ANIMAL COMPLEXITY (LEVELS OF ORGANIZATION)

Cells and Tissues: Animals face the same problems in life such as obtaining food, oxygen, maintaining their water balance, removing metabolic wastes and reproducing young ones.

Animal body plans differ in the graded of organization, body symmetry, number of body cavities and number of embryonic body layers. Five major grades or levels of body complexity are recognized in animals, each of which being more complex than the one preceding it. These levels are (i) protoplasmic, (ii) cellular, (iii) cell tissue, (iv) tissue-organ, and (v) organ-system.

Protoplasmic group: These are the simplest eukaryotic complete organisms that perform all the basic functions of life seen in more complex organisms. They carry out all these functions of life within the framework of a single cell. The cytoplasm is differentiated into subcellular structures called organelles which are capable of performing specialized functions. Animals at this level are at the protoplasmic grade of organization.

Cellular group: Multicellular animals are known as metazoans and their cells are specialized for performing the various tasks performed by organelles of unicellular forms. Some metazoans are provided with tissues while others have neither tissues nor organs. The most primitive metazoans have aggregations of cells that are concerned with reproduction, nutrition etc. Each of these aggregations of cells is not strongly associated to perform collective function. These organisms are at the cellular level of organization, e.g., *Volvox* and Sponges such as *Leucosolenia* sp.

Tissue group: Tissues are aggregations of morphologically and physiologically related cells that perform a specific function. Animals with such an organization are at the cell-tissue grade of organization, such as nerve net of cnidarians in cellular level of sponges. All other metazoans have their tissues organized into functional units called organs, which have more specialized

functions than tissues. Animals at this level are at the tissue-organ level or grade of organization e.g., Platyhelminth. When animal organs work together to perform some functions, then the highest level of organization, i.e. the organ-system, is attained e.g. alimentary canal of *Homo sapiens* is made up of different organs working to carry out the process of digestion (nutrition).

EMBRYOLOGY

OOGENESIS

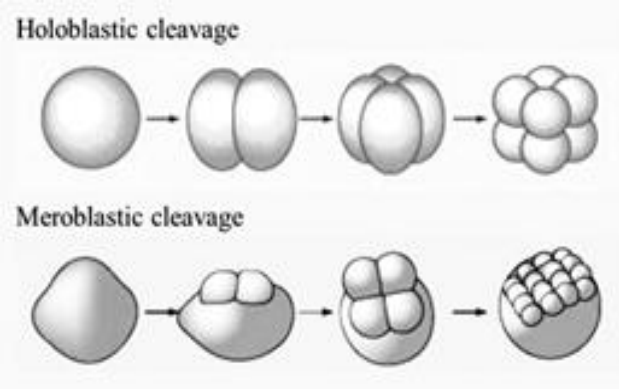
Oogenesis is the process that leads to production of female gamete called ovum. [Egg]. The ovaries begin to develop early in fetal life of the female. At birth, all the ova that the female will produce in her lifetime are present. The ovaries give rise to oogonal cells which develop into oocyte. ***Meiosis*** begins in all oocyte before female fetus is born but stops before the first division is complete and remains arrested until puberty.

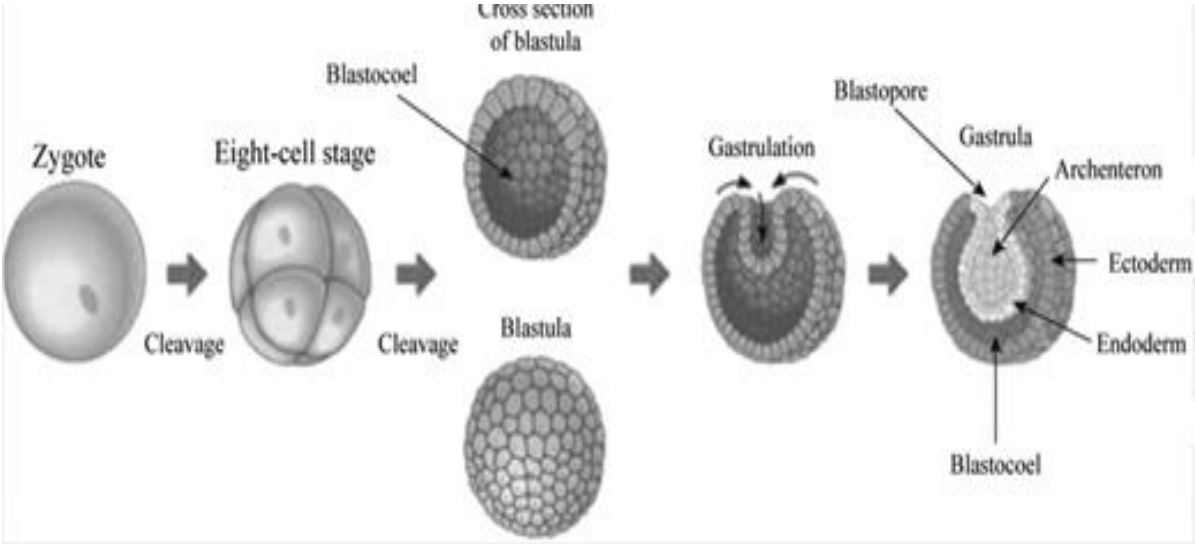
From puberty onwards, each month, as a result of hormonal influences, certain numbers of primordial follicles resume their mitotic division. At the same time, the follicular cells that surround the oocyte start to divide by mitosis and increase in number forming several layers of the follicular cell. At this time, the follicle is called the '***secondary follicle'***

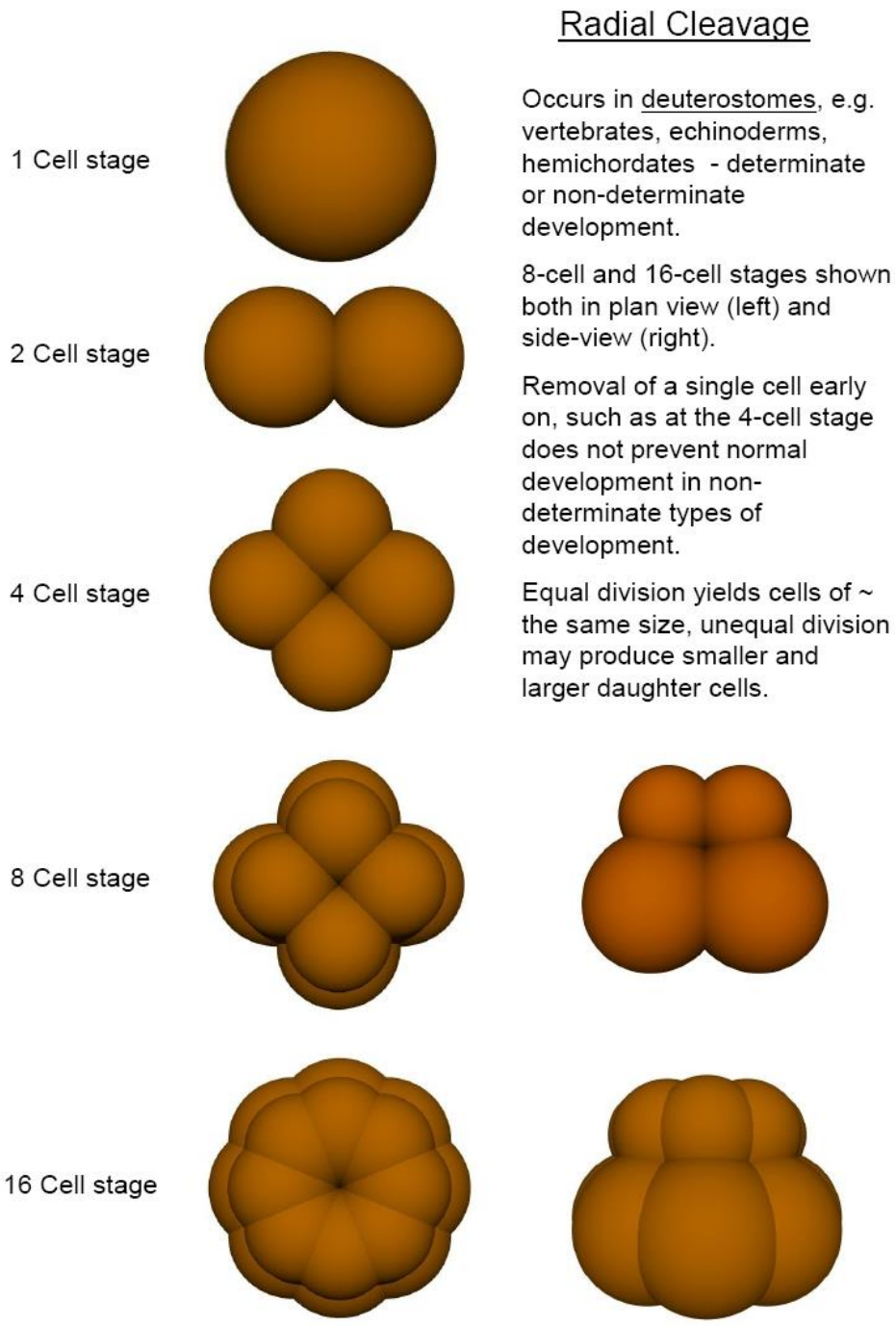
Between the follicular cells and the oocyte, amorphous substance is produced that lies between them, this substance is called '***zona pellucida'*** the first layer of the follicular cells has long processes of cytoplasm passing through the zona pellucida to end on the oocyte. This layer is known as '***corona radiata***. The follicular cells increase further in number and gradually, fluid starts to accumulate amongst them; eventually forming a cyst. The follicle is now said to be in ***tertiary stage***. The fluid increases in volume and becomes so very large that the oocyte is pushed to the extreme end and the follicle itself bulges out of the surface of the ovary. Usually, only one gets to the stage of forming a large cyst known as the 'Graafian follicle 'or quartenary follicle' just before ovulation takes place, the oocyte completes its ***first mitotic*** division producing two disproportionate cells; ***one large ova*** which contains all the cytoplasm and the

second cell with no cytoplasm at all known as the '***polar body'***. The polar body is pushed to the outside of the oocyte lying between it and the zona pellucida.

At ovulation the follicle ruptures pushing out some fluid, oocyte, the corona radiata and the cloud of follicular cells known as the ***'cumulus oophorus'***. The oocyte commences its ***second mitotic*** division which becomes arrested at ***metaphase II***. The oocyte will only complete its second mitotic division if fertilised.







Egg Types and Cleavages

Although there is a great deal of variation in size, the ovum is always large when compared with spermatozoon and indeed, the largest animal cells known, are the ova of birds. The large

size is due to the large quantity of cytoplasm that is present. The yolk serves as a source of nourishment for the young organism until it can fend for itself. The heavy yolk present in the eggs of chocolates is as a rule, aggregated chiefly towards one pole of the cell, i.e., the **vegetative pole** or **vegetal pole** while the egg nucleus lies near the other pole known as the **animal pole**, in a region which is relatively or completely free from yolky substance. Eggs of this type are said to be **telolecithal.** Telolecithal eggs differ, however, in the extent to which the cytoplasm is charged with yolk. Moderately telolecithal egg of a frog with holoblastic cleavage for example, the yolk is confined to the vegetal pole or hemisphere of the egg. Heavy telolecithal in the eggs of fishes, reptiles, birds and some mammals (monotremata) the amount of yolk present is so great that the non-yolky part is restricted to a small cap at the animal pole. The eggs of Amphioxus and the eutherian mammals are exceptional in that only minute amounts of yolk are present and hence, they are called **microlecithal egg cleavage:** the repeated division of fertilized egg to convert large cytoplasm mass into a large cluster of cells called blastomeres. The quantity of yolk present and the nature of the yolk gradient i.e., the sharpness of separation of the yolk from the cytoplasm play important parts in determining the type of cleavage undergone by the fertilized egg. If yolk is evenly distributed, then it would merely slow down division, but its uneven distribution in telolecithal eggs causes the cleavage planes to be impeded particularly in the vegetal pole or hemisphere. This leads to the production of blastomeres of unequal size, with those near the animal pole being smaller than those nearer the vegetal pole. A further result is that the blastocoel becomes exocentric in position and lies nearer the animal pole. In many of the larger eggs (fishes, reptiles and birds) where yolk is present in great quantities and is separated sharply from the cytoplasm (which is confined to a small cap i.e., the **blastodisc** at the animal pole), cleavage is inhibited altogether in the yolky parts of the egg, the cytoplasmic blastodisc alone being capable of cell division. This type of cleavage, in which the cleavage furrows do not pass completely through the egg, is said to be

partial or **meroblastic** in contrast to the **total** or **holoblastic** cleavage experienced by eggs having a smaller concentration of yolk (amphioxus, amphibians and most mammals). The cleavage of a blastodisc produces a cap of cells called blastoderm.

The provision of food material in the form of yolk in the egg is an important factor in determining the age at which the young animal emerges into the world by the hatching of the egg. The greater the quantity of yolk, the more advanced the stage of development reached prior to hatching and the greater the chance of survival.

Concept of Development or Phase of Ontogenic Developments

The processes leading to the development of a new individual starts before fertilization of the egg because the ripening of the egg and the formation of spermatozoa (gametogenesis) create conditions from which subsequent embryogenesis takes its start.

The 2nd phase of development is fertilization where the egg is activated by a spermatozoon and start developing.

The 3rd phase of development is the period of cleavage. Cleavage results in the formation of a large number of a large number of cells from a single fertilised egg by a number of mitotic cell divisions. During this period the size of the embryo does not change but the cleavage cells, or blastomeres become smaller and smaller with each division. This is a compact heap of cells or cells arranged in a hollow spherical body known as blastula, with a layer of cells known as blastoderm surrounding a cavity known as blastocoel.

The 4th phase of development is gastrulation. During this process the single layer of cells, i.e. blastoderm, gives rise to two or more layers of cells known as the germinal layers of cells known as the germinal layers. The external germinal layer is the ectoderm which always gives rise to the skin epidermis and the nervous system. The next germinal layer is the mesoderm

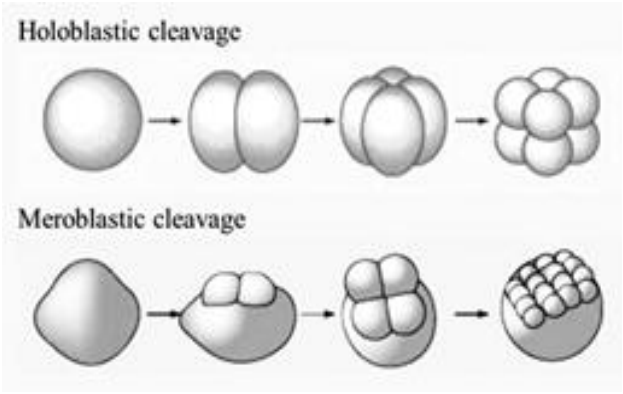
which is the source of the muscles, the blood vascular system, the lining of the 2^o body cavity, i.e., the coelom, and the sex organs. In many mammals, particularly the vertebrates, the excretory systems and most of the internal skeleton are also derived from the mesoderm. The third and innermost germinal layer, the endoderm, forms the alimentary canal and the digestive glands.

