

University of Salhi Ahmed .Naâma .

Faculty of Science

Department of Natural and Life Sciences



جامعة النعامة
University of Naama

Course Handout

Zoology

L2 / S3

Intended for students L2 SNV :

Directed by

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Academic year: 2025-2026

Subject Description

<i>Subject Order Number</i>	<i>Code : UEF 2.1.1</i>
<i>Subject Title</i>	<i>Zoology</i>
<i>Subject Type (Fundamental/Complementary)</i>	<i>Fundamentals</i>
<i>Subject Semester</i>	<i>Semester 3</i>
<i>Department</i>	<i>Natural and Life Sciences</i>
<i>University</i>	<i>Salhi Ahmed Naâma University Center</i>

Preamble

This subject covers various aspects of zoology, including morphology, development and reproduction, systematics, and the diversity of animal species.

The course is aimed at second-year students in the core curriculum of biology, agronomy, and ecology, with the aim of developing a general skill for their studies. It is recommended that students have already acquired basic knowledge of animal biology.

The purpose of the subject zoology is to study animal diversity in detail, namely the classification of different phyla, classes and orders, morphology, anatomy, behavior and their interactions with the environment.

SYLLABUS

Zoology

1. Subject Objectives

The purpose of the subject zoology is to study animal diversity in detail, namely the classification of different phyla, classes and orders, morphology, anatomy, behavior and their interactions with the environment.

2. Educational Prerequisites

- **Animal Biology (L1 .S2.)**

3. Hourly Volume

Teaching Unit	Subject	VHS	V.H weekly				Coeff	Crédits
	Title	14-16 weeks	C	DW	PW	Others		
Fundamental Unit Code: UEF 2.1.1 Credits: 6 Coefficients: 3	Subject Zoology	67.30	3h00	-	1.30	82.30	03	06

4. Evaluation mode

Continuous	40%
Exam	60%

5. Know-how and skills

This program aims to teach the scientific foundations of zoology: the biodiversity, structure, behavior, reproduction, development, origin, distribution, and relationships of animals with their environment. It draws on various disciplines such as morphology, anatomy, and genetics of animal species.

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General introduction

The animal world is characterized by its significant diversity compared to other living beings, remarkable adaptations in different environments, and essential roles in ecosystems. From species useful in the decomposition of organic matter to pollinating species, animal species play important roles in the food chain.

Vertebrates and invertebrates today constitute the major kingdom of all other kingdoms.

This diversity is the subject of zoology, which encompasses the different branches

1. Introduction of the animal kingdom

Definition of Zoology

Zoology is a science that studies the animal world

1.1. Basis of Classification

1. Prokaryotes: membrane, nucleus, and organelles are absent (bacteria).

2. Protists: presence of nuclear membrane and organelles.

3. Animal Kingdom: Multicellular organisms (Metazoa):

(from the Greek, meta = several, zoa = animal).

4. Plant kingdom: fixed species with a cell wall.

5. Fungi: chlorophyll absent, saprophagous.

How do you classify animals? Systematics is the science of classifying species according to morphological characteristics.

1.2. Zoological Nomenclature

Species Definition

Animal species are individuals with the same morphological characteristics and reproductively isolated.

Taxonomy: The science that describes and names each species using a two-part nomenclature (genus and species).

Hierarchical classification

Animal species are grouped into genera, families, orders, classes, phyla, and kingdoms.

Vernacular name

Vernacular name is common name in the local language,.

Hierarchical classification ;

kingdoms.

phyla

classes

orders

families

genera

species

1.3. Evolution and Phylogeny

1.3. Evolution and Phylogeny

Protozoa (kingdom Protista) are heterotrophs. The rest of the tree forms the animal kingdom, containing heterotrophic multicellular organisms.

The coelom (= cavity). Species that possess bilateral symmetry are grouped into three groups characterized by the presence of an internal cavity (filling tissue between the digestive tract and the body wall):

(Acoelomates) without a coelom

(Eucoelomates) a true coelom

Protostomes vs. Deuterostomes

The phylogenetic tree is based on the characteristics of embryonic development. Protostomes; the appearance of the mouth in the first stage. Deuterostomes in the second stage.

1.4. Numerical importance of the Animal Kingdom

Phylum	Number of Species
• Arthropods; insects	1,300,000
• Mollusks; snails	110,000
• Nematoda; worms	90,000
• Chordata; mammals	47,200
• Platyhelminthes; parasitic worms	15,000
• Annelids; earthworms	15,000
• Echinoderms	6,000

2. Subkingdom Protozoa



• 2.1. General Information on Protozoa

Introduction:

Protozoa are the first animals in the evolutionary series.

- They are microscopic heterotrophic and unicellular
- they including the organelles essential to any cell (mitochondria, Golgi, lysosomes, microtubules, etc.).

Protozoa feed either by phagocytosis or osmosis . division (binary division)is .Reproduction mode .

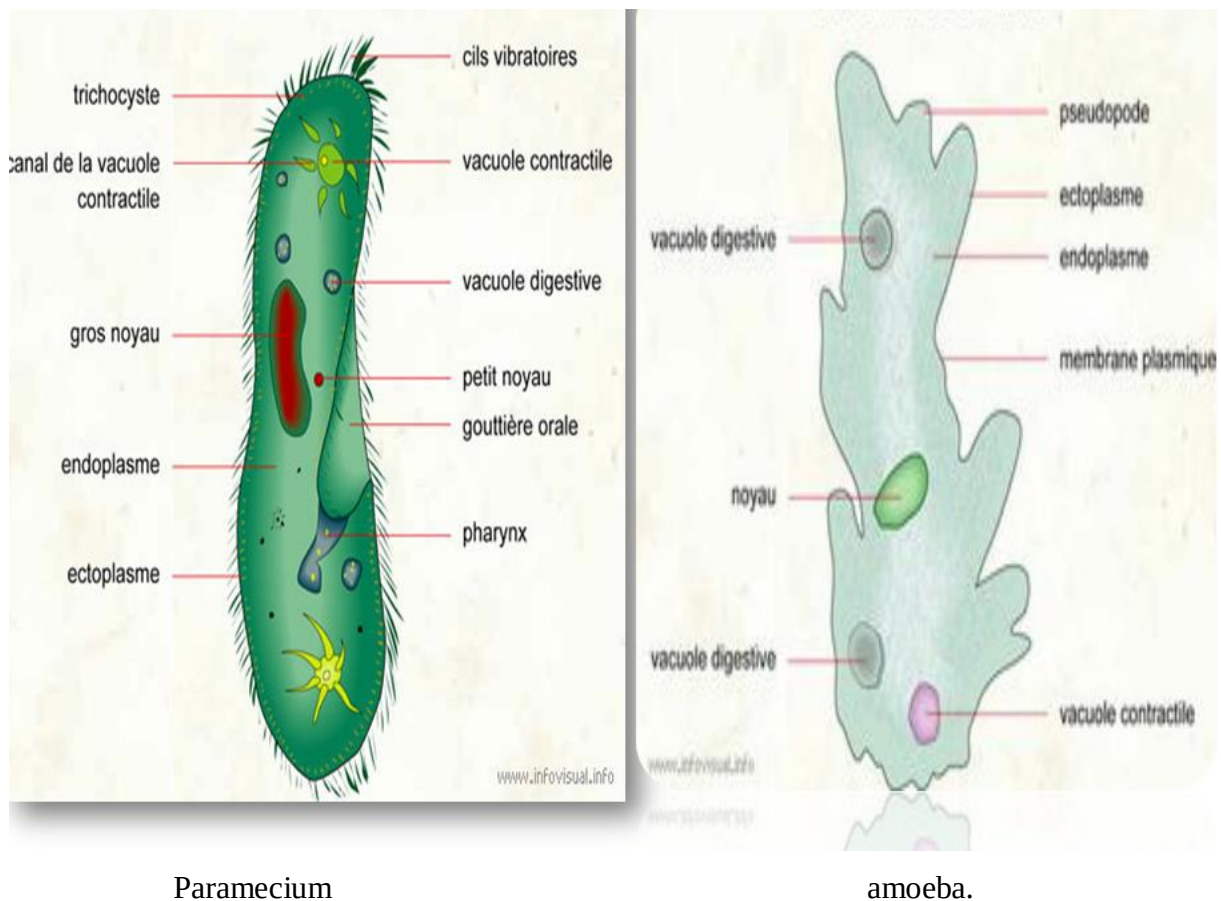


Figure 1: structure of two protozoa paramecium and amoeba

Distribution of Protozoa

They can be found:

- **In the free state:** They are decomposers and consume microbes.
- **Parasite; (Pathogens)** cause diseases such as leishmaniasis and malaria in humans.
- **Symbiont; Symbiosis:**

Locomotion in Protozoa

1. Rhizopoda.

Example: amoeba.

2. Cilia and 3. Flagella.

. Example of Cilia: Paramecium

Example of flagella: trypanosomes



Figure 2 : microscopic photos of three species of protozoa paramecium amoeba and trypanosomes

Digestion and Feeding

Protozoa feed in two ways:

Phagocytosis,

Pinocytosis,

2.2. Classification

2.2.1. Sarcomastigophora Phylum

Example: Trypanosomes; *Trypanosoma Gambiense*:

Trypanosomes are parasitic protists, flagellated protozoa. They are the cause of sleeping sickness in humans. They have a single, forward-facing flagellum that allows them to swim in the blood of their host.

-*Trypanosoma Gambiense* is transmitted to humans by the bite of the tsetse fly.

-The trypanosomes then multiply in the human intestine, then in the salivary glands. In humans, the parasite multiplies first in the lymph nodes and then in the blood plasma.

