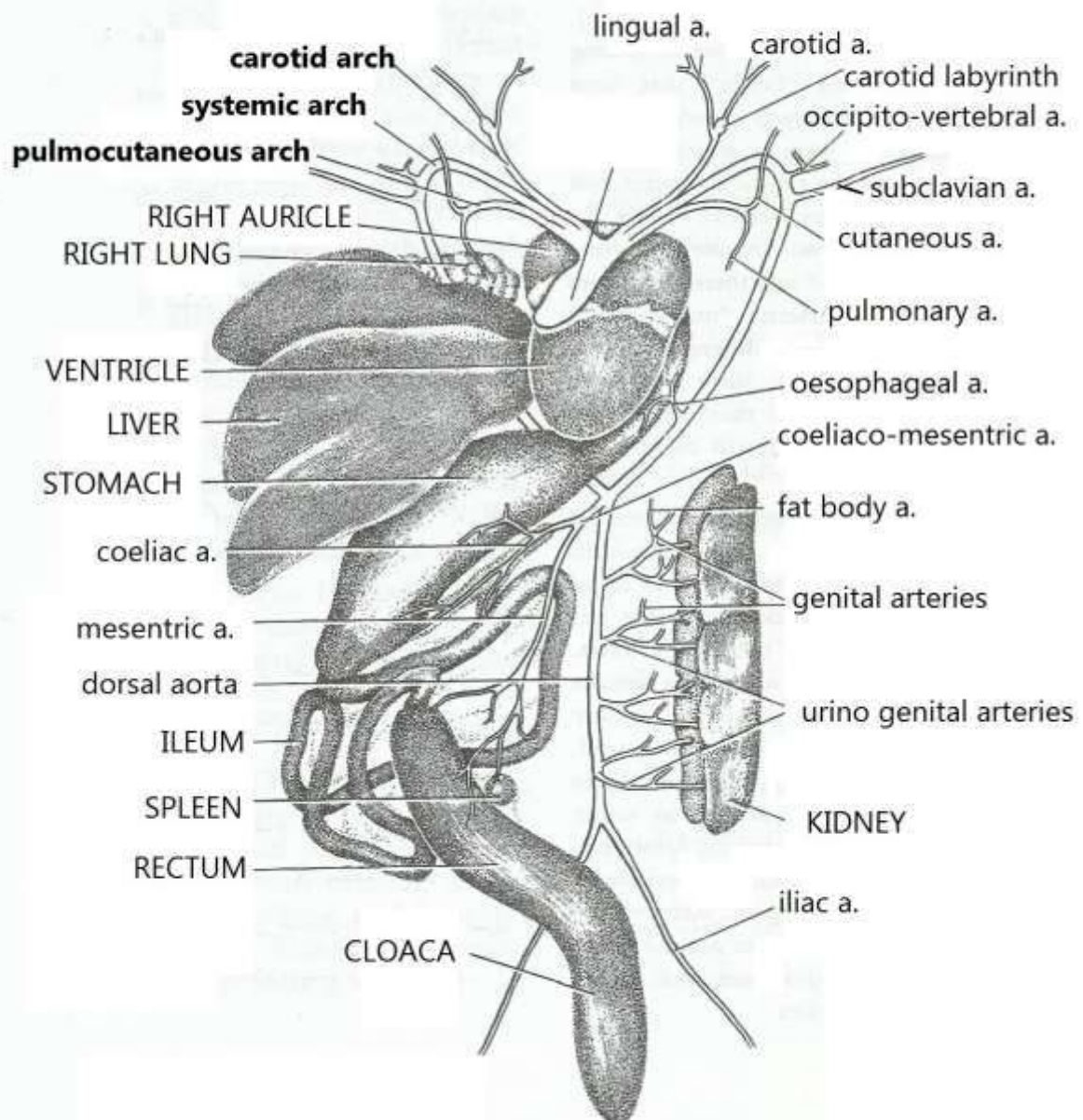


6. Arterial System

 Draw a labelled diagram



How to tie and cut the anterior vena cava?