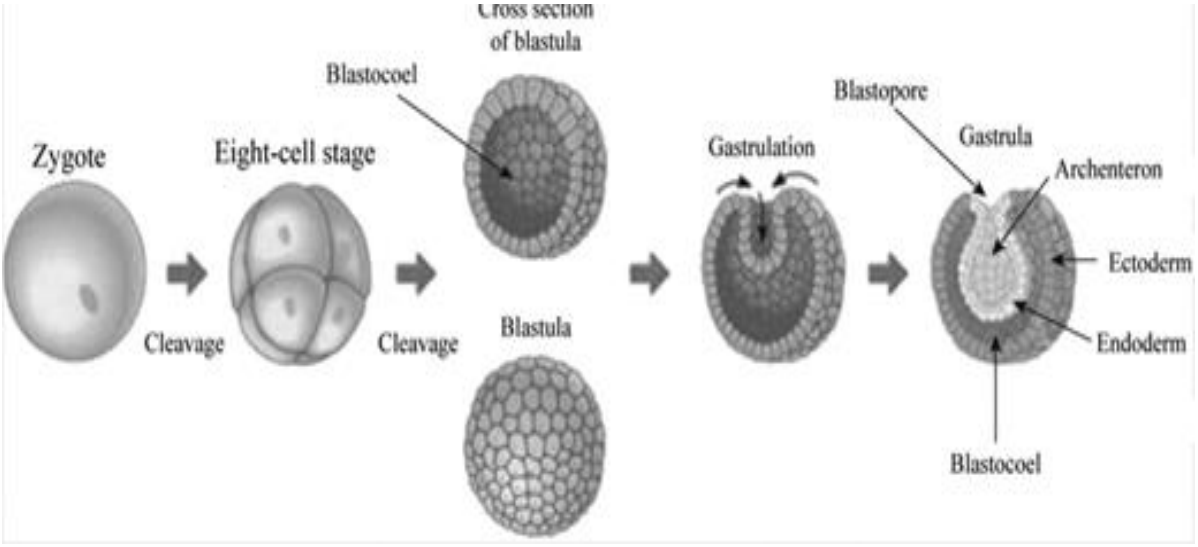
The germinal layers are produced by the disappearance of a part of the blastoderm from the surface and its enclosure by the remainder of the blastoderm i.e. ectoderm. The unfolding or pushing in of the endoderm and mesoderm is known as invagination, and the resulting embryo is known as a gastrula and hence the term gastrulation. It the gastrula is formed by invagination. The cavity of the double-walled cup is called Archenteron, and the opening leading from this cavity to the exterior is called blastopore.

The 5^{th} phase of development is organogenesis (i.e. organ formation). The masses of cells of the three germinal layers split up into smaller groups of cells, each of which is destined to produce a certain organ or part of the animal. Every organ begins its development as a group of cells segregated from the other cells of the embryo. This group of cells are called rudiments of respective organ. The rudiments into which germinal layers become subdivided are called primary organ rudiments. Some of these primary organ rudiments are very complex, containing cells destined to produce a whole system of organs such as the entire nervous system or alimentary canal. These complex organ rudiments later become subdivided into secondary organ rudiments.

The sixth phase of development is the period of growth and histological differentiation. After the organ rudiments are formed, they grow and greatly increase their volume so that the animal (embryo) gradually achieves the size of its parents. Sooner or later the cells in each rudiment become histologically differentiated, i.e. they acquire the structure and physicochemical properties which enable them to perform their physiological functions. Sometimes the animal

emerging from the eggs possesses special organs which are absent in the adult but which are necessary for the special mode of existence of the young animal. In this case the young animal is called a larva. The larva undergoes metamorphosis before being transformed to the adult. Many animals possess considerable plasticity and maybe able to repair injuries sustained from the environment or caused experimentally lost parts may be regenerated, and this means that the developmental processes may sometimes be repeated in an adult or adolescent organism.

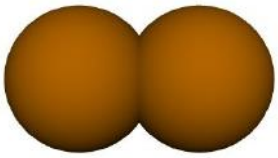

Holoblastic cleavage
Meroblastic cleavage


Zygote
Eight-cell stage
Cleavage
Cleavage
Blastocoel
Cross section of blastula
Blastula
Gastrulation
Blastopore
Gastrula
Archenteron
Ectoderm
Endoderm
Blastocoel

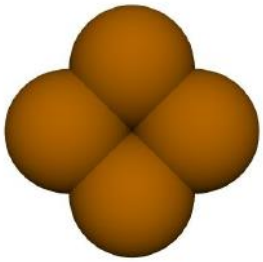
Radial Cleavage

1 Cell stage

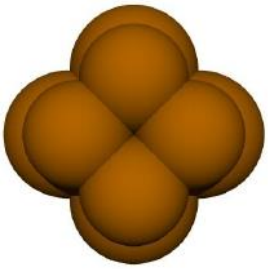
2 Cell stage

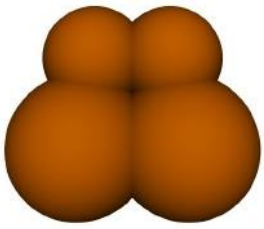


4 Cell stage

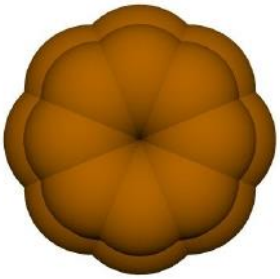


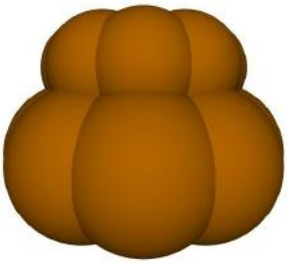
8 Cell stage





16 Cell stage





Occurs in deuterostomes, e.g. vertebrates, echinoderms, hemichordates - determinate or non-determinate development.

8-cell and 16-cell stages shown both in plan view (left) and side-view (right).

Removal of a single cell early on, such as at the 4-cell stage does not prevent normal development in non-determinate types of development.

Equal division yields cells of ~ the same size, unequal division may produce smaller and larger daughter cells.

ANIMAL DIVERSITY, CLASSIFICATION AND THE BINOMIAL NOMENCLATURE

ANIMAL DIVERSITY

- **There are about 1.8 million described species of plants and animals out of which animals account for about 1.4 million species.**
- **It has also been estimated that there could be as many as tens of millions of animal species that are not yet identified or described, especially in the environments that are difficult to explore, e.g. ocean floor.**
- **The diversity of animals necessitates the need for zoologists to specialise in different areas, as it is practically impossible for a zoologist to be a specialist in over one million species of animals.**

Animal diversity necessitates the need to create different areas of specialization in Zoology and create an avenue for a better understanding of the various taxa. Hence, the following sub-disciplines of Zoology (based on taxonomy):

- **Protozoology**: the study of protozoa
- **Entomology**: the study of insects
- **Malacology**: the study of molluscs (e.g. snails, octopus)
- **Carcinology**: the study of crustaceans (e.g. crabs, shrimps)
- **Ichthyology**: the study of fishes
- **Herpetology**: the study of amphibians (e.g. toads, frogs, salamanders, snakes, crocodiles)
- **Ornithology**: the study of birds
- **Mammalogy**: the study of mammals

ANIMAL CLASSIFICATION

- The branch or sub-discipline of zoology that studies the classification of, and the evolutionary interrelationships among animal groups is called **SYSTEMATICS**.
- Any grouping of animals (organisms) that shares a particular set of characteristics forms an assemblage known as **TAXON** (Plural: TAXA).
- Hence, the scientific classification of animals is known as **TAXONOMY** while the study of evolutionary groups among species is known as **SYSTEMATICS**.

Modern taxonomists use the following taxa which are listed in hierarchical order, starting from the largest taxonomic unit (using human as a case study):

Domain: Eukarya

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Primates

Family: Hominidae

Genus: *Homo*

Species: *sapiens*

NOTE: In the classification of an animal, the trend is as listed above, i.e. Domain, followed by Kingdom, Phylum, Class, Order, Family, Genus, Species

BINOMIAL SYSTEM OF CLASSIFICATION

- All animals are classified into hierarchies based on their relatedness.
- The modern and universal system of animal classification is known as the **Binomial Nomenclature**.
- The binomial nomenclature was primarily developed for plants by a Swedish Biologist known as **Karl von Linne (Carrolus Linnaeus)** (1707-1778).
- This binomial nomenclature system has since been adopted for animals.
- Using the binomial nomenclature, each kind of organism (animal) is allotted a two-part name.
- The first part indicates the genus while the second part indicates the species to which the animal belongs.
- Both (genus and species) names (also known as zoological names) must either be italicized or underlined (if it is handwritten).

EXAMPLES

- The genus name for Lion is 'Panthera', while the species name is 'leo'
- Hence**, *Panthera leo*** (italicised if it is typed as the case is here)

  OR

- **Panthera leo** (underlined if it is hand-written)
- NOTE: The International Code of Zoological Nomenclature (ICZN) stipulates that no two kinds of animals have the same binomial name, and every animal has only one correct binomial name.

WHY USE BINOMIAL NAMES AND NOT COMMON NAMES?

1. All animals have their common names which could vary from one locality or language to another. For instance, a bird called ‘owl’ (common name) in English is called ‘owiwi’ in Yoruba. The same bird is called different names in other languages. This implies that a single species of animal could have hundreds of different common names.
2. A binomial name brings order to a chaotic world of common names. Once a species is allotted a binomial name, it goes by the name among scientists in all regions and languages of the world.
3. Some common names refer to a higher taxonomic category and do not specify a particular species in the taxon. For instance, dragonflies, crustaceans, catfishes are all common names for higher taxonomic categories. They do not specify the particular species in each case. Hence, the need for a binomial name.

KINGDOM ANIMALIA

- The Kingdom Animalia is the largest of the five kingdoms on Planet Earth.
- There are seven taxonomic groups in the animal kingdom, namely: kingdom, phylum, class, order, family, genus and species.
- While a phylum is the largest taxonomic group in the animal kingdom, a species is the smallest taxonomic unit in the kingdom.
  - The Kingdom Animalia is comprised of many phyla (plural of phylum), and each phylum consists of many classes.
  - Each class is comprised of many orders.
  - Each order is comprised of many families.
  - Each family consists of many genera (plural form of genus).
  - Each genus consists of many species.

- NOTE:
  - A phylum consists of animals that have more characteristics in common than those in the kingdom.
  - A class also consists of animals that have more characteristics in common than those in a phylum.

Assignment

Using the examples given above (i.e., phylum and class), describe the following taxonomic groups: order, family, genus and species.

OTHER DIVISIONS OF ANIMALS

1. Based on the presence or absence of vertebrae, animals can be broadly divided into two.

   i. Invertebrate animals – animals without backbones

   ii. Vertebrate animals – animals with backbones

OTHER DIVISIONS OF ANIMALS (CONT'D)

2. Number of embryonic layers: Based on this characteristic, there are two groups of animals.

- **Triploblastic animals**: These are animals in which the body wall is formed from three embryonic layers, known as ectoderm, mesoderm and endoderm.
  - Examples of triploblastic animals are members of the Phyla Platyhelminthes, Annelida, Arthropoda, Mollusca, Echinodermata and Chordata.
- **Diploblastic animals**: These are animals that have their body wall derived from two embryonic layers known as ectoderm and endoderm. A unique feature of this group of animals is the possession of a structureless feature known as MESOGLOEA.
  - An example of diploblastic animals are members of the Phylum Cnidaria.

OTHER DIVISIONS OF ANIMALS (CONT'D)

3. Another feature used to categorise animals is called the **COELOM**.

- A coelom is a fluid-filled body cavity that is formed by the splitting of mesoderm of triploblastic animals.
- All phyla in the animal kingdom can be divided into three based on this feature
  - i. **Acoelomate Phyla**: the phyla (animals) without coelom, e.g. Phyla Nemertea, Platyhelminthes.
  - ii. **Pseudocoelomate Phyla**: those with a second body cavity which occupies the space between the mesoderm of the body wall and the endoderm of the gut, e.g. Phyla Nematoda and Rotifera.
  - iii. **Coelomate Phyla**: those with true coelom, e.g. Phyla Arthropda, Annelida, Mollusca, Ectoprocta, Brachiopoda, Echinodermata, Hemichordata and Chordata.

DIVERSITY OF INVERTEBRATES

- Invertebrate animals far outnumber the vertebrates in the Kingdom Animalia.
- They account for approximately 90% of over one million species so far described by zoologists.
- There are more than 30 phyla of invertebrates in the Kingdom Animalia.

- Based on their numbers of species and individuals and/or participation in ecological communities, all invertebrate phyla can be divided into two:

I. Major Phyla

- These are the phyla with relatively high number of species (typically more than 1,000 species).
- Examples: Phyla Arthropoda, Mollusca, Protozoa, Platyhelminthes, Coelenterata, Nematoda, Porifera, Annelida, Echinodermata, Ectoprocta and Rotifera.

II. Minor phyla

- These are the phyla with relatively low number of species (typically lower than 1,000 species).
- Examples: Phyla Ctenophora, Nemertinea, Acanthocephala, Nematomorpha, Onychophora, Chaetognatha, Hemichordata.

NOTE:

- **The Phylum Arthropoda is the largest phylum in the animal kingdom being the phylum with the highest number of species. More than 80% of all known animal species are arthropods.**

- Invertebrates can also be divided into two based on body organisation and body size.

1. Lower Invertebrates
2. Higher Invertebrates

Lower Invertebrates

- They have a simple body organisation.
- They are generally smaller in size.
- They are near the base of the phylogenetic tree in the animal kingdom.
- Examples: Phyla Protozoa, Porifera, Coelenterata, Platyhelminthes and Nematoda.

Higher Invertebrates

- They have a complex body organisation.
- They are larger in size.
- They occupy a higher position in the phylogenetic tree of the animal kingdom.
- Examples: Phyla Mollusca, Annelida, Arthropoda and Echinodermata.

UNICELLULAR ANIMALS: THE PROTOZOANS

- There are many phyla of protozoans (unicellular animals) such that some protozoologists now regard the protozoans as a separate kingdom (i.e., Kingdom Protista).
- They include plant-like forms and animal species that are free-living, commensal, mutualistic and parasitic.
- The following phyla of protozoans have been described:
  - Phylum Sarcomastigophora
  - Phylum Labyrinthomorpha
  - Phylum Apicomplexa
  - Phylum Microspora
  - Phylum Acetospora
  - Phylum Myxozoa
  - Phylum Ciliophora

NOTE

- The three major phyla of protozoans (in terms of species composition) are Phyla **Sarcomastigophora**, **Ciliophora** and **Apicomplexa**.
- The Phylum Sarcomastigophora is the most species-diverse (i.e., has the highest number of species) followed by the Phylum Ciliophora and Apicomplexa.
- Hence, Sarcomastigophora > Ciliophora > Apicomplexa (based on species composition).

PHYLUM SARCOMASTIGOPHORA

- Sarcomastigophorans are protozoans that possess flagella, pseudopodia or both for locomotion and feeding.
- They have a single type of nucleus.
- The phylum can be sub-divided into three sub-phyla:
  1. Subphylum Mastigophora
  2. Subphylum Sarcodina
  3. Subphylum Opalinata

SUBPHYLUM SARCOMASTIGOPHORA

- They have one or more flagella for locomotion.
- There are autotrophic, heterotrophic and saprozoic modes of nutrition among members.
- There are two classes under this sub-phylum.

1. **Class Phytomastigophorea**: Chloroplasts are usually found among members of this class. Hence, they are autotrophic. Examples are *Euglena, Volvox* and *Chlamydomonas*.
2. **Class Zoomastigophorea**: They lack chloroplasts. Hence, members are either heterotrophic or saprozoic. Examples are *Trypanosoma, Trichomonas, Giardia, Leishmania*.

Subphylum Sarcodina

- They have pseudopodia for movement and for food gathering.
- They are naked or with shell or test.
- They have the following super classes:

1. **Superclass Rhizopoda**: Members of this group are the amoebae. They have pseudopodia which exist in a variety of forms such as lobopodia, filopodia and reticulopodia. Examples are *Amoeba, Entamoeba, Difflugia* and *Arcella*.
2. **Superclass Actinopoda**. These include the foraminiferans, heliozoans and radiolarians.

PHYLUM APICOMPLEXA

- They are the parasitic protozoans with an apical complex used for penetrating host cells.
- This implies that the name of the phylum was derived from its characteristic feature, i.e. apical complex.
- Cilia and flagella are lacking except in some reproductive stages.
- **Examples** are *Plasmodium, Isospora, Toxoplasma, Monocystis, Sarcocystis*.

PHYLUM CILIOPHORA

- They are protozoans with simple or compound cilia at some stage in the life history.
- They have two different types of nucleus (macronucleus and micronucleus).
- Most species are free-living although some are parasitic.
- Examples are *Paramecium* and *Vorticella*.