Diagram of a trypanosome

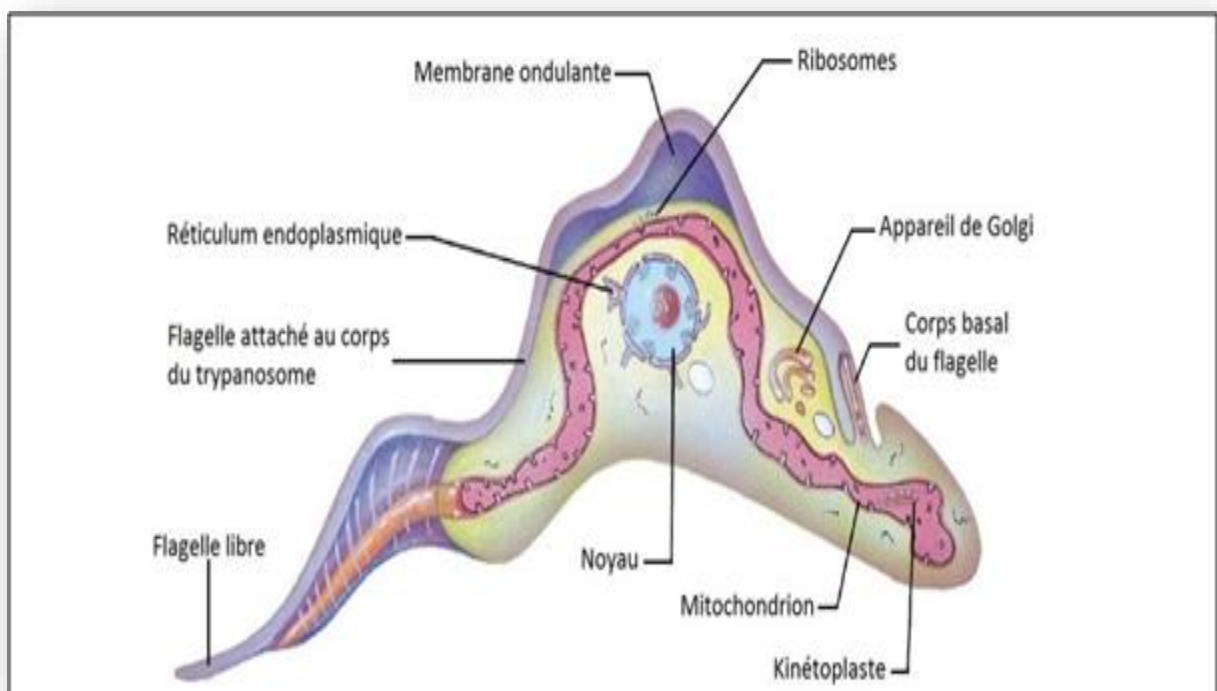


Figure 3 : structure of trypanosome

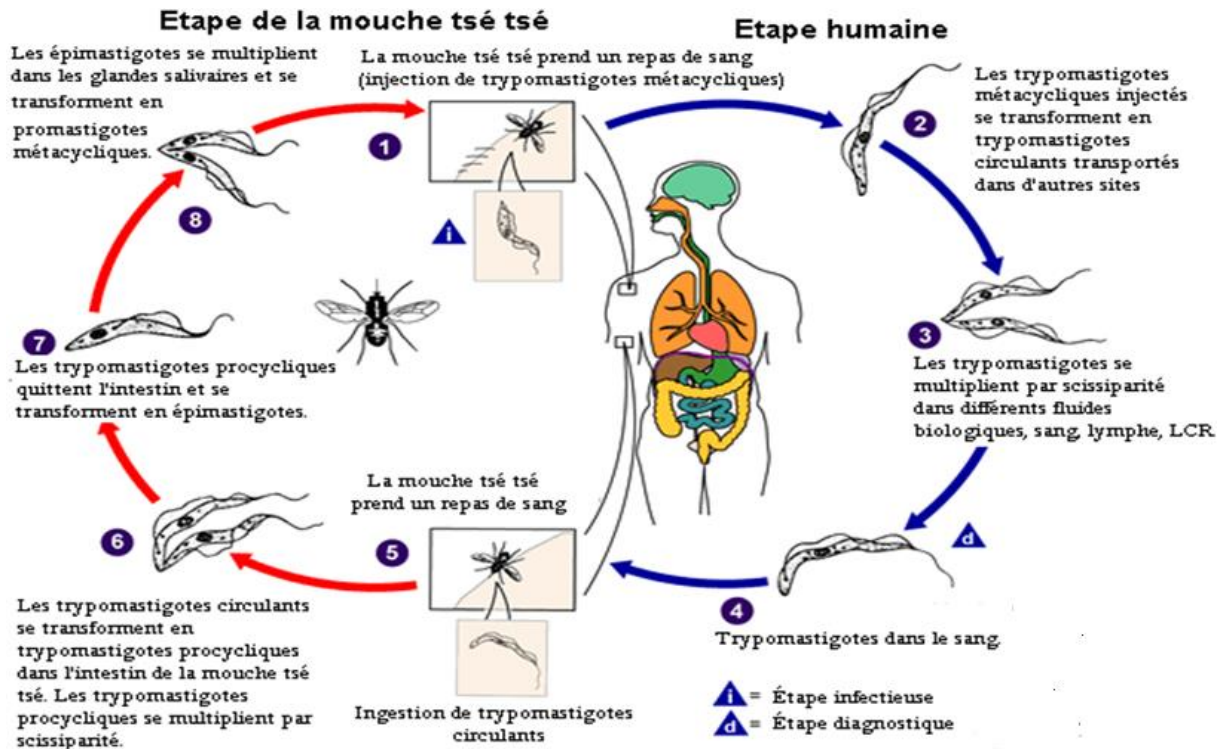


Figure4 : biological cycle of the *trypanosome* in the human body

Example 2. *Leishmania* sp.

These are small (2 to 6 μm in diameter) flagellated protozoan parasites transmitted by sandflies (dipterans).

Leishmania tropica, transmitted by *Phlebotomus*, causes skin ulcers.

Leishmania major is responsible for intestinal leishmaniasis.

2.2.2. Phylum Ciliophora

They are mostly free-living heterotrophs.

Ex: Paramecium caudatum

Paramecium is one of the first single-celled spece to be observed under a microscope. The cell size ranges from 100 to 400 µm in length.

.

2.2.3. Phylum Apicomplexa

Example: Plasmodium falsiparum (Plasmodium).

is a species of Plasmodium (parasitic protozoan) that causes malaria in humans. It is transmitted by the bite of a female Anopheles mosquito. The life cycle of Plasmodium is quite complex and requires 2 hosts:

- an intermediate host: the blood-sucking female mosquito of the genus Anopheles
- a definitive host: humans.

2.2.4. Phylum Cnidosporidia

Cnidosporidia are a subclass of sporozoa that have spores with polar layers and filaments. They are single-host parasites of vertebrates and invertebrates. Sporozoa include non-motile parasitic protozoa

3. Subkingdom Metazoa

3.1. Phylum Spongiaria



the basal phylum Metazoa are the Sponges (Porifera) , animals belonging to Aquatic organisms attached to the substrate, without organs or tissues, formed of cells grouped into two layers, with a skeleton made of calcareous or siliceous spicules.

Etymology: Porus (pore) ferare (to carry) (small holes).

General characteristics

- The external surfaces are pierced with pores, and at their apex, a large orifice opens: the osculum.
- Sponges feed by filtering water. Water enters through the inspiratory pores, is filtered, and then exits through the osculum.
- Sponges lack organs; digestion is carried out by choanocytes

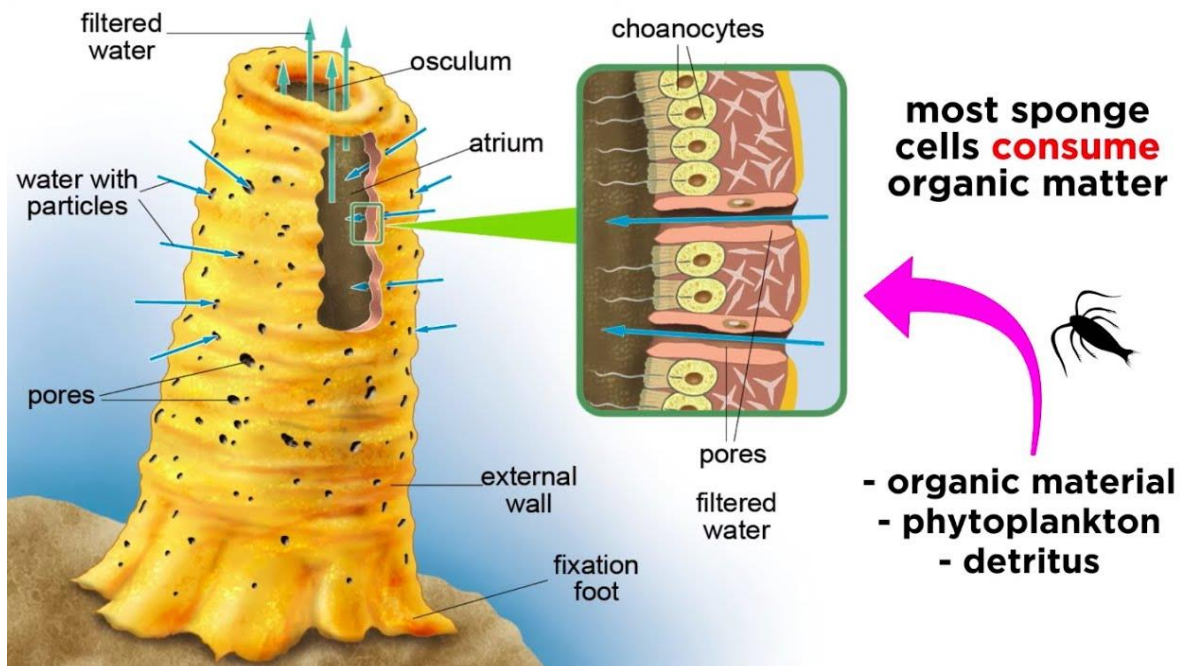


Figure 5: sponge structure

Classification

Sponges represent approximately 9,000 species divided into two groups:

Calcareous sponges: The skeleton of these sponges is composed exclusively of calcareous spicules

Siliceous sponges: The skeleton of these sponges is composed exclusively of siliceous spicules

Fundamental Functions

-Diet: The sponge eats particles, bacteria, algae, and microscopic animals living in the water: zooplankton & phytoplankton

-Reproduction

1. Sponges can be gonochoric (which involves two individuals) or hermaphroditic (which involves a single individual).
2. Sponges are capable of regenerating, even if crushed.

-Respiration:

Sponges rely on diffusion to obtain oxygen, facilitated by the movement of water created by the action of choanocytes.