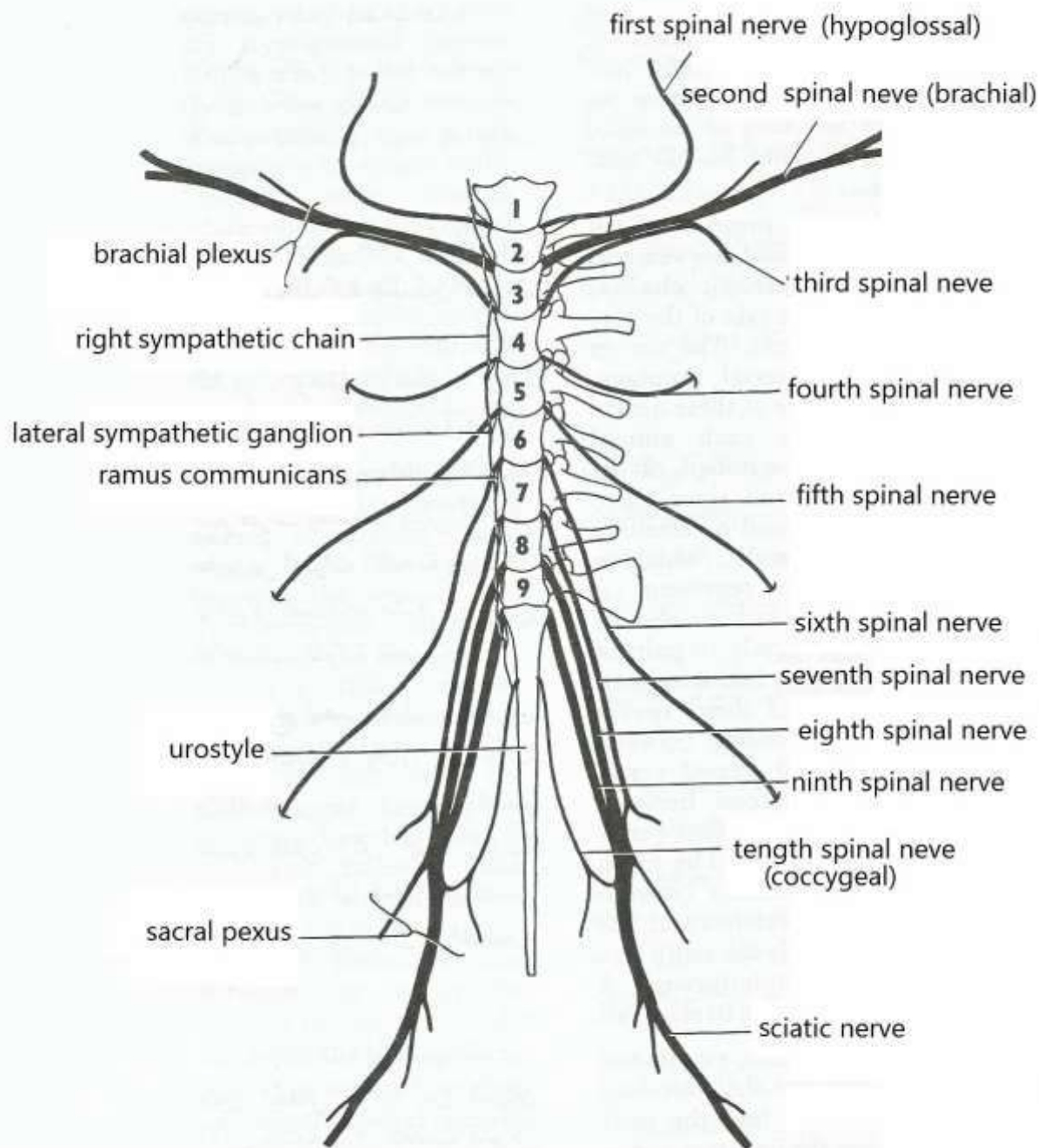


ARTERIAL SYSTEM

7. Spinal nerves and Sympathetic chain

✚ For help instructions follow the video in the link:
<https://www.youtube.com/watch?v=7G1KpkxFN0k>