RADIATE ANIMALS

- There are different types of body symmetry in the animal kingdom, e.g. radial symmetry, bilateral symmetry and pentaradial symmetry.
- Animals with radial symmetry are known as **radiate animals**.
- In radiate animals, the body parts are arranged symmetrically around a central axis.
- Radiate animals include the Phylum Cnidaria/Coelenterata and the Phylum Ctenophora.

Phylum Cnidaria

- Members possess radial or biradial symmetry.
- Biradial symmetry is a modification of radial symmetry such that a single plane passes through the central axis and divides the animals into mirror images.
- Being radially symmetrical, they have no anterior or posterior ends. Rather, the terms of direction in this phylum are based on the position of the mouth opening.
- The end of the animal's body that contains the mouth is the **oral end**, while the opposite end is the **aboral end**.

Phylum Cnidaria (Cont'd)

- One distinguishing feature of the cnidarians is the presence of special features known as **nematocysts** on their body wall.
- Nematocysts are used for feeding (food gathering) and defence.
- Another distinguishing characteristic of cnidarians is the alternation of generations in their life hsitories.
- Alternation of generations means the possession of two body forms, namely **polyp** and **medusa.**
  - Polyp is the asexual sessile form of cnidarians
  - Medusa is the sexual and free-swimming form of cnidarians.

Classification of the Phylum Cnidaria

- Class Hydrozoa, e.g. *Hydra, Obelia*
- Class Scyphozoa*, e.g. Aurelia*
- Class Anthozoa, e.g. *Anemones and corals*
- Class Cubozoa, e.g. *Chironex*

ZOO 101

INTRODUCTORY ZOOLOGY

Acoelomate animals

Animals that have three germ layers consisting of ectoderm, mesoderm and endoderm are referred to as triploblastic animals. The mesoderm which is the middle layer exists between the outer (ectoderm) layer and inner (mesoderm) layer. In lower triploblastic phyla, there is absence of body cavity (i.e coelom), it is the mesoderm which gives rise to reproductive and muscular systems around the internal organs. Animals that have no fluid-filled body cavity are referred to as Acoelomate animals.

Characteristics of Acoelomate animals

1. They are bilaterially symmetrical.
2. They have one internal cavity.
3. They are triploblastic, have 3 germ layers which include ectoderm, mesoderm and endoderm.
4. They have organ-system level of organization.
5. Occurrence of cephalization (head fused with sense organs).

One of the three phyla under the Acoelomate animals is the Phylum: Platyhelminthes (flatworms).Platyhelminthes is derived from two greek words ‘platy’- means flat and ‘helminthes’-worms. Platyhelminthes are commonly called flatworms.

Characteristics of Platyhelminthes

1. They have thin soft bodies.
2. They are flattened, ribbon-like organisms adapted for crawling.
3. There is absence of blood circulatory system.
4. The mesoderm (middle germ layer) consists of a parenchyma containing cells, fibres and muscles.
5. They have soft epidermis which is either cellular or ciliated.
6. They a branche and incomplete alimentary system with a mouth, pharynx but no anus.
7. They live a parasitic mode of life.
8. There is no circulatory or respiratory system.
9. The excretory system consists of protonephridia (flame cells).
10. The nervous system consists of a pair of anterior ganglia or a nerve connecting to one to five pairs of longitudinal nerve cords.
11. They have a complex reproductive system consisting of gonads, ducts and Accessory organs.
12. They are usually hermaphrodites.
13. Fertilization is in internal.

The phylum Platyhelminthes is divided into four classes;

(a) Turbellaria
(b) Monogenea
(c) Trematoda
(d) Cestoda.

Class: Turbellaria

They are mostly free living platyhelminthes that are predominantly marine. Most are bottom dwellers in marine or freshwater, living under stones or other hard objects. They are flat, leaf-like in shape. They are parasitic in nature. Some are endoparasites e.g Fecampia, species of which are parasitic in crustacean, some others are ectoparasitic.

Turbellarians are hermaphroditic. Gonads are usually present, except in all acoels, e.g Planarians. Excretory system consists of flame cells (protonephridia). Nervous system consists of two cerebral ganglia joined to form a "brain".

Class: Monogenea

The monogeneans are specialized parasites living in, or on a single host throughout life. The host is either an aquatic vertebrate (cartilaginous and bony fishes, amphibians) or an invertebrate (parasitic crustaceans and cephalopod molluscs). They are attached by elaborate adhesive organs called haptors which are often provided with suckers, clamps and hooks. Monogeneans are all hermaphrodites, most are oviparous (egg producing organisms) while a few are viviparous (animals that give birth to offspring). Life cycles of monogeneans are direct with a single host. Example of monogeneans include Polystoma which resides in the bladder of adult frogs.

Class: Trematoda

Trematodes are called flukes. They are almost exclusively endoparasitic in all classes of vertebrates. They have an oval or leaf-shaped body. They bear at least one adhesive organ in the form of a sucker. The body is covered by a tegument. The trematodes are mostly hermaphrodites.

The class Trematoda is divided into two sub-classes;

(i) sub-class- Aspidogastrea

(ii) sub-class- Digenea

The sub class Aspidogastrea is a group of endoparasitic trematodes which have only a single host, usually a mollusk. They lack an oral sucker e.g *Cotylaspis insignis* which is parasitic in freshwater mussels.

The sub class Digenea

This contains many species of medical and economic impotance. They have attachment organs and suckers around the mouth called oral sucker and ventral sucker called acetabulum. The life cycles involve two or more hosts; the primary or definitive host (the host in which sexual reproduction occurs, sometimes called the final host) being a vertebrate and the other hosts are known as secondary or intermediate hosts. The intermediate host is a mollusc. Example of trematodes include *Fasciola gigantic,* known as the liver fluke which occur in the liver of cattle and sheep in Africa, while *Fasciola hepatica* is the liver fluke which is found in Europe and America.

Another example of digenetic trematode is the human blood flukes called Schistosomes belonging to family Schistosomatidae. The Schistosomes are long, slender and they lack a

muscular pharynx. The male holds the female in its gynaecophoric canal. The Schistosomes are gonochoristic or dioecious which differs markedly from most other platyhelminthes. Ther are 3 species of Schistosomes which infect humans and they are *Schistosoma haematobium* and *S. mansoni* which occur in Africa, South America and the middle East while *S. japonicum* is confined to the far East (China,Japan and the Phillipines).

S.haematobium is transmitted by freshwater snail, *Bulinus globosus* in Nigeria and causes a disease known as urinary Schistosomiasis in humans (which is the presence of blood in the urine a phenomenon known as haematuria).

S. mansoni live within the mesenteric and portal veins of humans. The intermediate host of this blood fluke is the freshwater snail, *Biomphalaris pefeifferi*. The parasite causes intestinal Schistosomiasis.

Class: Cestoda

The tapeworms (members of cestoda) are always endoparasitic and almost all of them are gut parasites of vertebrates. The body of the tapeworm is divided into segments known as proglottids.

The body of the tapeworm is divided into 3 regions:

(i) the scolex which is the organ of attachment at the anterior end

(ii) the neck which produces segments or proglottids

(iii) the strobila.

The scolex of tapeworms varies. In some, it bears hooks on the rostellum. Three types of adhesive suckers exist in cestoda and they include bothria, bothridia and acetabulla.

Bothria occur in members of the order Pseudophyllidea e.g *Diphyllobothrium*.

Bothridia are found in the order Tetraphyllidea e.g *Acanthobothrium*.

Acetabula are the true suckers which are found in the order Cyclophyllidea e.g *Diphylidium, Taenia.*

Class: Cestoda Contd

In the class Cestoda, there are two sub classes, Cestodaria and Eucestoda. Cestodarians are unsegmented flatworms withouta digestive tract. The body is fluke-like with no scolex and is not divided into proglottids. They are hermaphrodites with a single set of reproductive organs.

The Eucestodes are large, strobilated tapeworms with well-developed scolex , neck and strobila. They are endoparasitic in the alimentary canals of various vertebrates, most of them require one or more intermediate hosts during their life cycle.

The Eucestoda is sub divided into five orders:

Order: Cyclophyllidea

Order: Pseudophyllidea

Order: Tetraphyllidea

Order: Diphyllidea

Order: Tetrarhynchidea.

Majority of common tapeworms belong to the Order Cyclophyllidea. For instance, two common tapeworms of humans, *Taenia saginata*, the beef tapeworm and the pork tapeworm *T. solium. T. solium* has four suckers and a rostellum. *T. saginata* is without hooks or rostellum. *T. pisiformis* occurs in the dog and other carnivores.

Dipylidium caninum is a tapeworm of the alimentary canals of dogs and cats. Flea is the intermediate host.

Diphyllobothrium latum is the fish tapeworm which belong to the Order Pseudophyllidea. The scolex is characterized by two bothria, one in either side.

Members of the Order Tetraphyllidea have four bothridia with suckers at their anterior ends. e.g *Acanthobothrium.*

Concluding Part of Acoelomate Animals

Eucoelomate Animals

Eucoelomate animals are true coelomates with schizocoels and enterocoels consisting of the Protostome and Deuterostome groups respectively.

Metameric Coelomates

Metameric coelomates are eucoelomates which include Annelida, Onychophora, Tardigrada and Arthropoda. These animals are triploblastic, coelomate, bilaterally symmetrical, with a tubular alimentary tract running from mouth to anus and with metameric segmentation. The metameric segmentation implies that the body has its muscles, nerves and internal organs subdivided in sets, each of which makes up a metameric segment.

Phylum: Annelida

Annelida is derived from latin word; annelus, meaning little ring. Members of the Phylum Annelida are schizocoelomate worms with bodies divided into many essentially similar and ring-like segments. This metameric segmentation is usually exhibited both internally and externally in such features which include muscles, nerves, circulatory, excretory and reproductive organs. Annelids are triploblastic and bilaterally symmetrical.

The annelid body consists of the head, segmented trunk and pygidium. The head bears the mouth comprising of prostomium and peristomium. The trunk segmentation is visible externally as annuli rings. The body wall of annelid consists of a thin cuticle, the epidermis, an outer layer of circular muscles and an inner layer of longitudinal muscles.

In annelid worms, there are no rigid skeletal elements but instead the coelomic fluid forms a hydrostatic or hydraulic skeleton against which the muscles act to change the body shape. The annelids have complete digestive tract. Digestion is extracellular. They have a closed circulatory system. Respiration is through the epidermis or by gills as found in some

tubicolous (tube dwelling) worms. Excretion is by nephridia. The nervous system consists of a pair of cerebral ganglia (brain) connected by circum oesophageal commissures. Sexes are either monoecious or they are dioecious with separate sexes.

The annelids are highly successful as a group, some members are modified for active, sedentary, endoparasitic or ectoparasitic lives in the sea, freshwater or on land. They include the earthworms, bristle worms and the leeches.

Classification of Annelids

Classification of Phylum Annelida is based primarily on the presence or absence of parapodia, chaetae and other morphological features. The phylum can be subdivided into three major Classes: Polychaeta, Oligochaeta and Hirudinoidea.

Earthworms

Earthworms are among the most widespread of invertebrate animals and are found mainly in the soils of grasslands, woodlands, shrublands and forests.

There is a great taxonomic diversity among tropical earthworms but the dominant ones are the representatives of the families Almidae, Glossoscolecidae, Megascolecidae, Ocnerodrilidae and Eudrilidae. In Nigeria, the eudrilids seem dominant. The family Eudrilidae is divided into two Sub families- Parendrilinae and Eudrilinae.

The body wall of earthworm consist of two concentric tubes, the outer body wall and the straight digestive tract, the space between them is the coelom. The body of an earthworm is long and cylindrical, blindly tapered at each end. The anterior segment contains the ventral mouth and a fleshy lobe, the prostomium which projects forward from its dorsal surface. The prostomium may be prolibous, proepilobous, epilobous or tanylobous.

Types of Prostomium

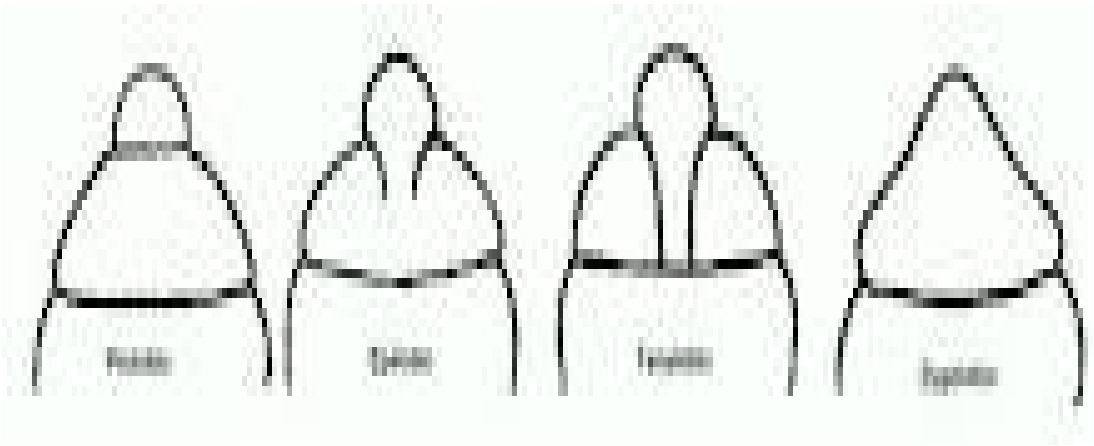


Fig 1 Fig 2 Fig 3 Fig 4

Fig 1 is Prolobous

Fig 2 is Epilobous

Fig 3 is Tanylobous

Fig 4 is Proepilobous

On each body segment with the exception of the first and the last, are minute chitinous, bristle-like chaetae. Each chaetae is secreted by the chaetal sac which is a tubular depression of the surface epithelium. There are many minute external openings on the body which are ;

(i) the spermathecal pore which is the opening of the accessory storage sac for sperm cells (spermatheca).

(ii) the small, inconspicuous female pores which are the openings of the oviducts.

(iii) the male pores, which are the openings of the sperm ducts.

(iv) the nephridiopore which is an excretory opening found on either side of each segment except the first three and the last segments.

(v) dorsal pores which connect the body cavity and exterior.

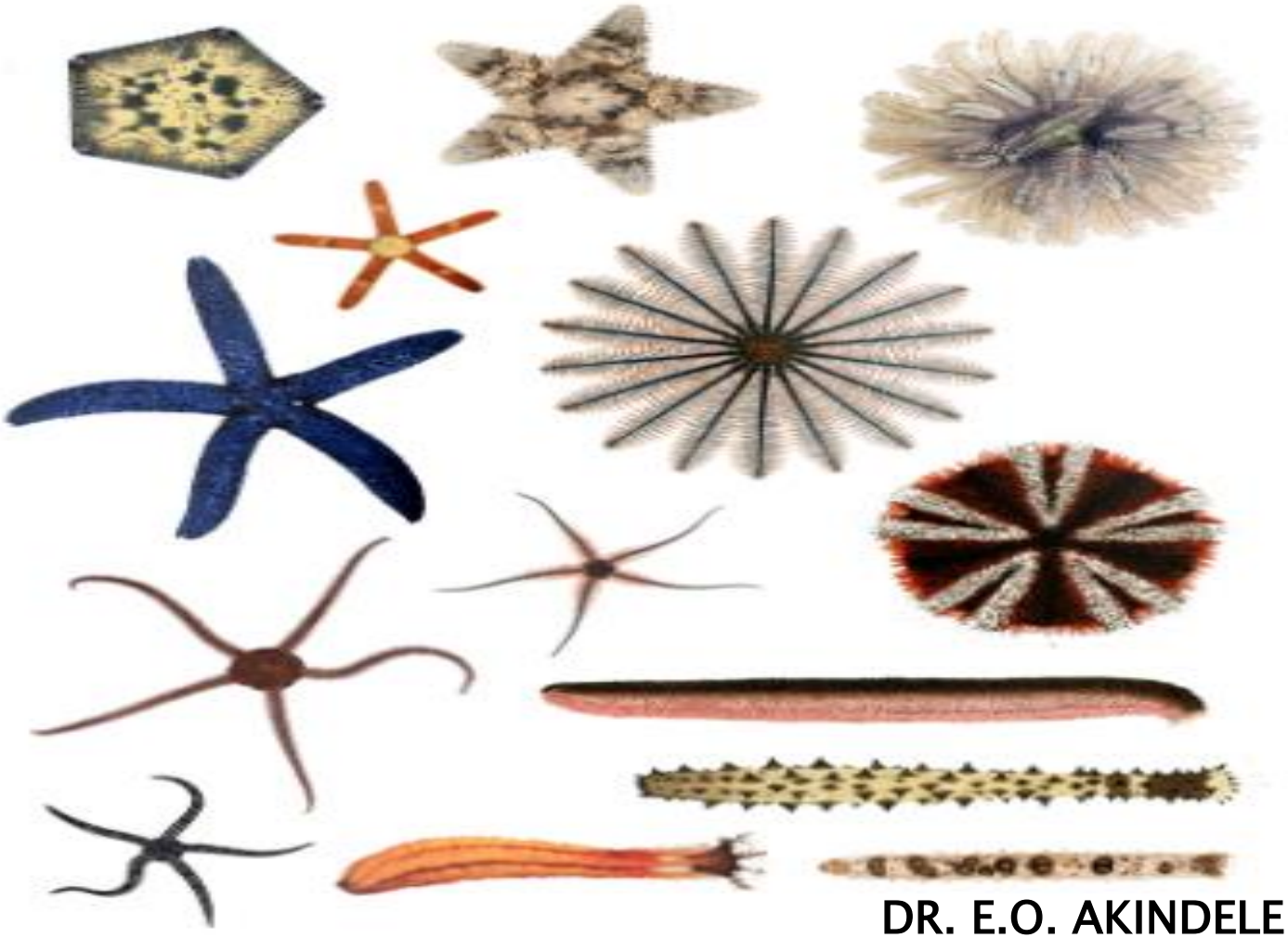
Dorsal pores are absent in eudrilid earthworms. There is no respiratory system, but gaseous exchange occurs within the blood capillaries close to the moist cuticle of the body wall.