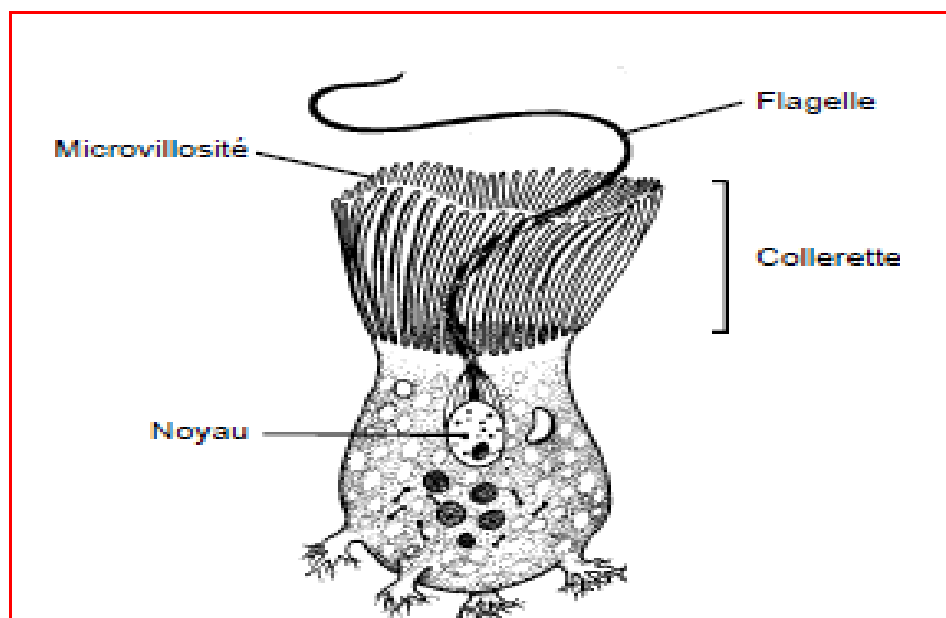


Figure 6. Choanocyte of a sponge.

Excretion and Osmoregulation

The large surface area to volume ratio of sponges allows them to rely solely on diffusion for the elimination of metabolic waste. Nitrogenous waste is eliminated in the form of ammonia. Most sponges live in marine environments and therefore do not have serious difficulties with osmoregulation. The few species that live in freshwater environments

Ecology: Role

Sponges generally inhabit coastal areas. Their abundance is limited by the availability of silica or calcium. Some sponges can decompose limestone rocks or shells. Sponges serve as shelters for multiple animals.

3.2. Phylum Cnidaria



Cnidaria is an animal phylum consisting of about 9000 species. They are diploblastic, almost all aquatic, radially symmetrical animals. Consequently, they have no right/left or dorsal/ventral sides. However, it is reported that some cnidarians at the beginning of their life cycle show some signs of bilaterality, which would support the bilaterality preceded the cnidarian–bilateralian divergence. Cnidarians evolved about 570 Ma, i.e., before the Cambrian explosion (Nelson R 2020).

Their body has two one-cell-thick layers of epithelial cells, the epiderm lining the outside of the body and gastroderm—the inside, developing, respectively, from embryonic layers ectoderm and gastroderm. Both layers contain epitheliomuscular cells. Between the two layers is a noncellular layer of mesoglea, a gelatinous substance consisting of collagen, which in many species contains muscle and nerve fibers and serves as hydrostatic skeleton. In vicinity of the muscle cells, cnidarians have neurons and, in many species, cnidocytes, stinging toxin-containing cell organelles that penetrate the prey tissues or catch it. The thin body walls allow cnidarians to transport nutritive substances throughout the body via diffusion

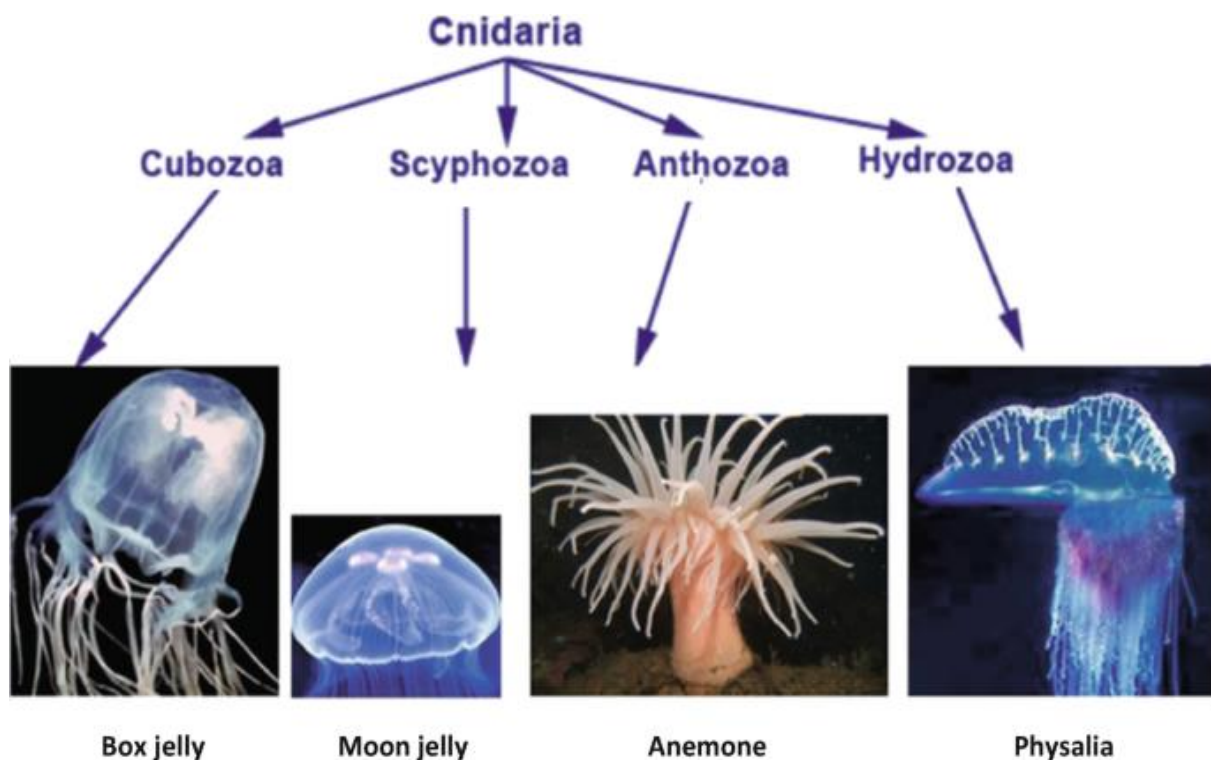


Figure7 : cnidaria classification

Architecture and Classification

Cnidarians have specialized cells: cnidocytes (or cnidoblasts). These animals exhibit radial symmetry, consisting of two layers (ectoderm and endoderm) separated by a mesenchyme, or mesohyl. However, unlike sponges, cnidarians possess true tissues.

The mouth of cnidarians is usually surrounded by tentacles that lead to the gastrovascular cavity. Most cnidarians have two stages: a medusa stage, usually planktonic, and a polyp stage, usually benthic and sessile. Jellyfish are free-swimming, umbrella-shaped species. The gastrovascular cavity is surrounded by the umbrella and tentacles. Reproduction is sexual in most cnidarians.

Classification of Cnidarians

Class Hydrozoa (from the Greek hydra = sea serpent)

Class Scyphozoa (from the Greek skyphos = cup)

Class Anthozoa (from the Greek anthos = flower)

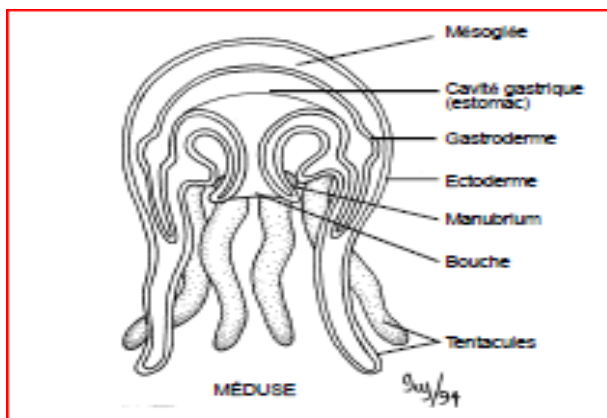


Figure 8 . Schéma d'une méduse. ©

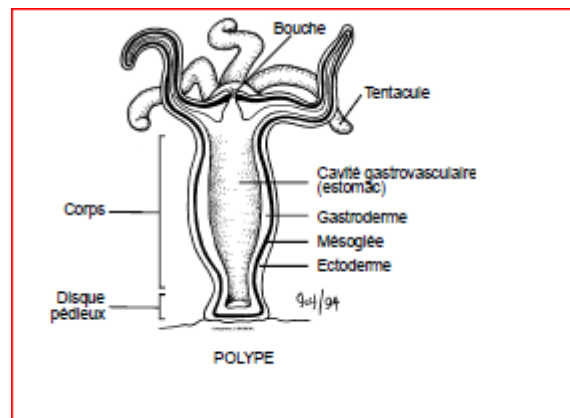


Figure 9. Schéma d'un polype

The three main classes of Cnidaria are distinguished, among other things, by the relative importance of the two life forms in the biological cycle

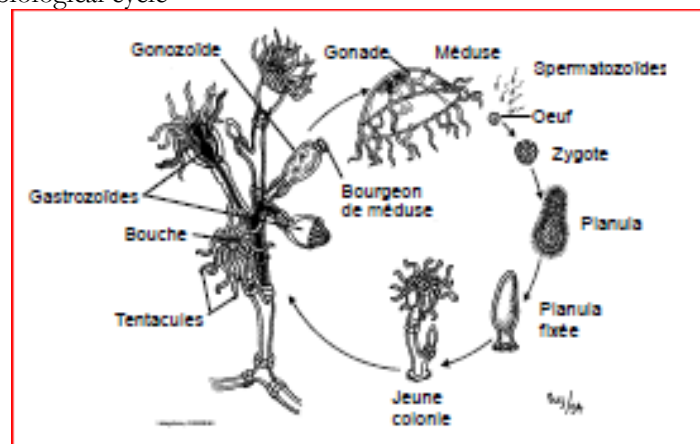


Figure 10. Life cycle of Obelia (Hydrozoan).

Fundamental Functions

The Cnidaria are diploblastic, aquatic animals with a simple body plan that is reminiscent of a bilaterian gastrula. The two body layers, an outer ectoderm and an inner endoderm, are separated by an acellular mesoglea, a composite connective tissue and basal lamina. The fossil record reveals that cnidarians are > 500-Myr-old and molecular phylogenies identified the Cnidaria as a sister group to the Bilateria (Thomas W.2011).

Diet: Cnidarians are carnivores and capture their prey using their tentacles and cnidocytes.

- Cnidocytes are used to attach, pierce, or poison the prey. Once captured, the prey is brought to the mouth using the tentacles.

Reproduction

Jellyfish multiply sexually by producing gametes that are released into the water. Polyps multiply by budding and regeneration.

Locomotion: Jellyfish are swimming species that use ocean currents. Some colonial cnidarians, such as corals, float around the substrate.

3.3. Phylum Ctenariae



Ctenophores are primitive marine species that are transparent and pelagic, diploblastic, acoelomate, and bilaterally symmetrical. The digestive gastric cavity, called the gastrovascular cavity, is internal and communicates with the outside world through a single orifice, serving as both a mouth and anus.