✚ Draw a labelled diagram

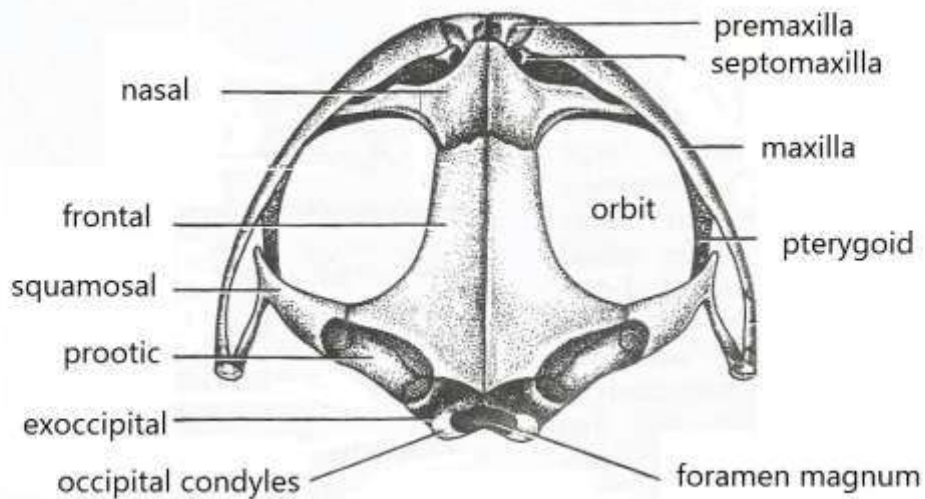


SPINAL NERVES AND SYMPATHETIC CHAIN

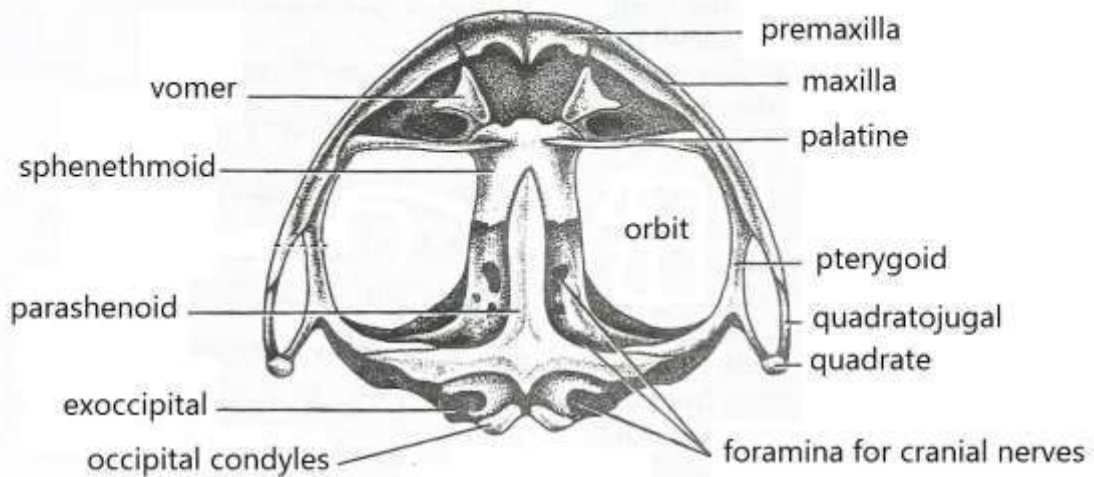
8. Axial Skeletal System

A. Skull

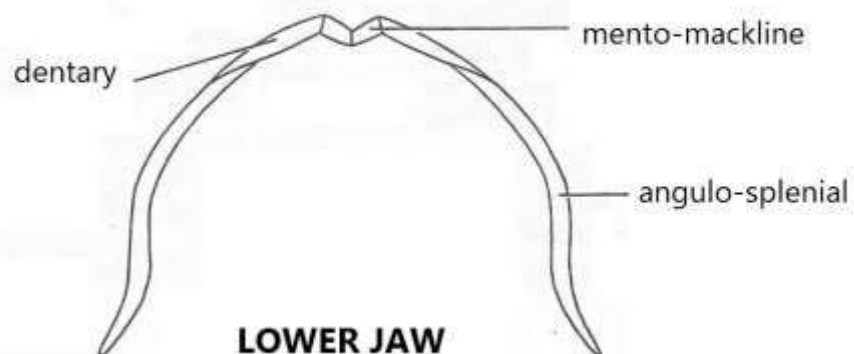
- ✚ For help of skeletal system follow the video in the link:
https://www.youtube.com/watch?v=ozSN3Tffr_Y
- ✚ Draw a labelled diagram



SKULL