The excretory system consists of a pair of nephridia. Each nephridium is made up of a ciliated funnel (nephrostome).

Locomotion in earthworm involves waves of muscle contraction which pass anteriorly along the worm.

The earthworm is monoecious, consisting of both male and female sex organs which are ventrally and anteriorly located.

PHYLUM ECHINODERMATA



DR. E.O. AKINDELE

Etymology and overview of the Phylum Echinodermata

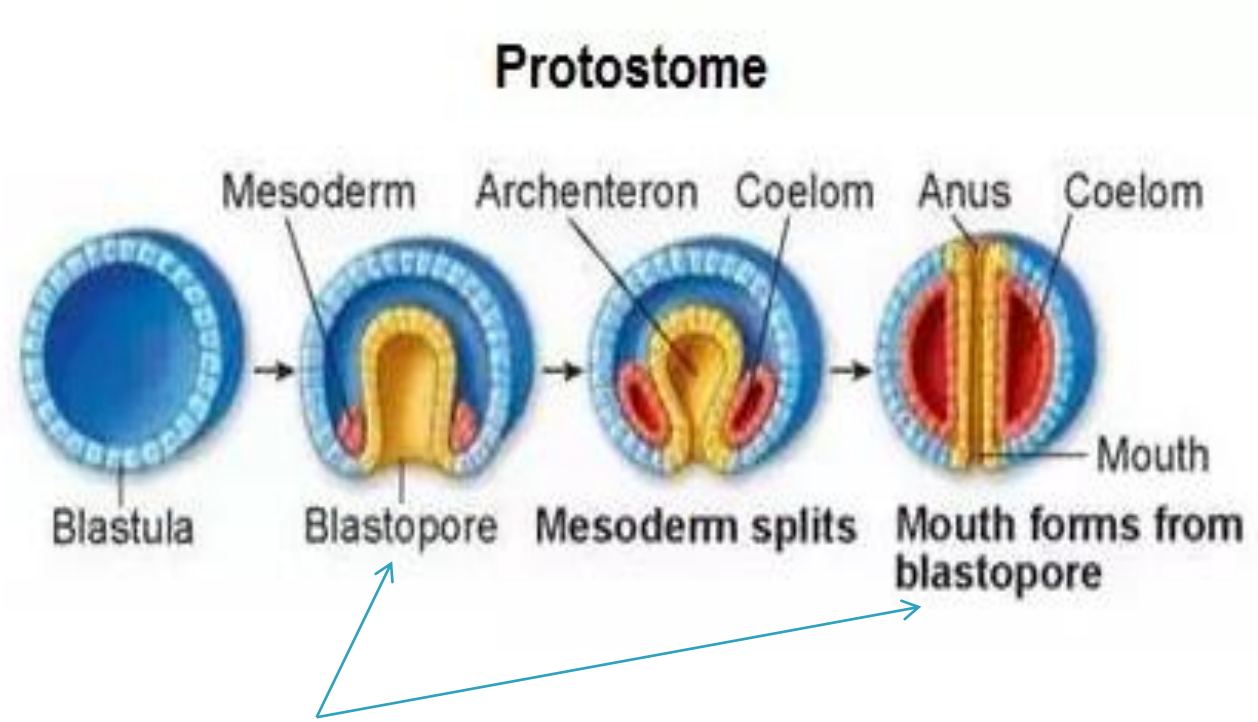
- The word 'Echinodermata' was derived from Greek words (*echinos* = spiny + *derma* = skin + *ata* = to bear).
- This is a phylum of spiny-skinned invertebrate animals which are exclusively marine.
- There are about 7,000 species of extant (living) echinoderms.
- They occur at all depths in the ocean

Relationships of Echinoderms to Hemichordates and Chordates

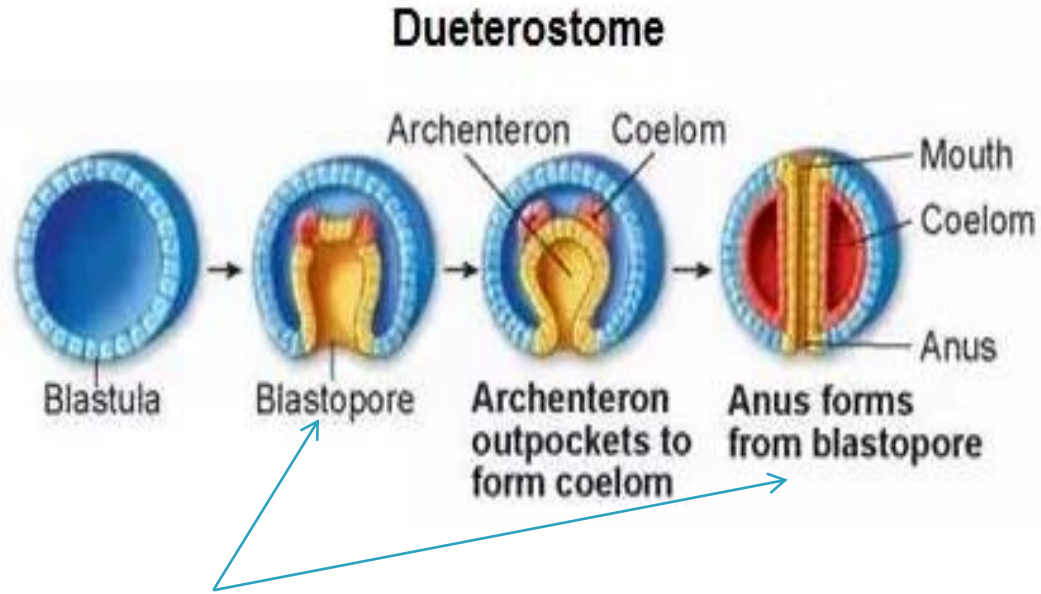
- Echinoderms are considered to be closely related to hemichordates and chordates due to their deuterostome characteristics.
- All animals can be classified into two based on their developmental characteristics.

1. Protostomes
2. Deuterostomes

1. **<u>Protostomes</u>**: These are animals which first embryonic opening (blastopore) develops into mouth of the adult animal, e.g. molluscs, annelids, arthropods.



2. **Deuterostomes**: These are animals which first embryonic opening (blastopore) develops into anus of the adult animal, e.g. echinoderms, hemichordates and chordates.



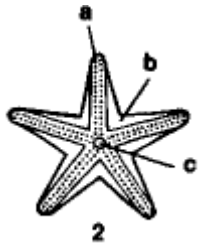
General Description (Characteristics) of the Phylum

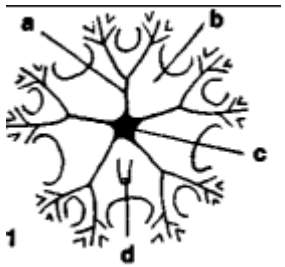
The general characteristics of the Phylum Echinodermata include:

- Calcareous endoskeleton that is of mesodermal origin and in the form of ossicles.
- Adults with pentaradial symmetry and larvae with bilateral symmetry.
- They lack a head and the body is differentiated into a central disc from which radiate five arms.
- They are not metamerically segmented.
- They lack gill slits and excretory organs. Respiration and excretion is by diffusion across the body wall.
- Water-vascular system that is composed of water-filled canals used in locomotion, attachment and/or feeding.
- The blood system is poorly developed since its functions has been taken over by the water vascular system.
- Complete digestive tract that may be secondarily reduced.
- A complex internal apparatus of fluid-containing tubes and bladders which appear outside as **tube feet**.
- Echinoderms are dioecious, i.e. sexes are separate and the zygote gives rise to a bilaterally symmetrical DIPLEURULA larva.

Pentaradial Symmetry of adult echinoderms

- This is the arrangement of the body shape of echinoderms in fives, or a multiple of five, around an oral-aboral axis.

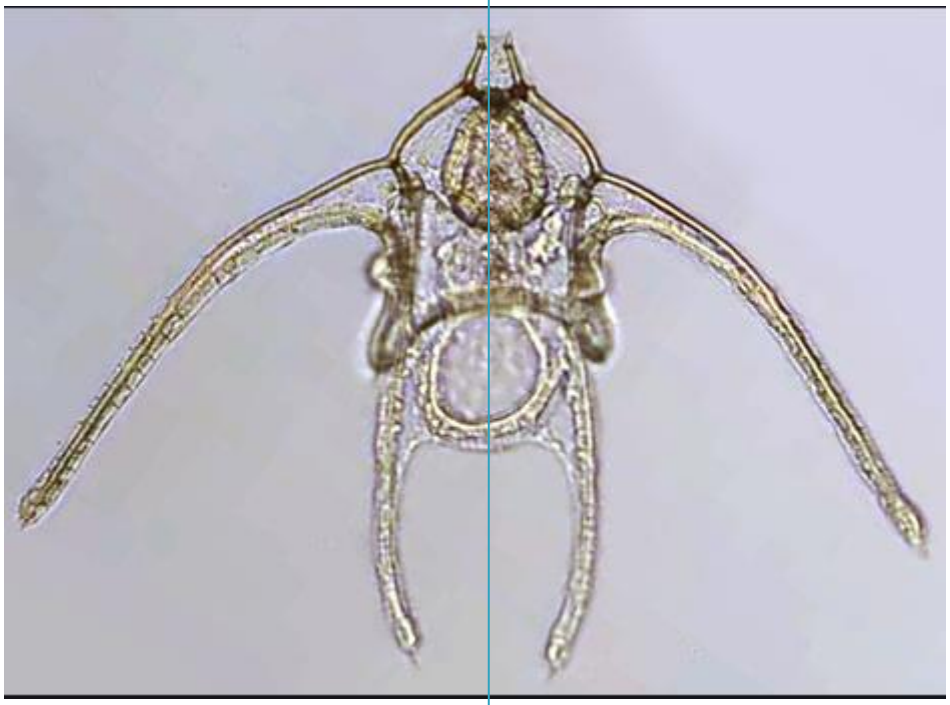




- Radial symmetry is an adaptive feature for a sedentary and slow-moving animals like the echinoderms, because it allows a uniform distribution of sensory, feeding, and other structures around the animals.

Bilateral symmetry of larval echinoderms

Bilateral symmetry: The arrangement of the body components of an animal such that one plane divides the animal into two halves which are appropriate mirror image of each other.

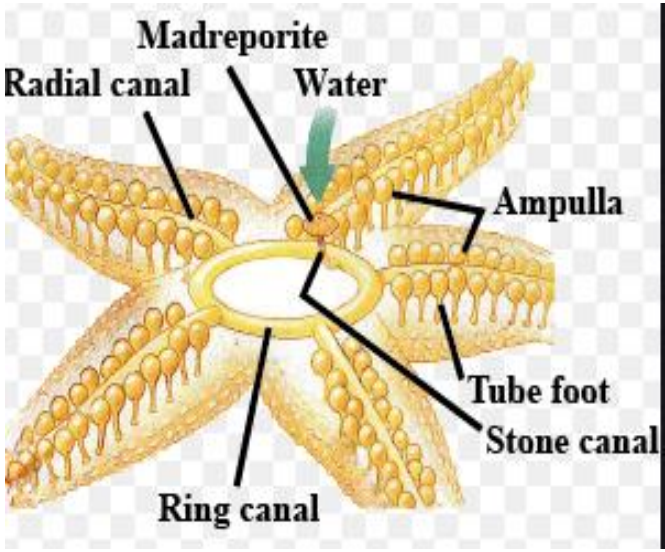


Skeleton

- It is of **mesodermal** origin.
- It consists of a series of **calcium carbonate plates** called **ossicles**.
- The ossicles are held in place by connective tissues and covered by an epidermal layer.

Water-vascular System and Tube Feet

- The water-vascular system of echinoderms is a series of water-filled canals, and **their extensions (outside) are called tube feet**.
- The water-vascular system includes a ring canal that surrounds the mouth.
- The ring canal usually opens to the outside or to the body cavity through a sieve-like plate called the **madreporite**.
- The **primary function** of tube feet is **feeding**. However, it serves some other functions such as **holding fast to a substrate** during locomotion or feeding, and **diffusion of respiratory gases and nitrogenous wastes** across the body wall.



CLASSIFICATION OF THE PHYLUM ECHINODERMATA

- The Phylum Echinodermata consists of the following classes:

1. Class Asteroidea (~1,500 species)
2. Class Ophiuroidea (over 2,000 species)
3. Class Echinoidea (~1,000 species)
4. Class Holothuroidea (~1,500 species)
5. Class Crinoidea (~630 species)

CLASS ASTEROIDEA

Characteristics

- The **sea stars** make up the Class Asteroidea.
- They are star-shaped.
- They possess **poorly demarcated, broad arms** containing a **large coelomic cavity**.
- A series of ossicles in the arm form an **ambulacral groove** that runs the length of the oral surface of each arm.
- The **ambulacral grooves** bear rows of **large tube feet** which are used especially in **feeding and locomotion**.
- **Respiration** takes place through **external gills (papulae)** which are restricted to the aboral surface.

CLASS OPHIUROIDEA

- The Class Ophiuroidea includes the basket stars and the brittle stars.
- Also known as 'snake-tail'
- It is the **most diverse group of echinoderms** with over 2,000 species.
- Members of this class have a central, rounded disc that is sharply demarcated from the **long, slender arms**; thus giving the **central disc a pentagonal shape**.
- The body cavity of the arms is filled almost completely with axial skeleton.
- The ambulacral groove is covered by the lateral arm-plates.
- Unlike the sea stars, the **madreporite** of ophiuroids is on the **oral surface**.

Brittle Star

Basket Star

CLASS ECHINOIDEA

- Members of this class include the sea urchins, sand dollars, and heart urchins.
- They are rounded, discoidal or heart-shaped.
- They are spiny-shaped.
- Their skeleton is called a **'test'.**
- The 'test' consists of **10 closely fitting plates** that arch between oral and aboral ends.
- The 10 plates consist of **five ambulacral plates** which have openings for tube feet, and **five interambulacral plates** which have tubercles for the articulation of spines.