These species live in open water or near the surface and move primarily under the influence of ocean currents. However, they possess permanent locomotory organs, in the form of eight rows of paddles made up of cilia modified with the presence of specific cells, the colloblasts, and a balancing organ, the statocyst, located opposite the mouth.

Classification

Ctenophores are divided into three classes: Filictenida, Nudictenida, and Platyctenida.

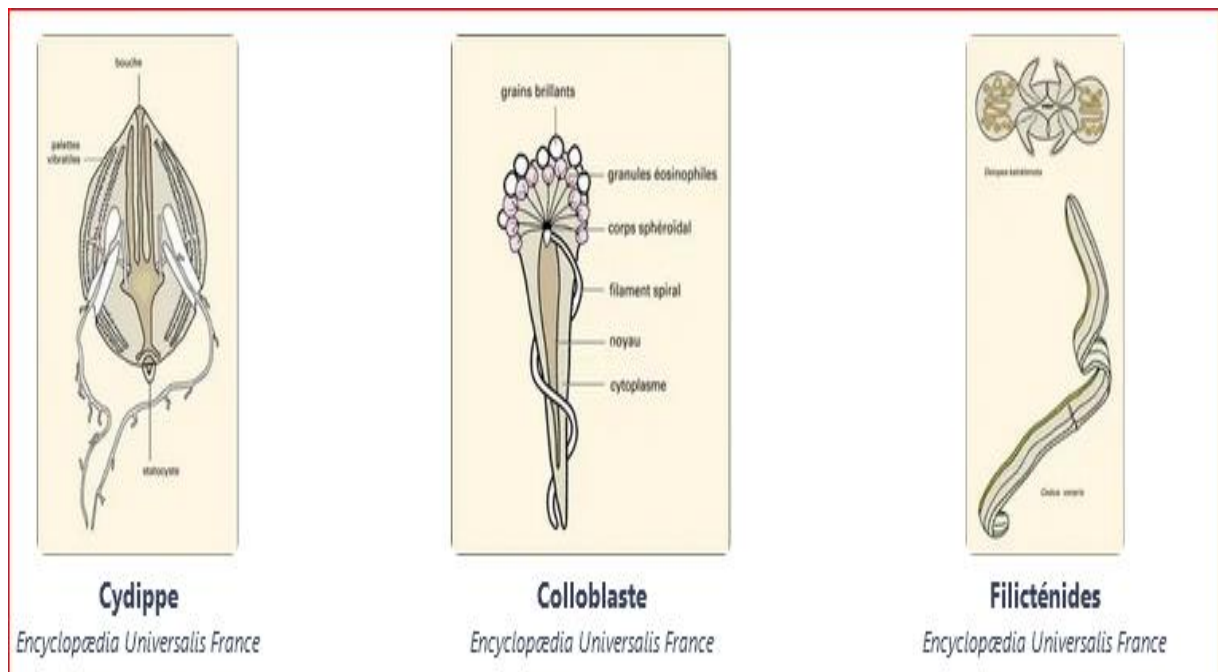
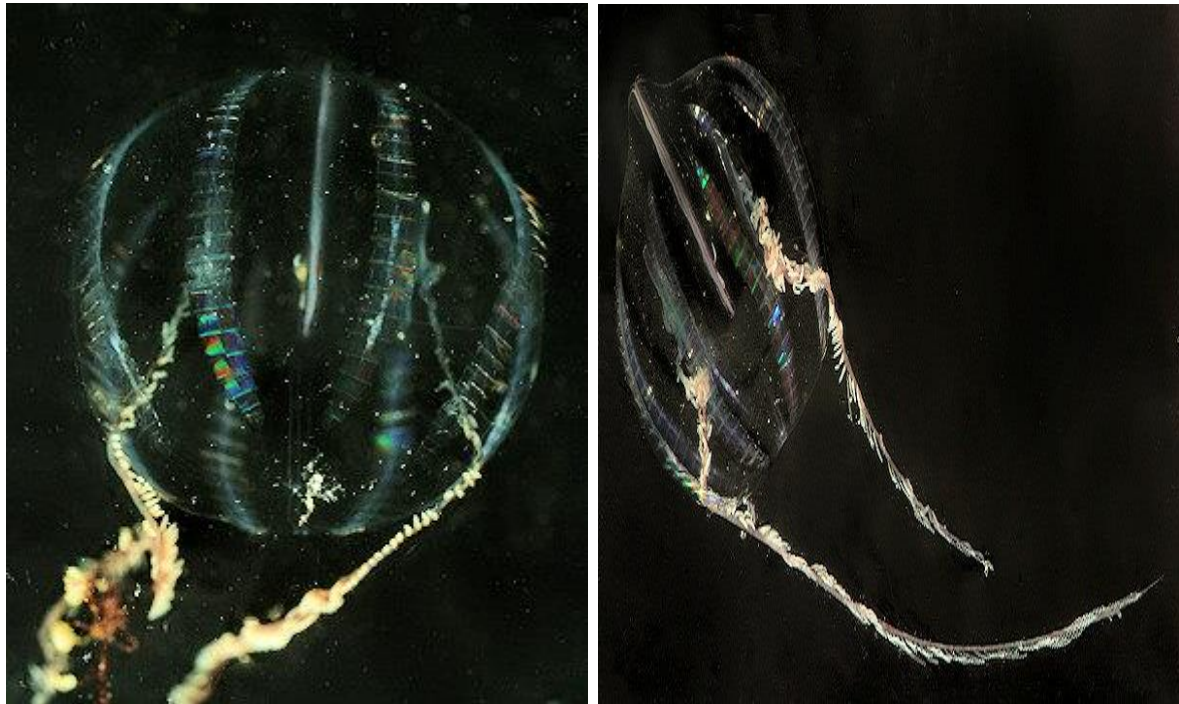


Figure 11; Ctenophores classification

two long retractable tentacles extend from the body when the animal hunts, above not visible because retracted



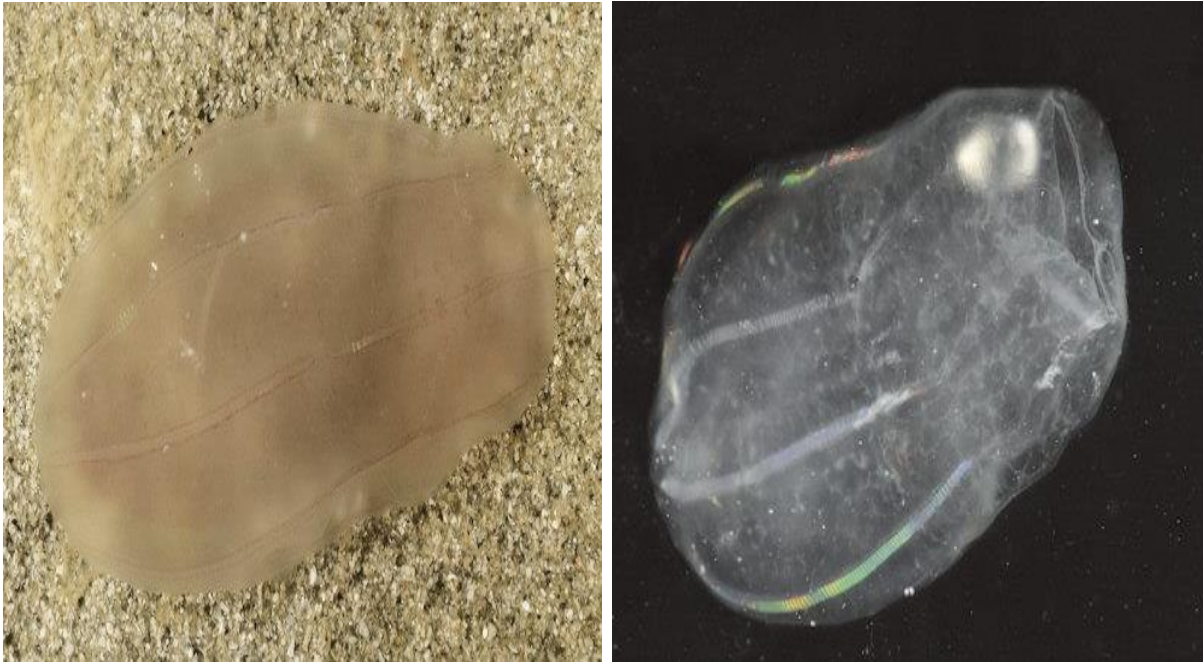
These tentacles have lateral branches that are spirally coiled when at rest, or deployed for fishing



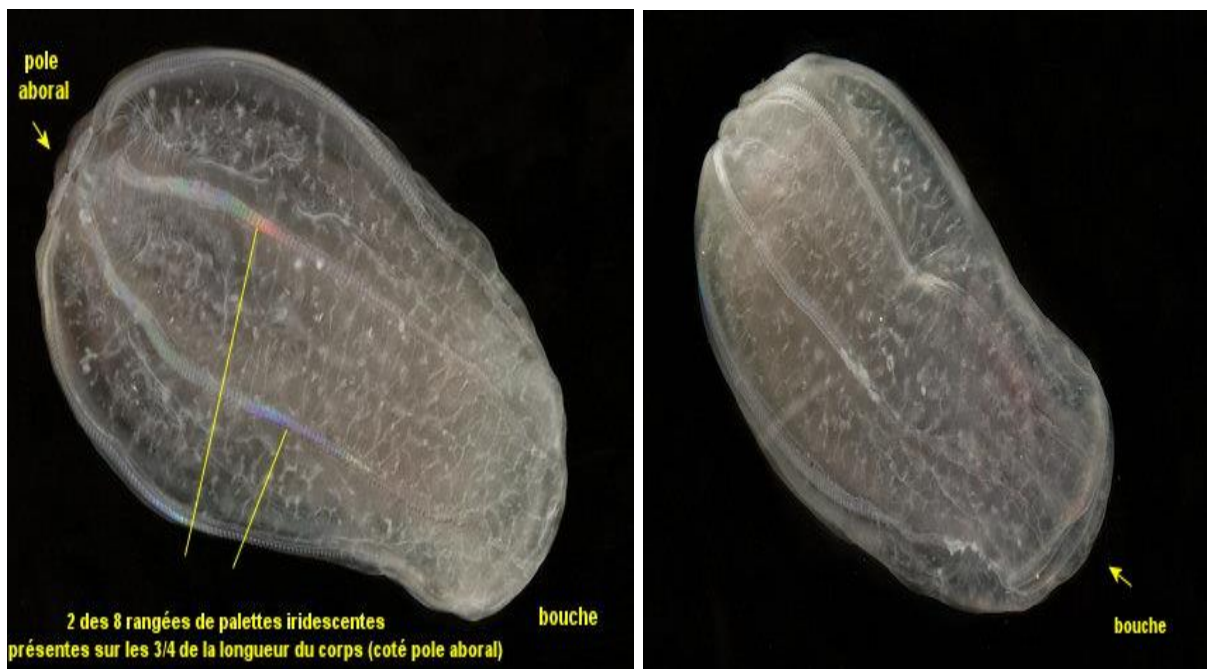
DORIS, *Pleurobrachia pileus* (O.F. Müller, 1776),