(Dorsal view)



SKULL
(Ventral view)



LOWER JAW
(Ventral view)

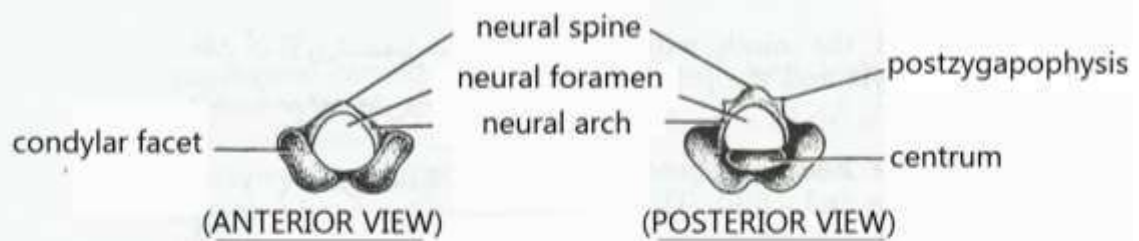
8. Axial Skeletal System

B. Verebral Column

✚ For help follow the video in the link:

https://www.youtube.com/watch?v=ozSN3Tffr_Y

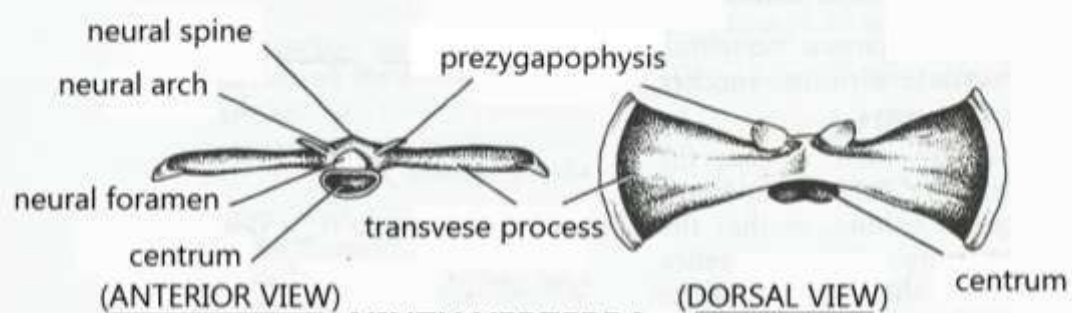
✚ Draw a labelled diagram



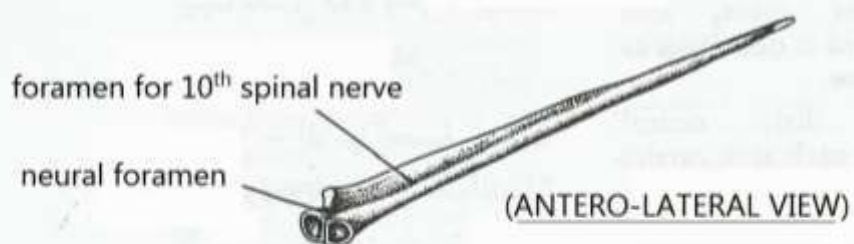
FIRST VERTEBRA (ATLAS)