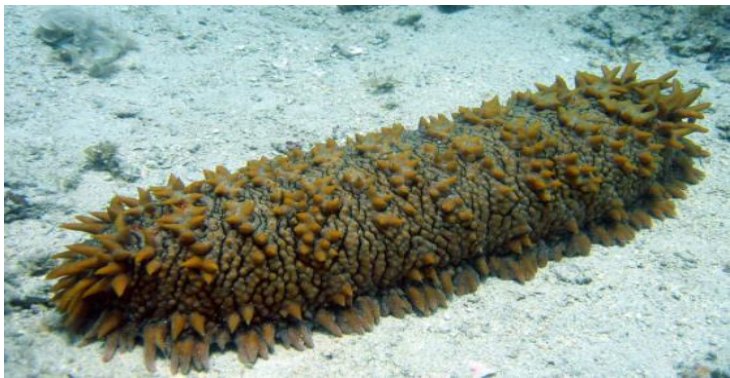
Sea urchins

Sand dollars

Heart urchins

CLASS HOLOTHUROIDEA

- Members of this class are commonly called **sea cucumbers**.
- Known as earthworms of the sea.
- Holothuroids (sea cucumbers) **have no arms** and they are **elongate** along the oral-aboral axis.
- They lie on one side, which is usually flattened as a permanent ventral side, giving them a **secondary bilateral symmetry**.
- **Tube feet** surrounding the mouth are **elongate** and referred to as **tentacles**.
- The **ossicles are microscopic** and do not function in determining body shape.
- The **madreporite** of sea cucumbers **is internal** and the water vascular system is filled with coelomic fluid.



CLASS CRINOIDEA

- This is **the most primitive class** of all living echinoderms.
- Members of this class include the **sea lilies** and the **feather stars**.
- Sea lilies **attach permanently** to their substrate by a **stalk**.
- The **unattached end** of a sea lily is called **the crown**.
- The **aboral end of the crown attaches to the stalk** by a set of ossicles called **the calyx**.
- The **crown** has **five arms** which attach at the calyx.
- The arms have smaller branches (known as **pinnules**), thus giving them a **featherlike appearance**.

CLASS CRINOIDEA (CONT'D)

- **Feather stars** are similar to sea lilies EXCEPT they **lack a stalk** and are **free-swimming** and/or **crawling animals**.

Note: The sea lily is attached to a substrate with its stalk while the feather star lacks a stalk and is free-swimming

PHYLUM CHORDATA

General Characteristics of Chordates

- Chordates are deuterostomate animals which are characterised by the following features:

1. They are bilaterally symmetrical.
2. They have an endostyle or thyroid gland.
3. They have a complete digestive tract.
4. They have a ventral heart with blood flowing forward ventrally and backward dorsally.

Unique Characteristics of Chordates (cont'd)

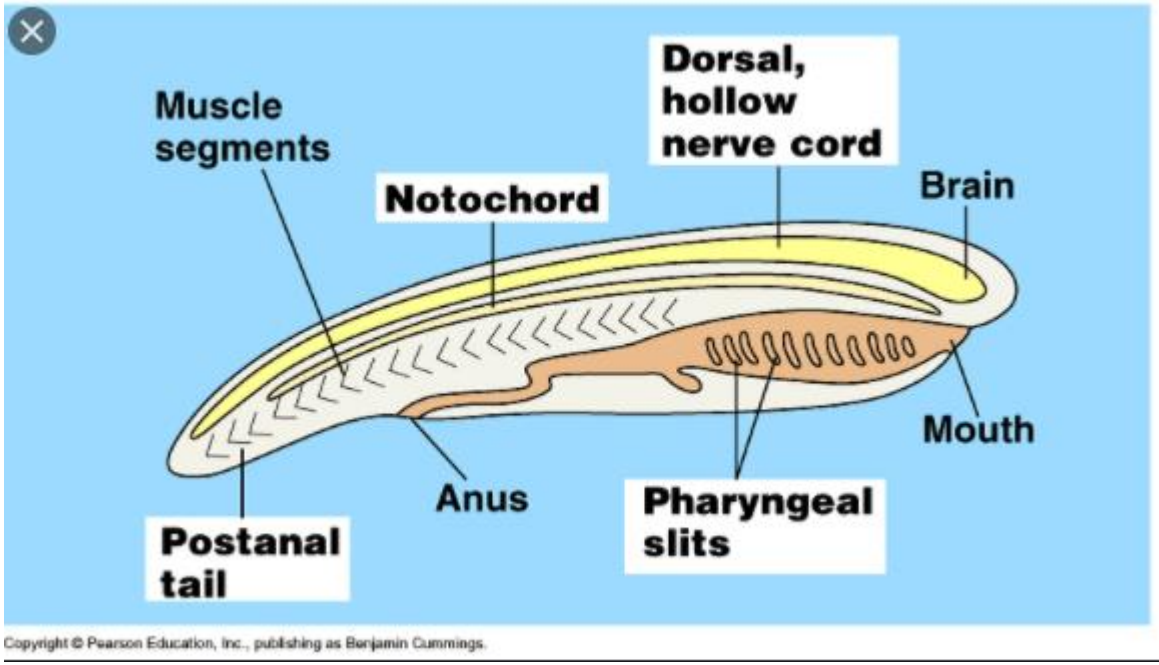
They also possess the following FOUR UNIQUE characteristics at some stage in their development:

1. The notochord:

A semi-flexible cartilaginous rod that runs along the length of the animal.

It is situated dorsal to the gut and ventral to the nerve cord.

2. **Dorsal nerve cord**: located dorsally above the notochord.



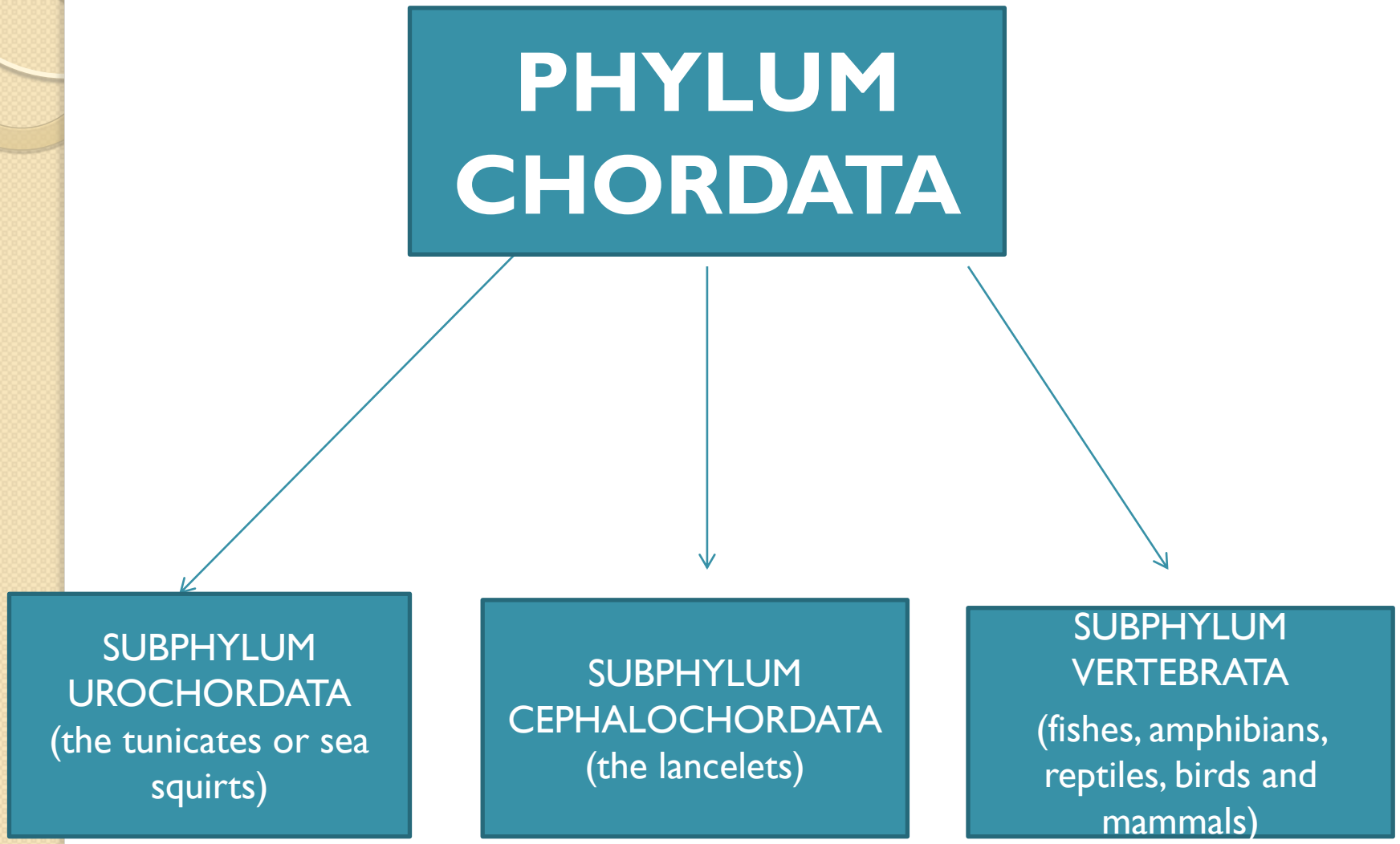
3. **Pharyngeal slits**: openings between the pharynx (throat) and the outside.

4. **Post-anal tail**:

A muscular tail that extends backwards behind the anus.

All chordates have post-anal tail at some stage of their lives.

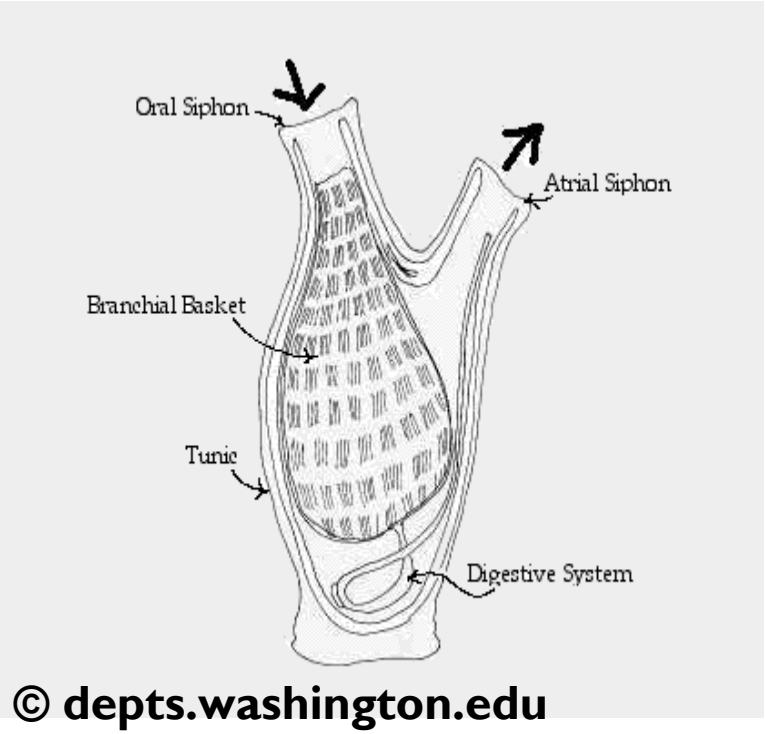
DIVISIONS THE PHYLUM



SUBPHYLUM UROCHORDATA

- This subphylum is subdivided into three classes, viz;
  - the **Larvacea**,
  - the **Ascidiacea**,
  - and the **Thaliacea**.
- The ascidians (tunicates or sea squirts) are the largest class and the most characteristic representatives of the urochordates.
- Urochordates have tadpole-like larvae with notochords in their tails. The notochords are lost in the adult stage.
- They are sessile as adults and are either solitary or colonial.

- Sessile urochordates attach their saclike bodies to rocks and other solid substrates.
- The unattached end of the body contains two siphons:
  - One siphon is the **oral siphon** which is the inlet for water circulation through the body and also serves as the mouth for ingestion of food particles.
  - The second siphon is called the **atrial siphon** and is the opening for excurrent water. Excurrent water carries digestive wastes from the anus out of the atrial siphon.



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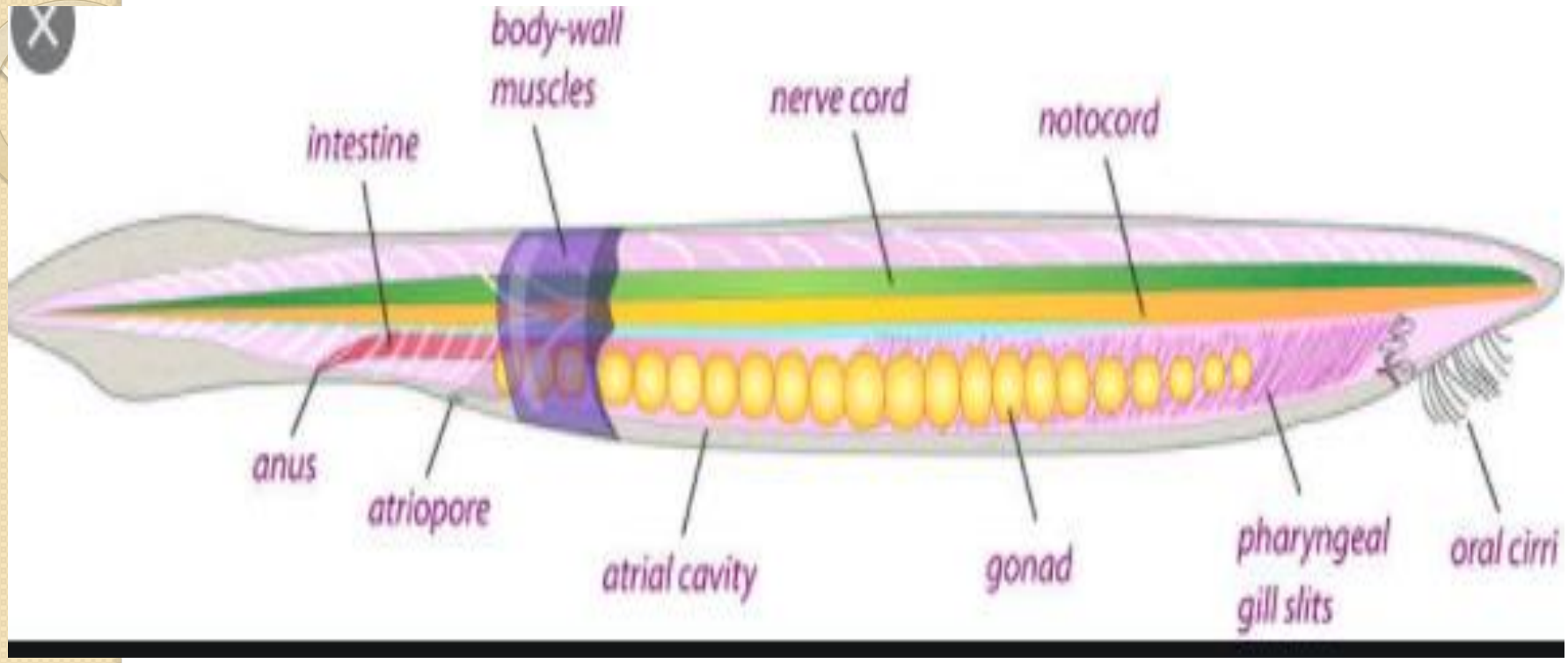
- The body wall of most tunicates is enclosed in a gel-like but tough covering known as **TUNIC** which is composed of proteins, salts and cellulose.
- Urochordates are monoecious (i.e. hermaphroditic) but cross-fertilization is the rule.
- Development is indirect (i.e. has a larval stage).

SUBPHYLUM CEPHALOCHORDATA

- The cephalochordates are also known as the lancelets.
- They are the most primitive of all living chordates.
- They are generally small (about 5 cm long) and tadpole-like.
- The body is elongate, laterally flattened and nearly transparent.
- Cephalochordates consist of two genera, *Branchiostoma* (amphioxus) and *Asymmetron*.

General Characteristics of the Cephalochordates

- The notochord extends from the tail to the head, hence the name 'cephalochordates'.
- An oral hood projects from the anterior end of cephalochordates.
- Ciliated cirri hang from the ventral aspect of the oral hood and are used in feeding.
- Food materials are initially sorted at the cirri, where large particles are thrown off and smaller particles are pulled into the mouth with water.
- Water passes from the pharynx through the pharyngeal slits to the atrium, and out of the body through the atriopore.
- Cephalochordates are dioecious.