Beroidae

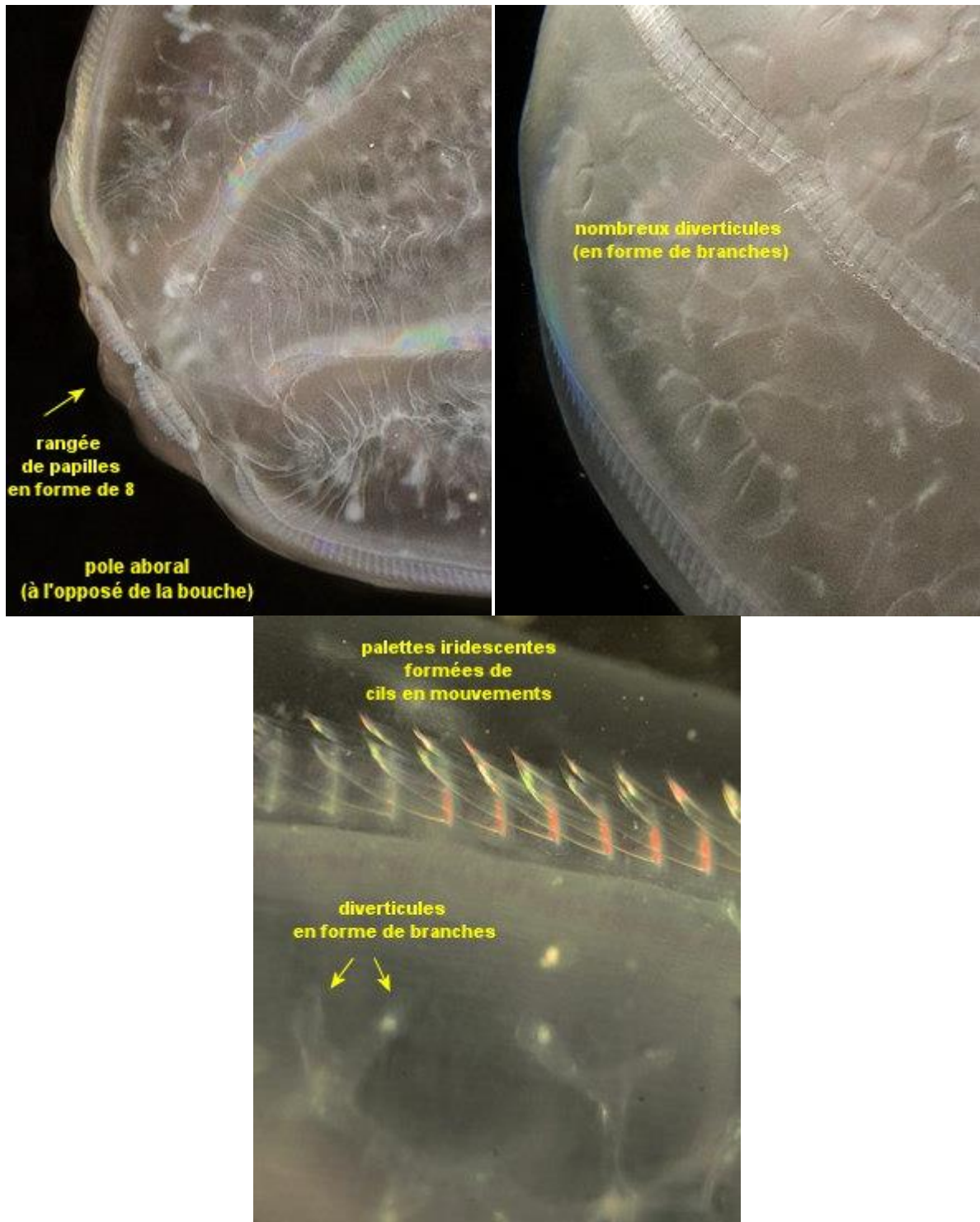
Beroe cucumis ici 5cm (mais peut atteindre jusqu'à 15 cm) corps transparent plus ou moins rose



corps gélatineux de forme ovale, avec 8 rangées de palettes constituées de cils qui diffractent la lumière



rangées de cils battant de façon synchronisée, ce qui permet le déplacement du cténaire



Beroë cucumis se différencie de *B. gracilis* par sa forme moins cylindrique et par la présence de nombreux diverticules visibles entre les rangées de palettes iridescentes.

Figure12 ; some ctenarian species

3.4. Phylum Platyhelminthes



The simplest animals that are bilaterally symmetrical and triploblastic (composed of three fundamental cell layers) are the Platyhelminthes, the flatworms. Flatworms have no body cavity other than the gut (and the smallest free-living forms may even lack that!) and lack an anus; the same pharyngeal opening both takes in food and expels waste. Because of the lack of any other body cavity, in larger flatworms the gut is often very highly branched in order to transport food to all parts of the body. The lack of a cavity also constrains flatworms to be flat; they must respire by diffusion, and no cell can be too far from the outside, making a flattened shape necessary (Alessandrello, A et al 1988) (R. Buchsbaum, et al 1987).

According Ruiz-Trillo et al (1999) , Platyhelminthes: Flatworms are triploblastic, pseudo-coelomate metazoan invertebrates with bilateral symmetry and a flat, non-segmented shape.

- They are present in almost all biotopes (marine, freshwater, terrestrial).

- From the Greek platys = flat and helmins = worms
- Can be free-living
- The majority of them (about 85%) are parasitic.

Architecture and classification

Platyhelminthes (from the Greek platys = flat and helmins = worms) are bilateral animals that possess three true cell layers: the ectoderm, mesoderm, and endoderm. As their name suggests, they are generally flattened, which increases their surface area:volume ratio. Flatworms can be free-living, like planarians, but the majority of them (about 85%) are parasitic. Parasitic species are more evolved than free-living species, and they have undergone a whole series of transformations. The free-living platyhelminthes best illustrate the characteristics of the phylum.(Winnepenninckx, B.et al 1995)

Classification of Platyhelminthes

Cestoda are parasites of the digestive tract of vertebrae and are called tapeworms (*Taenia*), ex; *Taenia saginata*.

Trematoda are parasites that have two hosts:

1. intermediate host (mollusk)
2. a definitive host (vertebrate).

Turbellarians are predators or scavengers and therefore have a free-living lifestyle. Their digestive tract, which is incomplete, is digitate, sac-shaped, or has three pouches.

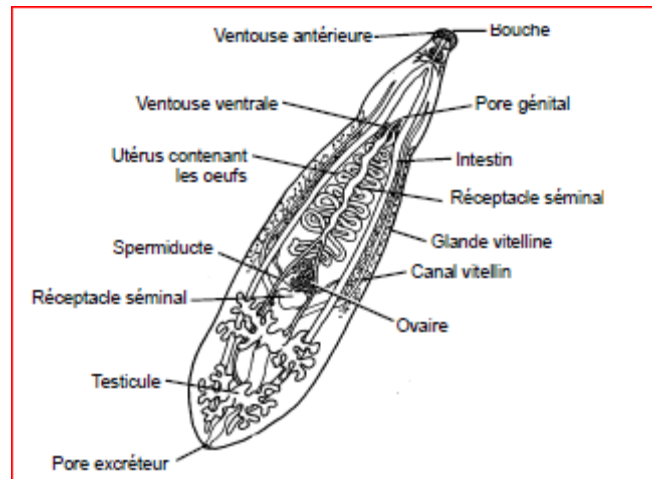


Figure 13. Longitudinal section of *Clonorchis sinensis*, a trematode parasitizing the human liver

Fundamental Functions

Locomotion

The locomotion of free-living flatworms is based on ciliary movement and muscle contraction.

Respiration: by oxygen diffusion.

Cestoda, which live in the intestines of vertebrates, have an anaerobic metabolism.

Reproduction: Most flatworms are hermaphrodites.

Asexual reproduction can occur by transverse fission. Flatworms have a regenerative capacity.

Excretion and Osmoregulation

One of the most primitive excretory systems appears in flatworms: the protonephridial network. This system is common in freshwater species and serves to eliminate excess water.

Reproduction

Plathihelminthes can reproduce both asexually and sexually. Asexual reproduction can occur by transverse fission. Furthermore, flatworms have a considerable regenerative capacity. In parasitic species that have multiple hosts, and whose chances of survival are reduced by the low probability of transmission from one host to another, there is very often a multiplication of larvae at several stages in the life cycle (larval amplification).

Most flatworms are hermaphrodites, but fertilization is usually cross-fertilization. Copulation allows two worms to store the sperm of the other individual. Fertilization occurs after copulation. Male gametes are therefore produced before the eggs (protandry), which reduces the chances of auto-fertilization.

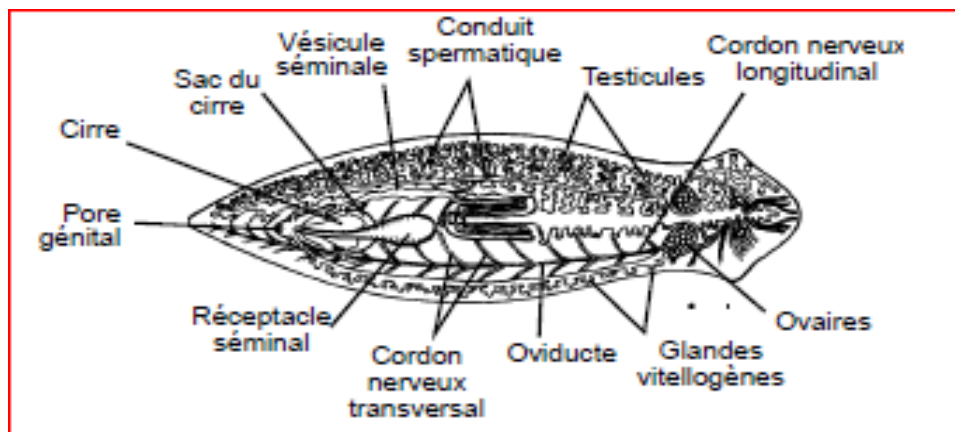


Figure 14. Reproductive system of a free-living flatworm,

The nervous system consists of a pair of cerebral ganglia, two longitudinal nerve cords, and a series of transverse nerves. Planarians have statocysts and typically eyespots that allow them to detect light. There are chemoreceptors in the cephalic region. Their mode of locomotion has favored a concentration of nervous and sensory structures in the anterior part of the body. In parasitic species, sensory structures are typically reduced or absent.