NORMAL VERTEBRA (2-8)



NINTH VERTEBRA



UROSTYLE

VERTEBRAL COLUMN

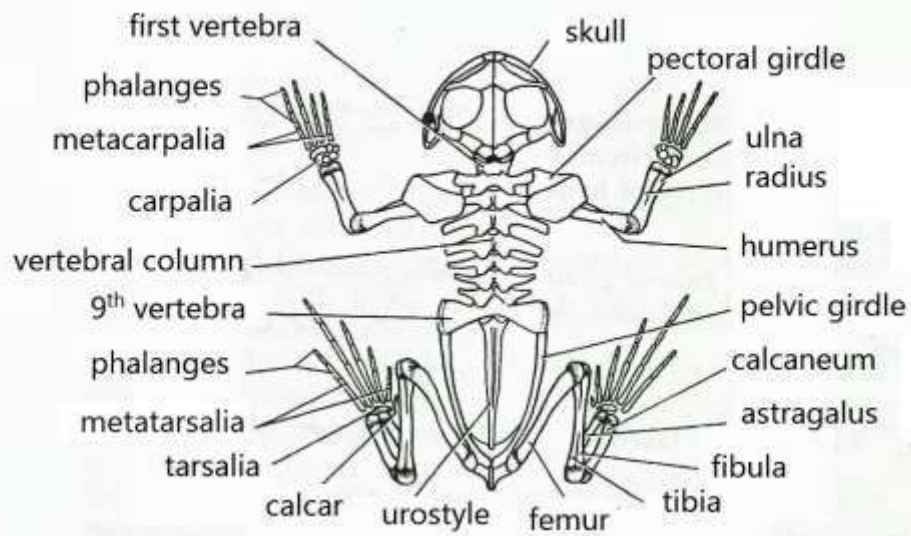
10. Appendicular Skeleton

A. Pectoral girdle & Forelimbs

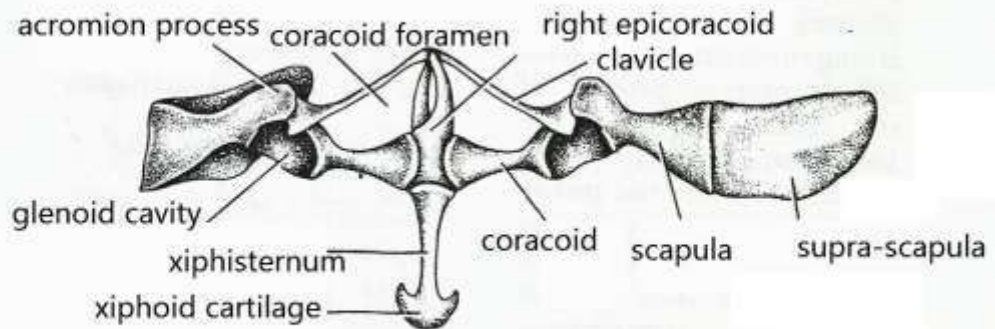
✚ For help follow the video in the link:

https://www.youtube.com/watch?v=ozSN3Tffr_Y

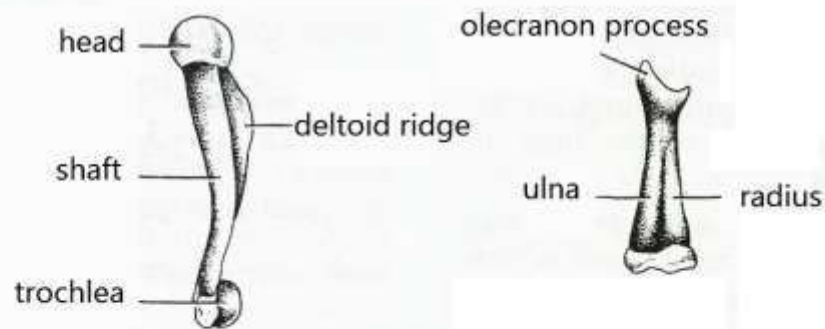
✚ Draw a labelled diagram



WHOLE SKELETON



PECTORAL GIRDLE AND STERNUM



HUMEROUS

RADIO-ULNA

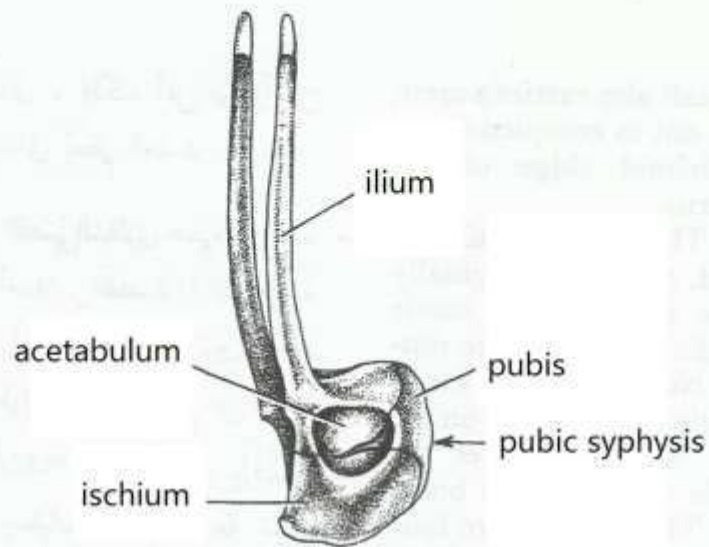
BONES OF FORE-LIMB

9. Appendicular Skeleton

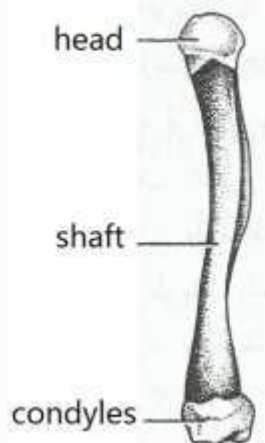
B. Pelvic girdle & Hindlimbs

✚ For help follow the video in the link:
https://www.youtube.com/watch?v=ozSN3Tffr_Y

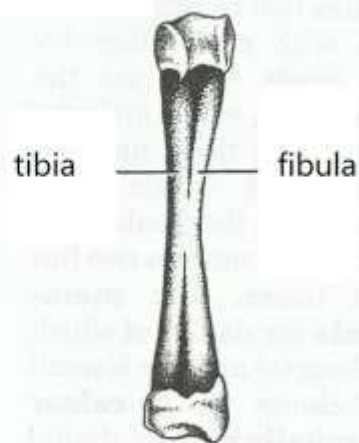
✚ Draw a labelled diagram



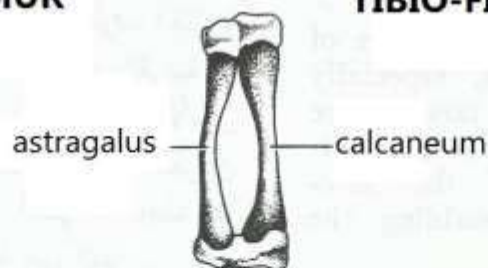
PEVIC GIRDLE



FEMUR



TIBIO-FIBULA



ASTRAGALUS AND CALCANEUM

BONES OF HIND LIMB