Longitudinal section of a lancelet

ZOO 101: INTRODUCTORY ZOOLOGY 1

Phylum: Mollusca.

The phylum Mollusca comprises the second largest invertebrate phylum and it is one of the most morphologically diverse animal groups. The term, Mollusca, is derived from the latin word, mollis, meaning soft.

Mollusca are triploblastic, coelomate and mostly bilaterally symmetrical. The body cavity is haemocoelic. They have non-segmented bodies consisting of 3 regions;

(i) an anterior head which is well developed

(ii) a ventral muscular foot used for crawling, burrowing

(iii) a centrally concentrated visceral mass.

The body is surrounded by fleshy mantle, the glandular surface of which secretes the hard calcareous skeleton either as plates that are embedded in the body wall or as a solid internal or external shell. This mantle often flows out to enclose a mantle cavity in which the gills or ctenidia lie, and into which open the arms, kidney and reproductive ducts.

Mollusc may have one shell, eight shells or no shell. All molluscs, except Aplacophora, have solid calcareous shells produced by shell glands in the mantle. The alimentary tract is complete with the buccal cavity opening into the oesophagus which in turn opens into the anterior region of the stomach. The posterior region of the stomach is called the style sac. A large digestive gland or hepalopancreas opens into the stomach and often there are salivary glands. The buccal region of the foregut is with a rasping tongue-like organ called the radula. The radula boars a number of teeth.

The blood of mollusk is referred to as haemolymph. It is without red colour since haemocyanin, the copper-containing pigmeny serves as the respiratory pigment in solution.

Many mollusc also have haemoglobin in their haemolymph. They have open circulatory system consisting of one or more auricles and one ventricle. In cephalopods, the circulatory system is closed with heart, vessels and capillaries.

Respiration in molluscs is by one to many ctenidia (gills) air-breathing lung in the mantle cavity, the mantle or by the epidermis. Excretion is by metanephridia, the walls of which are greatly folded.

The central nervous system of most molluscs is composed of a nerve ring around the oesophagus formed by three pairs of ganglia which include cerebral, pleural and pedal ganglia. The sense organs include those of touch, taste or smell and there are eyespots or complex eyes as well as statocysts for balance.

Sexes are separate in most species although many molluscs are hermaphrodites. Fertilization is either external or internal. Most molluscs are oviparous while a few are viviparous. The terrestrial, as well as some other forms, lay eggs. Egg cleavage is spiral. A free – swimming trocophore larva emerges from the egg in many molluscs. In marine, some freshwater forms and many molluscs groups (especially gastropods and bivalves), the trocophore stage is followed by a uniquely molluscan larva stage called a veliger which has a special locomotory and food-collecting organ known as the velum.

Molluscs are mostly marine, but various snails and some bivalves inhabit brackish waters and freshwater, while other snails and slugs are terrestrial. Molluscs can be grouped into 8 classes according to their symmetry and the characters of the foot, shell, mantle, ctenidia and nervous system. The classes are:

(i) Monoplacophora

(ii) Polyplacophora

(iii) Scaphopoda

(iv) Bivalvia (Pelecypoda)

(v) Cephalopoda

(vi) Neomeniomorpha

(vii) Chaetodermomorpha

(viii) Gastropoda

Class: Gastropoda

Gastropoda include those molluscs whose young stages are bilaterally symmetrical. They constitute the largest Class of Mollusc. They are found in marine environment, brackish waters, freshwater and terrestrial environment. Some serve as intermediate hosts for many kinds of parasites. The body of mollusc consist of anterior head and ventral foot. The head is well developed and bears one to two pairs of tentacles, eyes and statocysts. The foot is large muscular and flat, usually with a creeping sole but modified in swimming and burrowing. The visceral mass is usually contained in a dorsal shell.

The main diagnostic feature of gastropods is that, during development, they undergo torsion which is the anticlockwise rotation of the visceral mass and mantle through 180° on the foot so that the mantle cavity lies anterior or on the right side. Gastropods are both gonochoristic and hermaphrodite and some are dioecious. Most gastropod species are oviparous, a few are viviparous and, in some species, a trocophore larva develops. The Class Gastropoda is divided into 3 Subclasses:

(i) Subclass: Prosobranchia

(ii) Subclass: Opisthobranchia

(iii) Subclass: Pulmonata

Subclass: Pulmonata

Pulmonates are gastropods with the anterior mantle cavity well vascularized to form a lung. Pulmonates are monoecious and there are no larva stages as they develop directly into young snails or slugs.

Although pulmonates are primarily a terrestrial group, some species have returned to water and most of these aquatic pulmonated group are freshwater and some are marine. The marine forms include *Siphonaria grisea*, an intertidal marine form which occurs in Takwa Bay, Lagos. The Subclass Pulmonata is divided into four orders:

(i) Order: Archaeopulmonata

(ii) Order: Basommatophora

(iii) Order: Stylommatophora

(iv) Order: Systellomatophora

Order: Basommatophora

The basommatophorans are moderate-sized pulmonates with spirally coiled shells. The head bears a single pair of non-retractile tentacles with eyes at their base. They are usually without an operculum. Some freshwater basommatophorans including *Lymnaea, Bulinus* and *Biomphalaria* are medically important because they serve as intermediate hosts for some digenetic trematodes.

The stylommatophorans have two pairs of retractile tentacles, the posterior pair bearing eyes at their tips. The shell, when present, is usually spirally coiled in land snails, but sometimes there is no shell as in slugs e.g. *Limax*.

The giant African land snail, *Archachatina* (*Calachatina*) *marginata*, the Nigerian garden snail, Limicolaria aurora and the British garden snail, *Helix pomatia* are examples of stylommatophoran pulmonated gastropods.

The giant African land snail *Archachatina* (*Calachatina*) *marginata*

The body of the giant land snail, *Archachatina* is divided into two regions, headfoot and visceral mass. The fleshy head bears two pairs of retractile tentacles and a mouth. The head joins directly to a muscular foot which is roughly triangular in shape and which forms the main part of the animal. On top of the foot is the elongated conical, calcareous shell. On the right side, the common genital pore opens beside the head, and the small anus, the kidney opening and the respiratory pore known as the pneumostome are in the mantle edge (collar) underneath the shell.

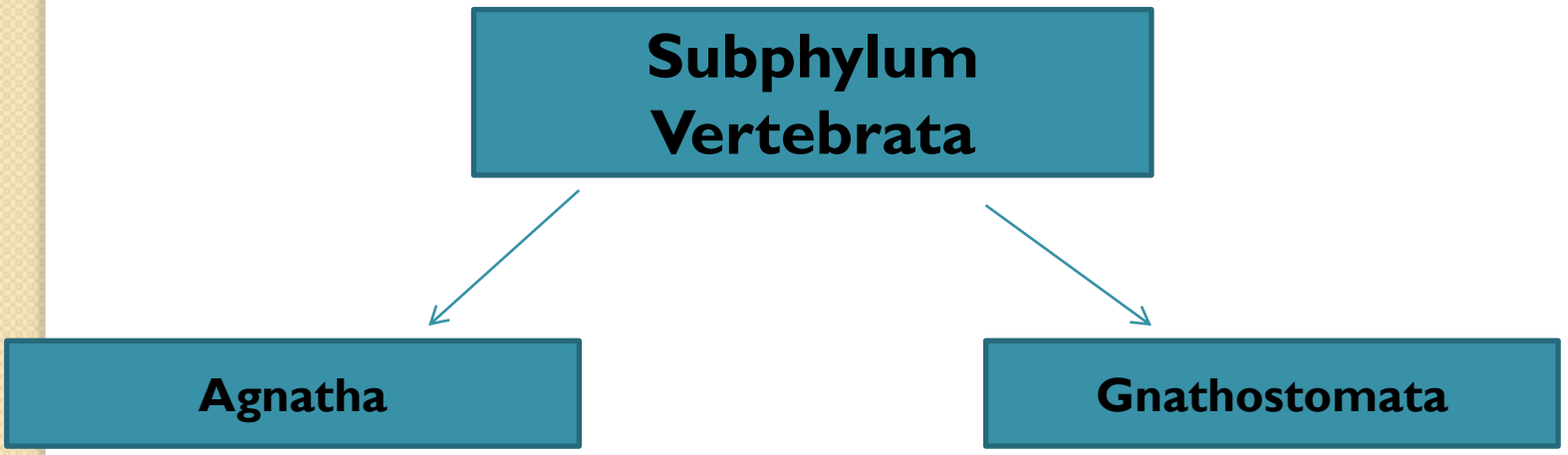
The digestive system consists of three sections, the fore, mid- and the hind-gut. The foregut includes the mouth bodered by upper and lower lips, the oesophagus and the crop. On the roof of the mouth is a dark brown horny jaw and a radula is also present. The midgut consists of the muscular, U-shaped stomach which is embedded in the digestive gland that occupies most of the visceral hump and the intestine which runs from the stomach undergoing a coiled course within the digestive gland to join the hindgut or the rectum.

The mantle with its rich network of blood vessels acts as a lung; air enters and leaves by the pneumostome. The circulatory system consists of a contractile heart which is linked to the various parts of the body by a series of distribution vessels, the arteries, and a series of collecting vessels, the veins. The heart has one atrium and one ventricle.

The reproductive organs are extremely complicated and each individual is monoecious. In a mature land snail, a small white lobulated gland, the ovotestis produces both eggs and sperm. A little hermaphroditic duct connects the ovotestis to the base of albumen gland. At this point this duct enlarges to become a common hermaphroditic duct with its female part (oviduct) leading to the vagina and the long male part (vas deferens) conducting sperm to the muscular penis. Both penis and vagina open into a common genital atrium.

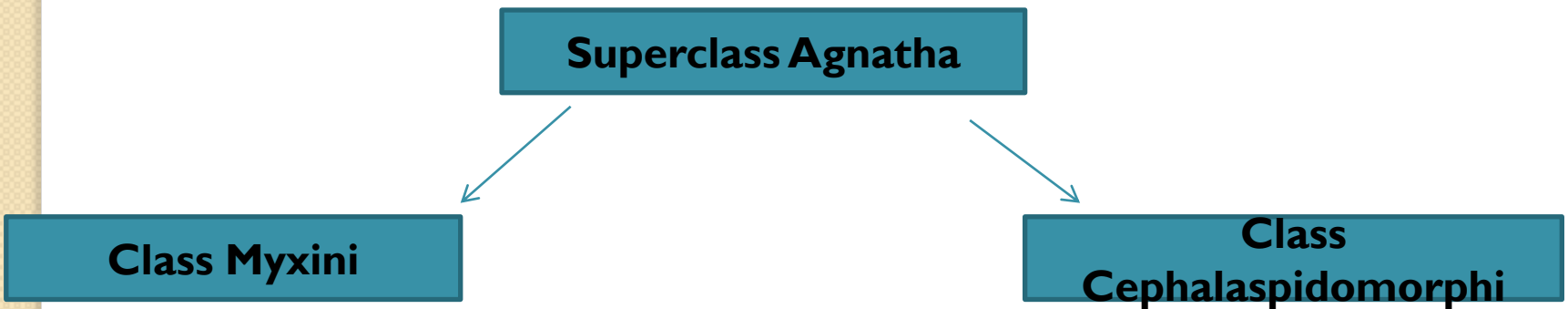
PHYLUM CHORDATA: SUBPHYLUM VERTEBRATA

- The Subphylum Vertebrata is the most diverse of the three subphyla in the Phylum Chordata.
- It has two divisions or superclasses, namely the Agnatha and the Gnathostomata



Superclass Agnatha/Cyclostomata

- Members of this class are fish-like vertebrates that lack jaws and paired appendages.
- They have sucker-like mouths.
- They possess a cartilaginous skeleton and a notochord that persists into the adult stage.
- The superclass has two extant (living) classes, namely the Class Myxini and Class Cephalaspidomorphi.



Class Myxini

- Members of this class are known as the hagfishes.
- They are exclusively marine.
- They are considered by most zoologists as the most primitive group of vertebrates.

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Class Cephalaspidomorphi

- Lampreys are the living representatives of this class.
- They are found in both freshwater and marine environments.

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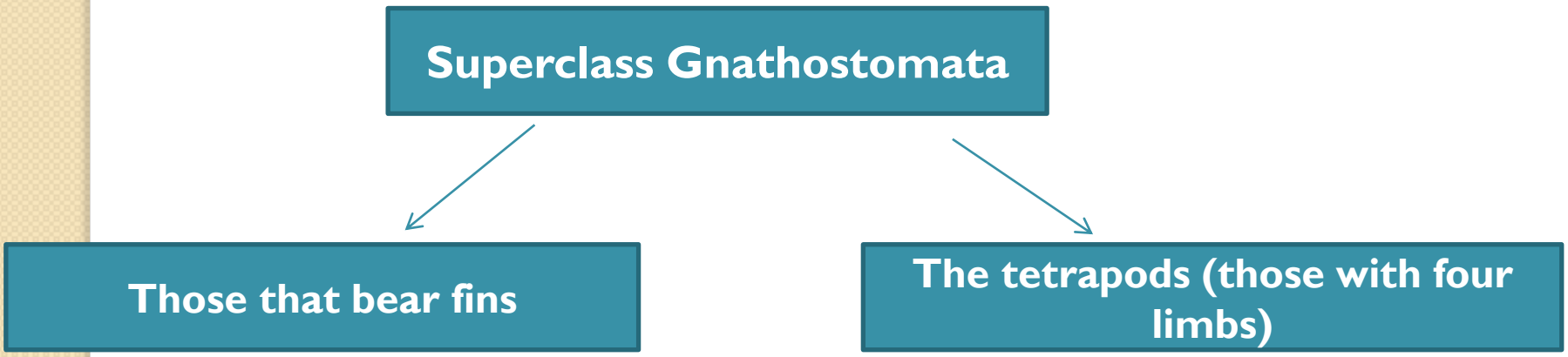
Superclass Gnathostomata

- This is a superclass of jawed vertebrates with paired appendages.
- It can be divided into two major categories, i.e.



Superclass Gnathostomata

1. **Those that bear fins**
   - Class Chondrichthyes
   - Class Osteichthyes
2. **The tetrapods**
   - Class Amphibia
   - Class Reptilia
   - Class Aves
   - Class Mammalia

NB: This arrangement follows the evolutionary trend

ass Chondrichthyes

- This is a class of vertebrate animals characterised by a **cartilaginous endoskeleton** and most members have epidermal **placoid scales**.
- Members of this class can be divided into two.

1. **Subclass Elasmobranchii**: This includes the sharks, skates and rays. They have **placoid scales**.

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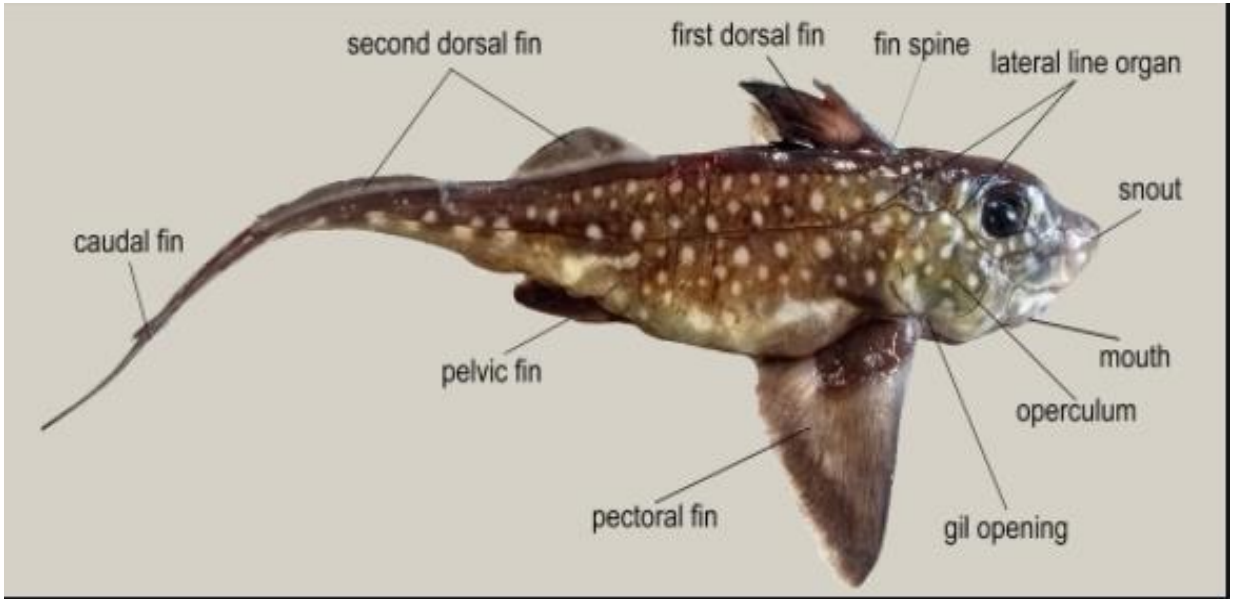
Class Chondrichthyes (cont'd)

Subclass Holocephali: A very good example is *Chimaera*. Holocephalans are different from elasmobranchs with the **presence of a gill cover** (operculum) and **lack of scales**.