3.5. Phylum Nematelminthes.



Nematodes (Nematoda: "tubular"), or round, slender worms, constitute a phylum of unsegmented worms. Classified as ecdysozoans, they are covered with a thick cuticle.

They represent a very significant portion of biological diversity on Earth and constitute, in terms of number of individuals, four-fifths of the animal kingdom. Ubiquitous, they are found in soils worldwide, but they are more numerous in the subarctic zone (38% of the total). More than 3,000 species currently described live "free" (in soil, water, sediment, dead wood, or in necromass where they are bacterivores[or detritivores or micro-predators). Some parasitize plants, fungi, or animals (in the latter case, they are most often gastrointestinal parasites, but a few species colonize other types of tissue, particularly muscle). Some pose a problem in agriculture because they parasitize plants or livestock, but most contribute to the proper functioning of agrosystems and are bioindicators of soil and plant cycles, stimulating their growth by improving nutrient cycling(D. W. Freckman1985,1988)

Nematofauna refers to the different species of nematode worms present in a given area.

Phylum Annelida Characteristics

- They are mostly aquatic; marine or freshwater some terrestrial, burrowing or tubicolous, sedentary or free-living, some commensal and parasitic.
- The body is elongated, triploblastic, bilaterally symmetrical, truly coelomate and vermiform.
- The body is metamerically segmented; externally by transverse grooves and internally by septa into a number of divisions; each division is called a segment, metamere or somite.
- Body organization is of organ grade system.
- The epidermis is of a single layer of columnar epithelial cells, covered by thin cuticle not made of chitin.
- The body wall is contractile or dermo-muscular consisting of outer muscle fiber circular and inner longitudinal.
- Appendages are jointed when present.
- Locomotory organs are segmentally repeated chitinous bristles called setae or chaetae, embedded in the skin. It may be bored by lateral fleshy appendages or parapodia.

- The presence of true schizocoelous coelom usually divided into compartments by transverse septa. Mostly well-developed in leeches. Coelomic fluid with cells or corpuscles.
- The alimentary canal is straight tube-like, complete, extending from mouth to anus. Digestion is entirely extracellular.
- Respiration occurs through moist skin or gills of parapodia and head.
- The blood vascular system is a closed type. Blood is red due to the presence of hemoglobin or erythromycin dissolved in plasma.
- Excretion is by metamerically disposed coiled tubes; nephridia which communicate the coelom to the exterior.
- The nervous system consists of a pair of cerebral ganglia; brain and double ventral nerve cord having segmentally arranged ganglia and lateral nerves in each segment.
- Receptor organs include tactile organs, taste buds, statocysts, photoreceptor cells and sometimes eyes with lenses in some.
- They are monoecious i.e. hermaphroditic or sexes separate cleavage spiral and determinate; dioecious or unisexual form also present.
- Their development is direct in monoecious form but indirect in dioecious form.
- Larva, when present is a trochophore is characteristics in case of indirect development, while in others this stage is passed through development.
- Regeneration is common.
- Asexual reproduction occurs in some.

Architecture and classification

The phylum Nematoda is characterized by an internal tube that constitutes the digestive tract, with a mouth and an anus. This arrangement allows for the specialization of the different regions of the digestive tract and more efficient digestion.

These species are characterized by a body covered with an impermeable cuticle, which allows them to colonize the terrestrial environment, particularly soils. Cell division (mitosis) stops very early during embryonic development, and the growth of these worms is due to the growth of their cells rather than to a contractile element increasing their cell number.

Ascarids are large worms that inhabit the large intestine of mammals;

Ascariasis: definition. Ascariasis is a parasitic disease caused by *Ascaris lumbricoides*.

The infectious eggs, containing the larva, can be found on plants, fruit, or in the soil and ingested. The larva leaves the liver and migrates to the lungs.

From the lungs, the larva travels up the trachea, into the esophagus, and is carried through the digestive tract to the intestine.

Locomotion

Nematodes characterized by high-pressure hydrostatic skeletal structure allowed easy locomotion for nematodes. The cuticle secreted by the syncytial epidermis is formed of several layers of spirally arranged collagen fibers with longitudinal muscles, which allows nematodes to move by rapid undulations. Locomotion ensures the circulation of fluid in the pseudocoelom. The high fluid pressure and the small size (less than 1 mm) of most nematodes make them almost impossible to crush.. (Edward Tyson,2020)

Respiration and Circulation

with the absence of both respiratory and circulatory systems. Nematode respiration occurs by diffusion through pores that pierce the impermeable cuticle. Although nematodes can live in terrestrial environments, they have poor resistance to desiccation and are mainly found in moist soils in terrestrial environments. The fluid contained in the pseudocoelom promotes circulation.

Food and Digestion

Nematodes are decomposers; saprophages or necrophages.

The digestive tract of nematodes is a simple tube devoid of muscles, except for the pharynx and rectum. These powerful muscles surrounding the digestive tract allow nematodes to ingest food.

The mouth of free-living carnivorous nematodes has three lips and a stylet.

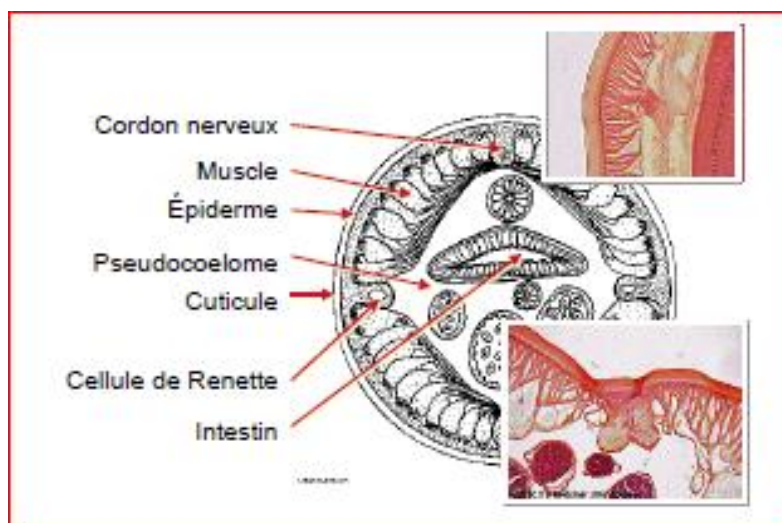


Figure 15. Cross section of a Nematode.

Excretion

Nematodes do not have protonephridia. Some of them have Renette cells, the function of which is not well understood. Nitrogenous waste is excreted in the form of ammonia in parasitic forms, and in the form of urea or uric acid in soil nematodes.

Reproduction

Nematodes are dioecious with enormous multiplication rates. The reproductive tract and digestive tract of both males and females open into the cloaca. Nematode sperm (amoeboid sperm) have neither flagella nor cilia.

Ecology

Many parasitize plant roots. *Anguina tritici*, commonly known as the wheat nematode, is affected by cyst nematodes and root-knot nematodes (*Meloidogyne*...).

Nematodes parasitize invertebrates and vertebrates. They live in cavities (intestine, kidney), in blood vessels, or in tissues. Threadworms are found in the digestive tract of arthropods and vertebrates (*Enterobius vermicularis* parasitizes humans). Roundworms inhabit the large intestine of mammals (*Ascaris lumbricoides* is found in the human intestine). parasitizes human lymphatic vessels and can cause elephantiasis. *Trichinella spiralis* causes trichinosis.

3.6. Phylum Annelida



-The word Annelids (from annellus, small ring)

-Annelida are metazoans, coelomates. They have bilateral symmetry, a head, a trunk, a tail.

-Annelida are one of the rare phyla to have colonized the marine, freshwater, and terrestrial environments.

-They are worm-like animals with a true coelom and a segmented hydrostatic skeleton where each part of the body can change shape without affecting the others.

-Annelida are characterized by body metamerization (division of the body into several units called metameres or segments).

the coelom (= cavity).; filling tissue between the digestive tract and the body wall),

(Acoelomates) without a coelom

(Eucoelomates) true coelom

Hydrostatic skeleton Skeleton formed by a closed cavity filled with liquid and surrounded by a wall that contains muscles. Bilateral symmetry A type of symmetry in which a single plane of symmetry divides the organism into two identical halves.

General characteristics:

- Formed of a series of successive rings called metameres,
- The mesoderm is organized into coelomic vesicles.
- Existence of a closed circulatory system,
- The digestive system is complete with a mouth
- The nervous system includes a pair of cerebral ganglia
- From a phylogenetic point of view, Annelids are similar to Arthropods (insects)

The mesoderm is the intermediate embryonic layer located between the outer layer (ectoderm; epidermis) and the inner layer (endoderm; digestive tract). The cells of this layer give rise to a large part of the organs

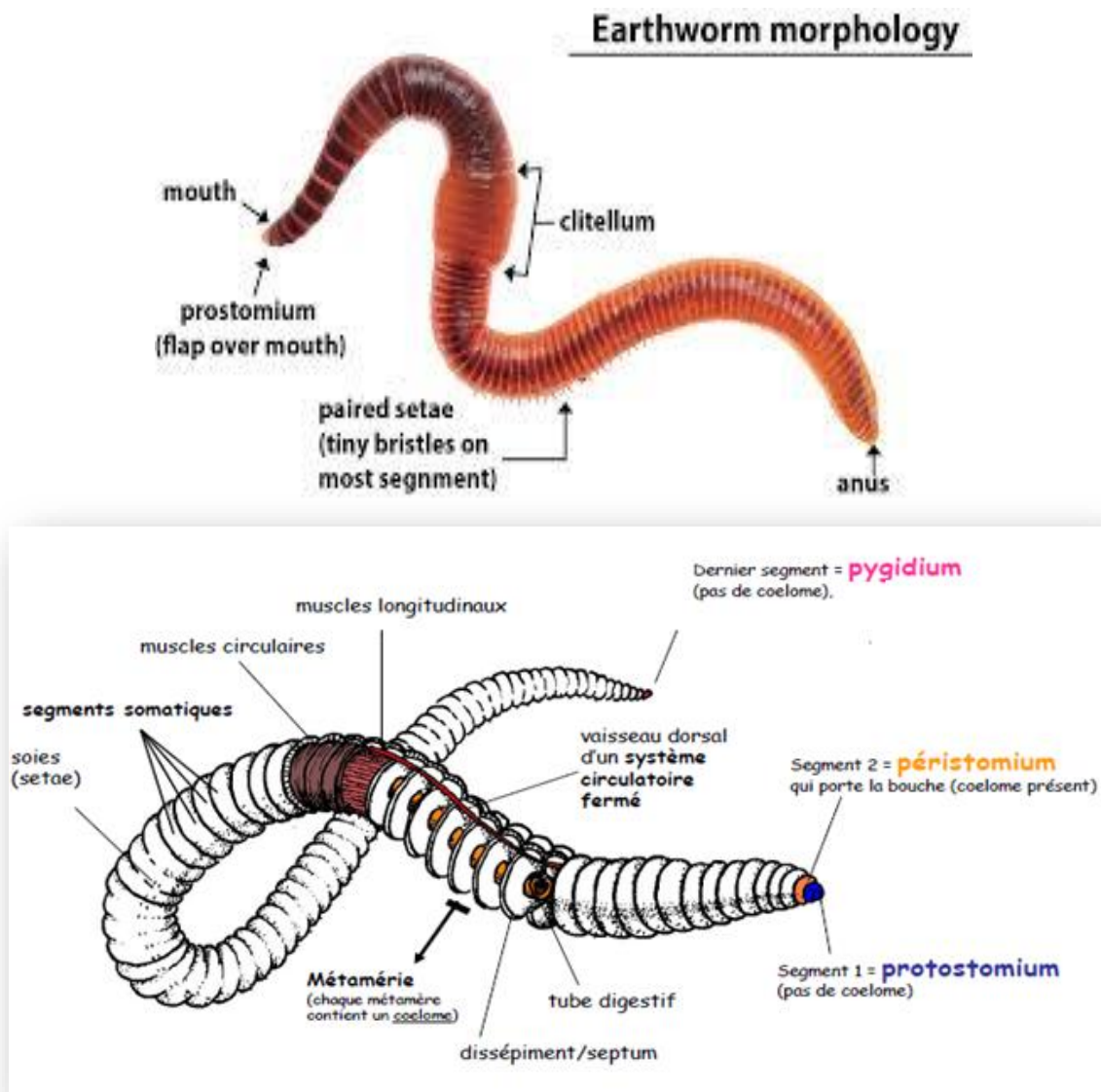


Figure 16 : Annelids morphology

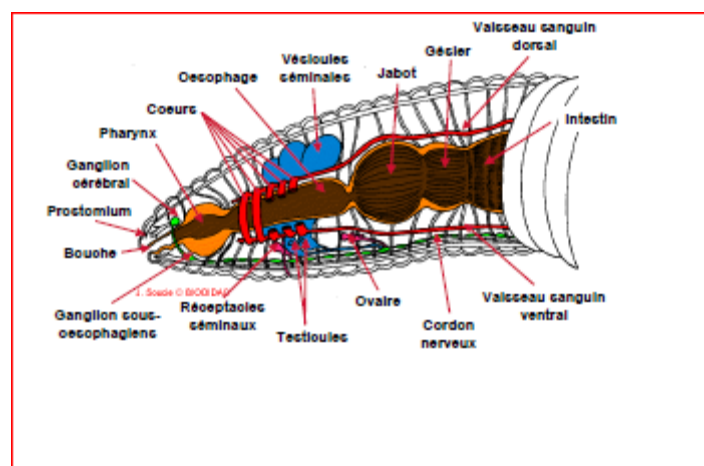


Figure 17. Lateral section of the anterior part of an earthworm illustrating the internal organs

Systematics

Annelids are grouped into three classes based on the abundance, rarity, or absence of setae:

1. Achaeta or Hirudinae (= without setae) Hirudinae (from the Latin hirudo = leech) are flattened, elongated, naked, and footless: the rings are short.

2- Oligochaeta (= little setae)

Oligochaeta (from the Greek oligos = few) have reduced or very small setae and do not possess pods. e.g., earthworms.

3- Polychaeta (= many setae)

Marine Polychaeta (from the Greek polys = many, and chaete = silk or long hair) are characterized by the presence of numerous setae, often borne on parapodia of highly variable shapes.

Fundamental functions of annelids

Diet and Digestion

Earthworms are detritivores that ingest soil and remove organic matter. Their muscular pharynx allows them to swallow the soil, which is then ground in the gizzard.

Respiration and Circulation

-Earthworm respiration occurs by diffusion through the permeable cuticle.

-Glands in the epidermis continually produce mucus, which keeps the surface moist and allows oxygen to diffuse into the animal.

-Marine polychaetes often have gills.

Locomotion

Annelid locomotion occurs by muscle contraction and stretching.

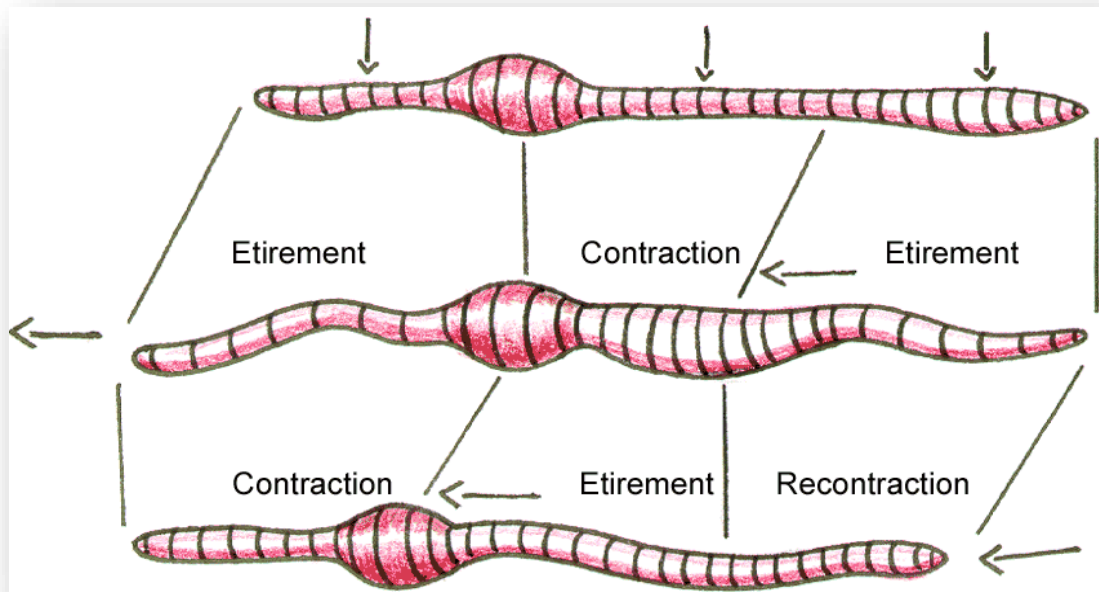


Figure 18; Annelid locomotion

Ecology; Role of Annelids

- Annelids are very abundant and serve as prey for multiple organisms (fish, birds, rodents, amphibians, and many invertebrates).
- Earthworms help decompose organic matter in the soil
- aeration of the soil,
- increasing soil fertility.

3.7. Mollusca Phylum



Introduction

The Mollusca Phylum has over 130,000 species and occupies an important place in the animal kingdom, both in terms of number (of species) and ecological role.

Mollusks mainly inhabit marine, freshwater, and terrestrial environments.

Latin mollis: soft (soft-bodied).

Characteristics:

- Mollusks are unsegmented, invertebrate animals with bilateral symmetry. Their body generally consists of a head, a visceral mass, and a foot.
- The visceral mass is covered in whole or in part by a mantle, which secretes a calcareous shell.
- The mantle is an envelope consisting of an integument and muscles that houses the other organs.
- The head is clearly distinguished and contains sensory organs such as eyes and tentacles.
- The shell is formed by a conical tube surrounded by a spiral.