NOTE: The first group of vertebrate animals to possess the operculum are the holocephalans.

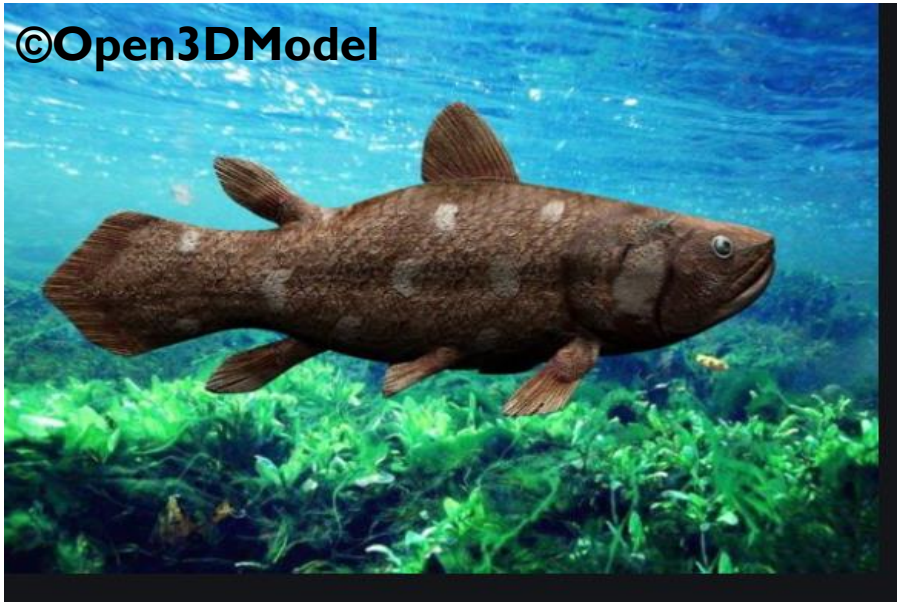


Class Osteichthyes

- This is the largest class of vertebrate animals.
- Members of this class have the following features:
  1. Some **bone** in their skeleton and/or scales
  2. An operculum covering the gill openings
  3. Lungs or a swim bladder
- It has two subclasses namely

1. **Subclass Sarcopterygii**
2. **Subclass Actinopterygii**

Subclass Sarcopterygii: They have muscular lobes associated with their fins, e.g. lungfishes (*Protopterus* in Tropical Africa) and coelacanths (*Latimeria* in Africa-Madagascar).



Subclass Actinopterygii: Their fins lack muscular lobes, hence they are called the ray-finned fishes, e.g. sturgeons, paddlefish, tilapia, cat fish etc.

PHYLUM CHORDATA:THE TETRAPODS

- Tetrapods constitute four out of the five major classes (divisions) of the **Superclass Gnathostomata.**
- Tetrapoda is a **non-taxonomic designation** of vertebrate animals which have four limbs, i.e. the **Amphibia, Reptilia, Aves and Mammalia**.

CLASS AMPHIBIA

- Members of this class derived their name from two Greek words, i.e. '**amphi'** (double) and **bios** (life).
- They move back and forth between water and land or live one stage of their life in water and another on land. Hence, they live a 'double life'.

General Characteristics

- They are poikilothermic (cold-blooded) animals.
- The skin is soft, glandular and without scales.
- Body is divided into head and trunk, i.e. they have no neck.
- Presence of two pairs of pentadactyl (i.e. five digit) limbs, though limbs are absent in some members.
- External ear is absent and the ear drum (tympanum) is on the skin surface.
- Heart is three-chambered (2 auricles and 1 ventricle).
- Respiratory organs are skin, gills and lungs.
- They are oviparous and fertilization is external.

- Extant (living) amphibians belong to three orders.
- Order Urodela or Caudata
- Order Gymnophiona or Apoda
- Order Anura

Order Urodela or Caudata

- Members of this order are the salamanders.
- They possess a tail throughout their lifetime. Hence, they are called the tailed amphibians.
- Limbs, when present, are relatively unspecialized.

Order Gymnophiona or Apoda

- Members of this order are the caecilians.
- They have no limbs or limb girdles.
- They look like large earthworms and are adapted to a burrowing life.
- Skin covers their eyes.

Order Anura

- Members of this order are the frogs and toads.
- Their vertebral column is short and there is no tail in the adult.
- The fore limbs are stout and the long, webbed hind limbs are used for jumping and swimming.
- Eyes are large and high on the head.

CLASS REPTILIA

- The earliest members of this class were the first to vertebrates to possess **amniotic eggs**.
- Amniotic eggs have extra-embryonic membranes that protect the embryo from desiccation, cushion the embryo, promote gas transfer, and store waste materials.

(Note the functions of amniotic eggs in reptiles/tetrapods)

General Characteristics of the Class Reptilia

- They are poikilothermic animals.
- Body is differentiated into head, trunk and tail.
- Skin is dry, rough, non-glandular and usually with scales.
- Lungs are the respiratory organ.
- Heart is **incompletely** four-chambered (2 auricles and 1 ventricle that is partially divided by a septum). **Only in crocodiles is the ventricular septum complete, i.e. only crocodiles have a four-chambered heart among reptiles**.
- Two pairs of pentadactyl limbs with clawed digits are present.
- Limbs are reduced in snakes and some lizards.

- Reptiles can be grouped into **three subclasses based on the presence or number of apertures (opening) in their temple regions behind the eyes**.
- 1. **Anapsida**: These are reptiles characterised by a skull that lack apertures in the temple region behind the eyes. The only extant (living) representatives of this subclass are the turtles.
- 2. **Diapsida**: These are the reptiles whose skull have two openings behind the eyes, e.g. crocodiles, lizards, snakes
- 3. **Synapsida**: These are reptile with one dorsal opening behind the eyes. Members of this group are extinct.

Class Reptilia (Cont'd)

- The Class Reptilia is currently comprised of three major orders.

1. Order Testudines or Chelonia (e.g. turtles, terrapins, tortoises)

- Teeth absent in adults and replaced by a horny beak.
- Short, broad body.
- Shell consists of a dorsal carapace and a ventral plastron.

2. Order Squamata (lizards, snakes)

- The largest order (95% of all living reptiles).
- Recongnised by the specific characteristics of the skull and jaws.

3. Order Crocodilia (crocodiles, alligators)

- Elongate, muscular and laterally compressed body.
- Tongue not protrusible.

CLASS AVES

Major Characteristics

- They have appendages (forelimbs) which are modified as wings.
- Presence of feathers
- They are endothermic and homoiothermic (regulate their body temperature internally)- they share this characteristic with the mammals.
- Heart is four-chambered (2 auricles and 2 ventricles). **(NOTE: The complete division of the ventricles was first seen in the Class Aves).**
- They have a high metabolic rate.
- A vertebral column modified for flight.
- Bones lightened by numerous air spaces.
- They have a horny bill but lack teeth.

NB: These characteristics are all adaptations for flight.

CLASS AVES (CONT'D)

- The Class Aves can be divided into about 27 orders which can also belong to any of the following two groups based on the presence or absence of keel (i.e. a ridge for attachment of flight muscle) around their sternum.

1. Carinates: These are birds that have a deep ridge (keel) for attachment of flight muscles. Hence, they are flying birds, e.g. hawks, eagles.

2. Ratites: These are birds with no keel on their sternum. Hence, they are flightless birds, e.g. ostrich, emu.

CLASS MAMMALIA

Members of this class possess the following distinguishing characteristics:

1. Presence of mammary glands.
2. Hair
3. Diaphragm separates the thorax and the abdomen
4. Three middle-ear ossicles
5. Dentition is **thecodont** (i.e embedded in sockets in the jaws) and **heterodont** (differentiated into incissors, canines, premolars and molars).
6. Respiratory organ is lung
7. Sweat
8. Sebaceous and scent glands.
9. A completely four-chambered heart
10. Large cerebral cortex.
11. External ear (pinna) is present

CLASS MAMMALIA

The Class Mammalia is comprised of two subclasses, one of which is now considered extinct.

1. Subclass Prototheria (extinct)

2. Subclass Theria (extant): This subclass can be further divided into three infraclasses.

- **Infraclass Ornithodelphia-** these are the monotremes (egg-laying mammals).
- **Infraclass Metatheria-** they are viviparous but young ones are born early and often carried in a marsupial pouch on the female's belly. Hence, they are called the marsupials.
- **Infraclass Eutheria**: They are also viviparous but young ones develop to advanced stage before birth. They have complex placenta. Members of this group are also called the placentals.

CLASS MAMMALIA (CONT'D)

- The Infraclass Eutheria is the most diverse comprising about 12 orders some of which are listed below:
- Order Insectivora, e.g. hedgehogs, moles, shrews (third largest mammalian order)
- Order Chiroptera, e.g. bats (second largest mammalian order)
- Order Primates, e.g. monkeys, great apes (apes and humans)
- Order Cetacea, e.g. toothed whales, toothless whales
- Order Carnivora, e.g. dogs, cats, sea lions, seals, otters
- Order Artiodactyla, e.g. pigs, hippopotamuses, deer, giraffes, sheep, camels

INTRODUCTORY ZOOLOGY I

ZOO 101

Pyhlum Arthropoda I – Crustacea (Aquatic Mandibulates)

Phylum Arthropoda

Arthropoda is formed from Greek words ***arthron*** meaning joint and ***podos*** meaning foot

Arthropods probably evolved from annelids, and with their jointed appendages and an exoskeleton. They have successfully invaded practically every habitat on earth.

Arthropods are the most diverse of all the animal phyla, with more species than all other animal phyla combined, most of them insects.

There are over one million described species.

The major Subphyla of living arthropods are;
Crustacea (crabs, lobsters, shrimps, barnacles, woodlice, etc.)
Myriapoda (millipedes, centipedes, etc.)
Trilobitomorpha (all fossil forms with body divided into three lobes).
Cheliceriformes (spiders, scorpions, mites, sea sppiders)
Hexapoda: Made up of Class Entognatha and Insecta.

Phylum Arthropoda

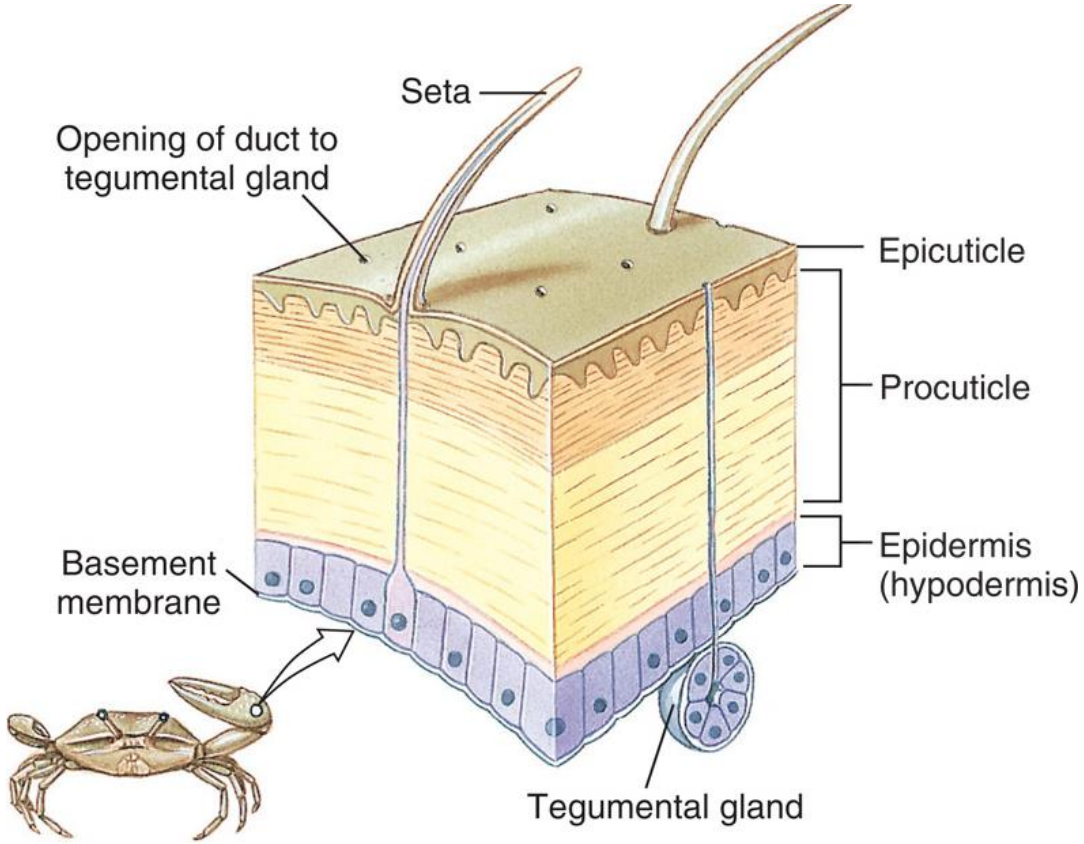
Distinguishing Features:

- Segmented body.
- Paired segmented appendages.
- Bilateral symmetry.
- Chitinous exoskeleton.
- Tubular alimentary canal with mouth and anus.
- Open circulatory system, a tubular dorsal blood vessel.
- Body cavity or coelom.
- Nervous system of anterior ganglia and paired nerve cords.
- Striated muscles in skeletal system.
- Respiration by gills, tracheae, or spiracle.

FEATURES OF THE SUBPHYLA

SUBPHYLA	MAIN BODY REGIONS	PAIRS OF LEGS	PAIRS OF ANTENNAE	WINGS
CRUSTACEA	two – cephalothorax and abdomen (some with head and trunk)	five or more	two	absent
MYRIAPODA	two - head and trunk	many - one or two per trunk segment	one	absent
ARACHNIDA	two - cephalothorax and abdomen	four	none (though palps may resemble antennae or legs)	absent
INSECTA	three - head, thorax and abdomen	three	one	usually present (but many wingless forms)

Arthropod’s body is usually covered in jointed exoskeleton called cuticle which is secreted by a single-layered epidermis. It has a thin impermeable outer epicuticle layer and a relatively thick, tough but permeable inner procuticle layer .



Cuticle and Epidermis of a typical Arthropod

Arthropods are similar to annelids in:

- Body metamerism
- Embryonic development
- Architecture of the nervous system

Arthropods differ from annelids in:

- Having rigid exoskeleton with chitin
- Absence of cilia
- General lack of intersegmental septa
- Reduction of true coelom
- Separation of the sexes
- Concentration of excretory organs and gonads
- Possession of compound eyes

Subphylum Crustacea

- Two main body regions.
- Two pairs of antennae.
- Simple eyes.

Crayfish

Subphylum Crustacea

- Formed from the Latin word *crusta* meaning hard shell.
- They are defined as mandibulate aquatic arthropods.
- There are up to sixty body segments in lower Crustacea while higher crustacea have a total of twenty body segments. The 2^{nd} and 3^{rd} segments bears antenna (two pairs) which is a unique feature of Crustacea among other arthropods.
- Body is divided into two distinct regions; cephalothorax (which is a fusion of the head (cephalon) and thorax) and abdomen.
- Possesses 1 pair of mandibles and 2 pairs maxillae.
- The appendages are biramous.
- Possess cephalic shield or carapace which may grow beyond the head to form rostrum.

Subphylum Crustacea – Adaptations

- Feeding mechanism vary from microphagous to trapping of particles by fine setae on some appendages as well as predatory feeding in some larger crustaceans such as isopods, decapods and amphipods.
- Gaseous exchange is achieved with the use of gills which are usually associated with the thoracic or abdominal appendages.
- The vascular system is an open system in which there are no blood vessels, hence the blood is not separated from the interstitial fluid. The system has a muscular heart which is enclosed in a pericardium membrane.
- The main excretory organ of adults crustaceans are paired tubular structures in the ventral part of the head. The organ is made up of an end sac which consists of small vesicles, saccule and a spongy mass, labyrinth.

Subphylum Crustacea – Classes

- The subphylum is divided into five classes
- Remipedia
- Cephalocarida
- Branchiopoda
- Maxillopoda
- Malacostraca

Class Remipedia

- Formed from Latin word *remipedes* meaning oar-footed.
- A very small class in terms of diversity, made up of about twelve species described so far.
- Body divided into two regions head and trunk (thorax and abdomen). The trunk is made up of 25-38 segments each bearing paired, biramous, paddle-like appendages.
- Carapace is absent but the head is covered with a cephalic shield.
- There is only one living order – Nectiopoda
- Examples are *Speleonectes* and *Lasionectes*

Class Cephalocarida

- Formed from Greek words *kephale* meaning head and *karis* meaning shrimp
- Inhabiting marine waters.
- Tiny, elongate crustaceans about 2-4 mm in length.
- Detritus feeders
- Body divided into head and trunk (eight thoracic segments and eleven abdominal segments).
- They are true hermaphrodites discharging both eggs and sperm through a common duct which opens on the 9^{th} segment.
- Example: *Hatchinsoniella*

Class Branchiopoda

- Formed from Greek words *branchie* meaning gills and *podos* meaning foot.
- Among the most primitive crustaceans.
- Possess Phyllopodia – flattened and leaflike appendages which are the main respiratory organs and also used in suspension feeding and for locomotion.
- Presence of cephalic, shield-like carapace and sessile compound eyes.
- Mostly found in freshwater and often short-lived.
- Divided into three Orders;
    - Anostraca commonly called fairy shrimps.
    - Notostraca
    - Diplostaca

Class Maxillopoda

- Possess 5 cephalic, 6 thoracic and 4 abdominal segments. Thorax segments are fused with the head in some groups.
- Presence of carapace as well as simple and compound eyes with unique structure known as maxillopodan eyes.
- Divided into seven subclasses;

  -Thecostraca (barnacles)

  - Tantulocarida (deep water marine parasites)

  - Branchiura (fish lice)

  - Pentastomida (toungueworms)

  - Mystacocarida (mystacocarids)

  - Copepoda (copepods)

  - Ostracoda (ostracods)

Class Malacostraca

- Largest class of crustaceans including lobsters, crabs, shrimps, beach hoppers etc.
- Body consists of 20 segments; 6 head segments, 8 thoracic segment (about 3 of these may become associated with the head) and 6 abdominal segments except the order Leptostraca which has 7 abdominal segments.
- Possess 19 pairs of appendages; 5 pairs in the head region, 8 pairs in the thorax and 6 pairs in the abdomen.
- Paired, sessile and stalked compound eyes.
- Antennary and maxillary glands as excretory organs.
- Divided into two subclasses;
    - Phyllocarida
    - Eumalacostraca

INTRODUCTORY ZOOLOGY I

ZOO 101

Pyhlum Arthropoda II – Cheliceriformes and Myriapoda

Subphylum Cheliceriformes

The body is made up of two regions; Cephalothorax or prosoma and abdomen or opisthosoma.

Prosoma bears 6 pairs of appendages that include chelicerae, pedipalps and 4 pairs of walking legs.

No antennae

Presence of an additional appendage known as ovigers in male pycnogonids. This is found between the pedipalps and the first walking legs. Ovigers bears the developing eggs.

Opisthosoma has 12 segments and bears terminal postsegmental telson.

Opisthosoma is sometimes subdivided into two regions; mesosoma and metasoma.

Subphylum Cheliceriformes

Large and diverse group of arthropods

Comprise of two distinct classes;

Class Pycnogonids – sea spiders

Class Chelicerata – spiders, scorpions, pseudoscorpions, mites and ticks,

horseshoe crabs and extinct giant water scorpions.

Class Chelicerata

- Terrestrial, mostly free-living and predacious.
- Small sized
- Presence of poison glands and poison jaws for killing prey, including small insects and small animals.
- Spiders possess special silk secreting glands.
- Silk is used to build nests, shelters and egg cases.
- Mites and ticks can occur in large numbers as pests. causing diseases in humans and in agricultural and domestic animals.
- Some of the predaceous group help in the biological control of pest populations.
- Appendages absent in opisthosoma but persist as large platelike limbs called gill books in horseshoe crabs.
- Gill books function in locomotion and gas exchange.
- Further differ from other arthropods in the absence of compound eyes and true jaws.

Class Chelicerata

- Divided into two subclasses; Merostomata and Arachnida
- Subclass Merostomata is made up of;
  - Order Eurypterida – are now all extinct
  - Order Xiphosura – horseshoe crabs, an example is *Limulus polyphenus*

  - Subclass Arachnida is divided into 11 order. Some of these are;
    - Araneae – spiders
    - Scorpiones – scorpions
    - Pseudoscorpiones – pseudoscorpions
    - Acari – mites and ticks
    - Ricinulei – ricinuleides
    - Uropygi – uropygians

Subphylum Myriapoda

- Body divided into two regions; cephalon (head) and an elongated, homonomous (similar structure), many segmented trunk, not differentiated into a thorax and abdomen.
- Presence of 4 pairs of cephalic (head) appendages; antennae, mandibles, 1st maxillae and 2nd maxillae.
- Additional structures on the head; clypeus, platelike labrum, tongue-like hypopharynx.
- Many posses repugnatorial glands on trunk segments.
- Lack compound eyes.

Subphylum Myriapoda

- Divided into four classes; Chilopoda, Diplopoda, Pauropoda and Symphyla

- **Class Chilopoda (Centipedes)**

  - dorsoventrally flattened bodies
  - trunk with almost 200 segments
  - one pair of walking legs per segment
  - most species are harmless to humans, although many tropical species are dangerous.
  - highly sensitive antennae which are richly supplied with tactile and tactile and chemosensory setae.
  - the first trunk appendages are modified into prey-catching prehensile claws called prehensors or forcipules used to stab prey and inject poison.

Subphylum Myriapoda

- **Class Diplopoda (Millipedes)**
  - inhabits soil, beneath leaves, stones, barks and decaying logs
  - cylindrical body with 25 to 100 segments
  - Body divided into head, thorax (with four segments) and trunk.
  - Head bears seven-jointed antennae, mandibles and 1st maxillae which are fused to form flaplike gnathochilarum.
  - Divided into two subclasses; Penicillata and Chilognatha
  - Subclass Penicillata contains a single order Polycenida eg. *Polyxenus*
  - Subclass Chilognatha contains 14 orders some of which are;
  - Glomerida, Sphaerothoriida, Platydesmida, Spirobolida and Spirostreptida

Subphylum Myriapoda

- **Class Pauropoda (Millipedes)** named from Greek words *pauros* meaning small and *podos* meaning foot.
  - minute, whitish and soft bodied.
  - inhabits moist soil, leaf litter or decaying vegetation.
  - lack eyes but posses pair of sense organs that resemble eyes.
  - presence of nine pairs of six-jointed ambulatory legs on the trunk segment.
  - example *Pauropus sylvaticus*

Subphylum Myriapoda

- **Class Symphyla** name is formed from the Greek words *sym* meaning together and *phylon* meaning tribe.
  - small sized (about 2 – 10 mm long)
  - Long, unbranched antennae
  - 14 body segments, 12 of which have ambulatory legs.
  - 13th segment bears a pair of spinnerets and a pair of long sensory hairs
  - Primarily herbivorous with many occurring as pest that consume live plants.

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ZOO 101

Pyhlum Arthropoda III – Hexapoda

SubPhylum Hexapoda

- These are arthropods with 3 pairs of legs hence the name hexapoda.
- Comprises mainly insects and their kins.
- Divided into two classes; Entognatha and Insecta
- Body is always divided into head, thorax and abdomen comprising five, three and eleven or fewer segments respectively.
- Head bears eyes (compound eyes & 3 simples eyes-ocelli), a pair of uniramous, multiarticulate antennae, mouthparts (mandibles, maxillae & labium).
- Antenna has 3 regions; scape, pedicel and flagellum.
- Mouth is bordered anteriorly by labrum, posteriorly by labium and on the sides by mandibles and maxillae. In the middle is a an unpaired tongue-like hypopharynx.
- Mouthpart are adapted for different feeding habits such as;
  - Piercing and sucking
  - Sucking and lapping
  - Long siphoning
  - Sponging
  - Biting and chewing

Insect Success

Insects have one of the widest distributions on the globe. Insects are found almost everywhere on the planet earth.

Insect species live in deserts. Other species are found in hot springs, where temperatures reach 180°F, others are found on mountains at an elevation of 18,000 feet.

Insects are very abundant in tropical rain forests, and still other species are found in the arctic, where temperatures drop to -40°F.

Because of their great diversity, insects provide an understanding of the adaptability of animal systems and biological mechanisms that survive the physical and biological challenges necessary to exist in these environments.

Factors responsible for the success of insects

Reproductive capacity: Most insects produce huge numbers of offspring and many species produce several generations each year. This large reproductive capacity is related to insects adaptability to a wide range of environmental factors.

Small size: Insects easily can hide from predators by using microhabitats and because of the use of microhabitats, more habitats are available for use by insects compared to larger animals.

Water loss reduction: Insects have several mechanisms to reduce water loss. One structural mechanism is the waxy coating over the exoskeleton of insects. In addition, most insects do not excrete liquid water; they reabsorb water from their waste products.

Factors responsible for the success of insects

Special Appendages: Insects have different types of appendages (for example, legs, wings, and mouthparts). Insect species possess various forms of mouthparts that are used to feed on a wide variety of substances.

Wings: Insects are the only invertebrate animals which have wings and these structures have been advantageous for insect survival.

Development: Many insect species are found in one type of habitat in the immature stages and another habitat in the adult stage. For example, a caterpillar feeds on plant matter while an adult butterfly feeds on nectar.

Factors responsible for the success of insects

Factor	Effect
CUTICLE (EXTERNAL EXOSKELETON)	**Tough and waterproof, the cuticle helps to protect insects from predators and also from dehydration**
FAST REPRODUCTION	**Insects evolve at a high rate and adapt quickly to changing environmental conditions.**
FLIGHT	**This allows insects to escape from enemies, to find new habitats and food sources rapidly, and to establish new colonies.**
WING FOLDING & PROTECTION	**Insects able to fold their wings back along their bodies & protect it under hard covering known as elytra, wings folding allowed them to use a far greater range of microhabitats, such as cracks and crevices in dead wood, inside leaf litter, or under stones. It also meant that they could hide from predators through decreased surface area.**
INSULATED CENTRAL NERVOUS SYSTEM	**Insulation of the central nervous system allows nerves to work efficiently and also allows survival in hot or dry places.**

Factors responsible for the success of insects

Factor	Effect
SIZE	**Small size allows utilization of a wide range of microhabitats —a tree, for example, may support hundreds of insect species.**
SHORT LIFE CYCLE	**This allows many generations within a given time for selection and evolution to take place.**
VARIATION IN THE LIFE STYLE OF DIFFERENT STAGES	**Variation in the life style of different stages in an insect's life (e.g. caterpillar versus butterfly) reduces competition for resources within the species.**
SENSORY SOPHISTICATION	**The sensory capabilities of insects surpasses most other organisms.**
EVOLUTIONARY INTERACTIONS	**Evolutionary interactions with other organisms - coevolution leads to greater specialization and speciation.**
ADAPTATION OF APPENDAGES	**Appendages such as mouthparts, wings and legs have often become highly specialized.**

Insect Classification

- Insects are classified in 2 subclasses and over 30 orders by morphology (wings and mouthparts) and development.

Subclass: Apterygota, primitive wingless insects

Subclass: Pterygota, winged insects

Subclass: Pterygota

1. Division: Exoterygota, wings develop on the outside, synonymous with hemimetabolism, immatures look similar to adults.

2. Division: Endoterygota, wings develop on the inside, synonymous with holometabolism, immatures look different from adults.

Apterygote

ORDER	CHARACTERISTICS	EXAMPLES
Collembola	They are small wingless insects. They are soft-bodied and primitive. They are sometimes referred to as springtails because of the possession of a furcula used for jumping.	Snow-fleas, *Folsomia* spp, Symphpleona
Protura	They are tiny wingless insects. They have cone-shaped heads without antennae and feed mainly on decayed organic matter	Telson tails, Eosentomon
Diplura	They are small insects usually active at nights. Their bodies are usually white, they possess long antennae and wingless.	Japygids
Thysanura	Small insects with compound eyes, very long thread-like antenna. Body often covered in scales	Silverfish, firebrats, common bristletails.
Mallophaga	Minute, wingless insects, mouthparts modified for chewing. They are usually parasitic on birds and mammals.	Biting lice
Siphonaptera	They have powerful hind legs which enable them to jump from host to host. They are wingless parasites of birds and mammals	fleas

Exopterygote

ORDER	CHARACTERISTICS	EXAMPLES
Ephemeroptera	They are soft-bodied insects, possess very short antenna, wings are membranous with many veins. Many species die few hours after reaching adulthood.	Mayflies
Plecoptera	They are ancient group of insects whose early stages occur in water. Adult wings are usually transparent and delicate. They possess long antenna.	Stoneflies, forestflies, willowflies, stallflies, roachflies
Odonata	They usually possess short antennae, very keen vision, brightly coloured four large wings	Dragon flies, damsel flies
Orthoptera	They produce sounds using their wings or legs. They are high jumping insects.	Grasshoppers, locusts, crickets.
Hemiptera	Small insects with sucking mouth parts. They are also parasitic in nature	Bedbugs, aphids, cicadas
Phasmida	They usually resemble sticks or leaves. They are usually found in dense shrubs in tropical regions	Walkingsticks, leaf-insects
Dictyoptera	They are characterized with long antennae, fan-like wings, they usually have triangular-shaped heads.	Cockroaches, mantids

Exopterygote

Isoptera	They are social and nest building insects. They are usually white or colourless. They possess strong mouth parts	Termites
Thysanoptera	They are very small insects, they possess fringe of hairs at the border of their wings. They are usually active during thunderstorms	Thrips
Dermaptera	Characterized by large, delicate wings and pincers are the end of their abdomen	Earwigs

Endopterygote

Diptera	They are known as true flies, they can fly backwards, sideways, forward. They possess a pair of wings and halteres which helps them balance	Mosquitoes, houseflies, blowflies, fruitflies, black flies
Anoplura	They are tiny and similar to biting lice but their mouthparts are adapted for sucking.	Sucking lice
Neuroptera	They are small to large soft-bodied insects with two pairs of membranous wings covered with a delicate network of veins. Antennae are usually thread-like	Ant-lion, alder flies, snake flies, lacewings
Trichoptera	Adults resemble dull moths, they are four-winged and their wings are covered with hairs. They usually live near water.	Caddisflies
Coleoptera	They have hard bodies. They are the largest order of insects. They have a pair of wings which are usually protected by a hard covering called elytra	Beetles, weevils, fireflies
Hymenoptera	They are small to medium sized insects, possess four membranous wings, and have narrow waists which shows a clear separation of abdomen from the thorax. Some species are social in behaviour	Honeybees, wasps, ants
Lepidoptera	They possess two pairs of wings having numerous scales of varying colours, they have large compound eyes with mouth modified for sucking plant nectar	Butterflies, moths