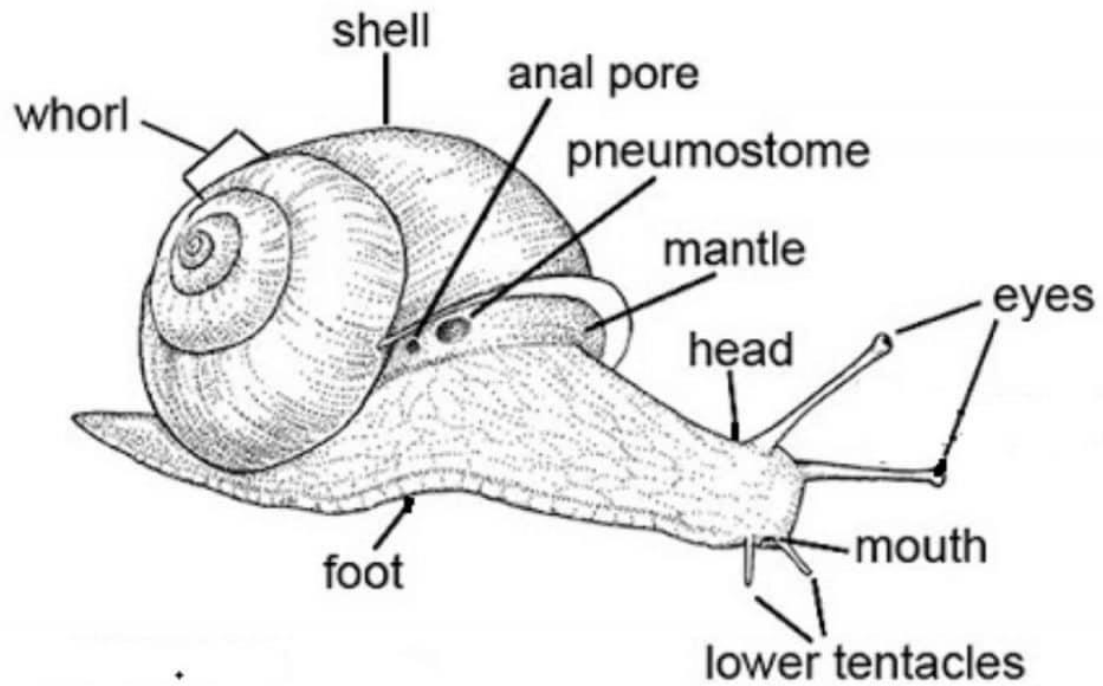


Figure 19: mollusca morphology

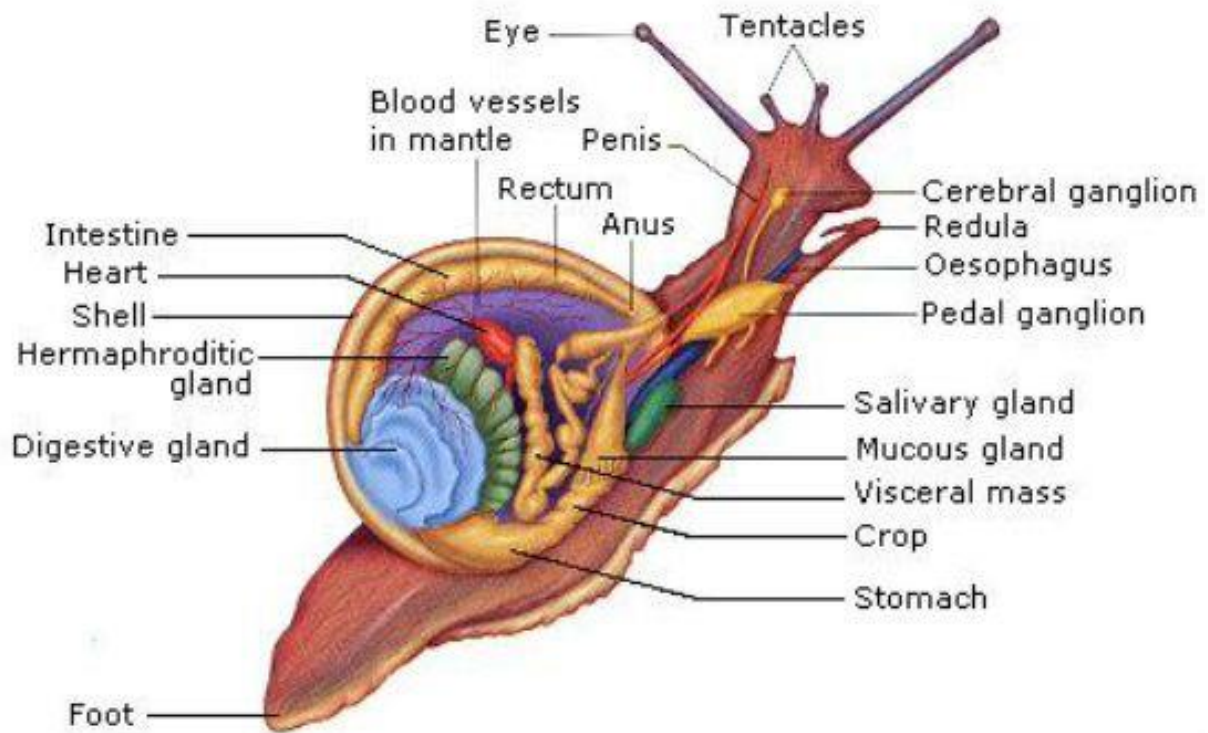


Figure 20: mollusca anatomy

Mollusk Classification

There are seven classes of mollusks:

- Animal Kingdom
- Metazoa Subkingdom
- Mollusk Phylum
 - Class Monoplacophora
 - Class Aplacophora
 - Class Polyplacophora
 - Class Scaphopoda
 - Class Lamellibranchia (= Bivalves)
 - Class Cephalopoda
 - Class Gastropoda $\frac{3}{4}$ of mollusk species



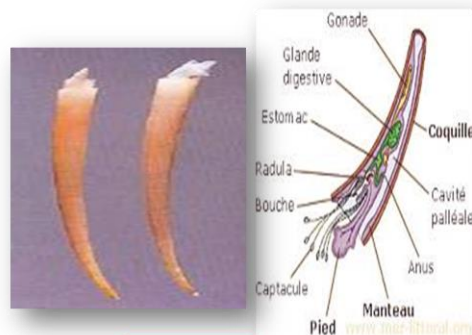
Le polyplacophore herbivore (algues)



les Monoplacophores



les Lamellibranches (= Bivalves),



le scaphopode

Figure 21: Mollusk Classification

1. Class Cephalopoda

- Cephalopoda (from the Greek Képhalê = head, and the plural podes = feet, meaning feet to the head)
- Cephalopoda are a class of mollusks, whose heads are equipped with tentacles. The most popular are the species called octopus, squid, or cuttlefish, as well as nautilus.
- There are approximately 800 living species

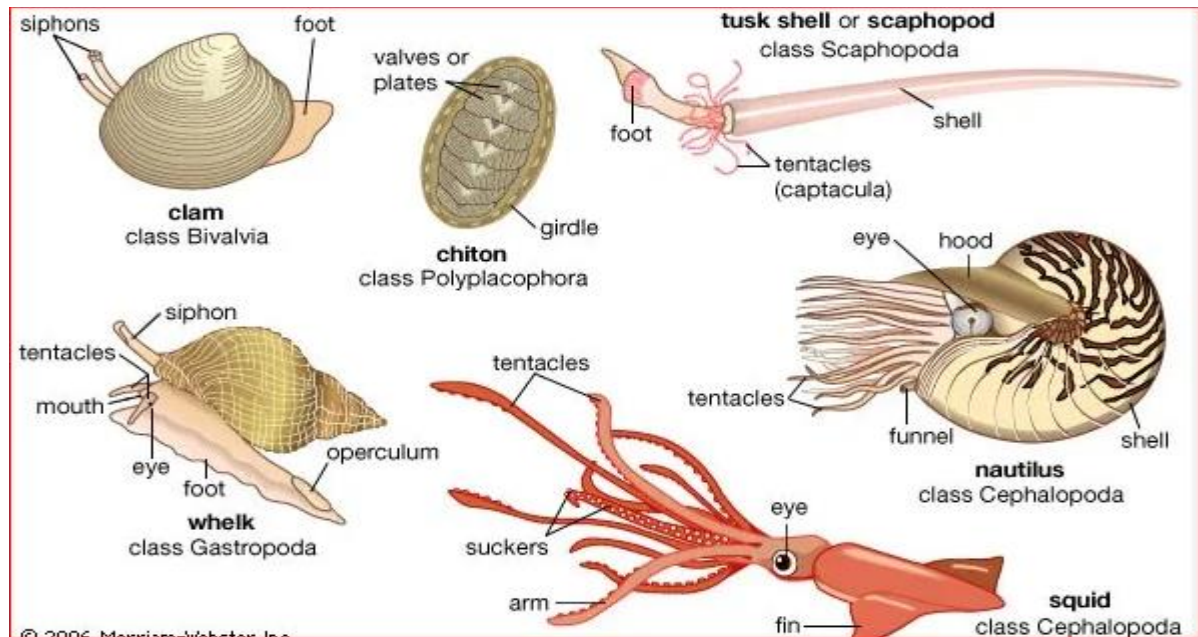


Figure 22: Cephalopoda morphology

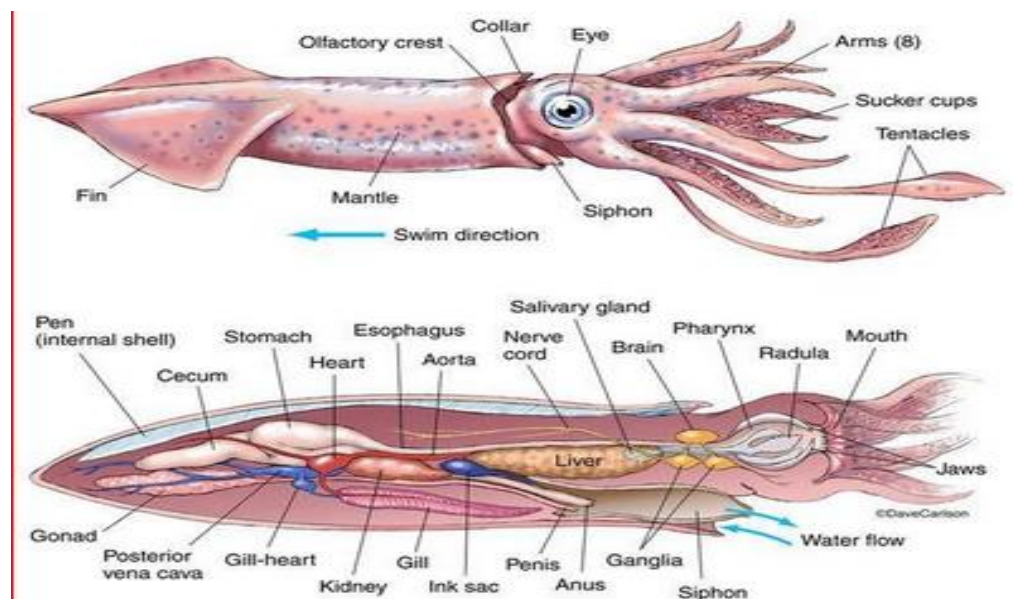


Figure 23 : Cephalopoda anatomy

Classification

Subclass Tetrabranchials

They have four gills, four auricles, and four kidneys. They have between 40 and 50 retractable tentacles.

They are now represented by only one genus: Nautilus.

Subclass Dibranchials

Dibranchials have two gills, two auricles, and two kidneys.

a\ *The order Decapods*. Decapods have ten arms. Ex: Cuttlefish, Sepia, Squid.

b\ *The order Octopoda*. Octopoda have eight arms. They do not have a shell. Example: Octopus.

2. Class Gastropoda.

- The class Gastropoda includes three-quarters of mollusk species. The head is well-defined and bears sensory organs such as eyes and tentacles. The foot is very muscular and often called the "creeping sole."

- The shell is formed by a conical tube spiraling around a rigid axis (the columella).

Class Gastropoda

- *Subclass Pulmonata*. Pulmonata are found in freshwater and terrestrial environments. The lung communicates with the exterior through the pneumostome.

- *Order: Stylomatophores*. They are almost all terrestrial (genus Helix). The outer shell is well-developed. In slugs, the shell is reduced.

3. The class Lamellibranchs (or Bivalves).

General characteristics:

- Marine species
- The mantle is developed and produces two symmetrical lobes
- Absence of a clearly differentiated head
- The digestive tract has no jaw, radula, or pharynx.
- Respiration is carried out through the gills

Classification of lamellibranchs

The classification is based on the structure and shape of the gills.

1. The order Protobranchia. The gills are made up of simple filaments, and the mantle is widely open. e.g., *Nucula* sp.

2. The order Mesobranchia: The gills are more complex, made up of direct and reflexed filaments. e.g., *Mytilus* (mussel)

Fundamental Functions

1. Mollusk Locomotion

The foot plays a role in mollusk locomotion;

- Gastropods move by crawling (snails).
- Cephalopods move primarily by their tentacles, projecting water from their mantle cavity through a siphon. These tentacles are also used for food intake.
- Several bivalves do not move at all, and their foot is transformed into sticky filaments that serve to attach the animal to the substrate.

2. Mollusk Respiration

- The respiratory system consists of a lung in terrestrial gastropods (snails).
- In aquatic mollusks, the gills vary in shape. They are the site of respiratory exchange.

3. Feeding and Digestion

- The radula is involved in the feeding of all mollusks, except, of course, bivalves, which lack it. This rasp-like structure is well adapted to grazing vegetation.

Mollusk diets:

- -phytophagous
- -predators
- (decomposers).

4. Reproduction

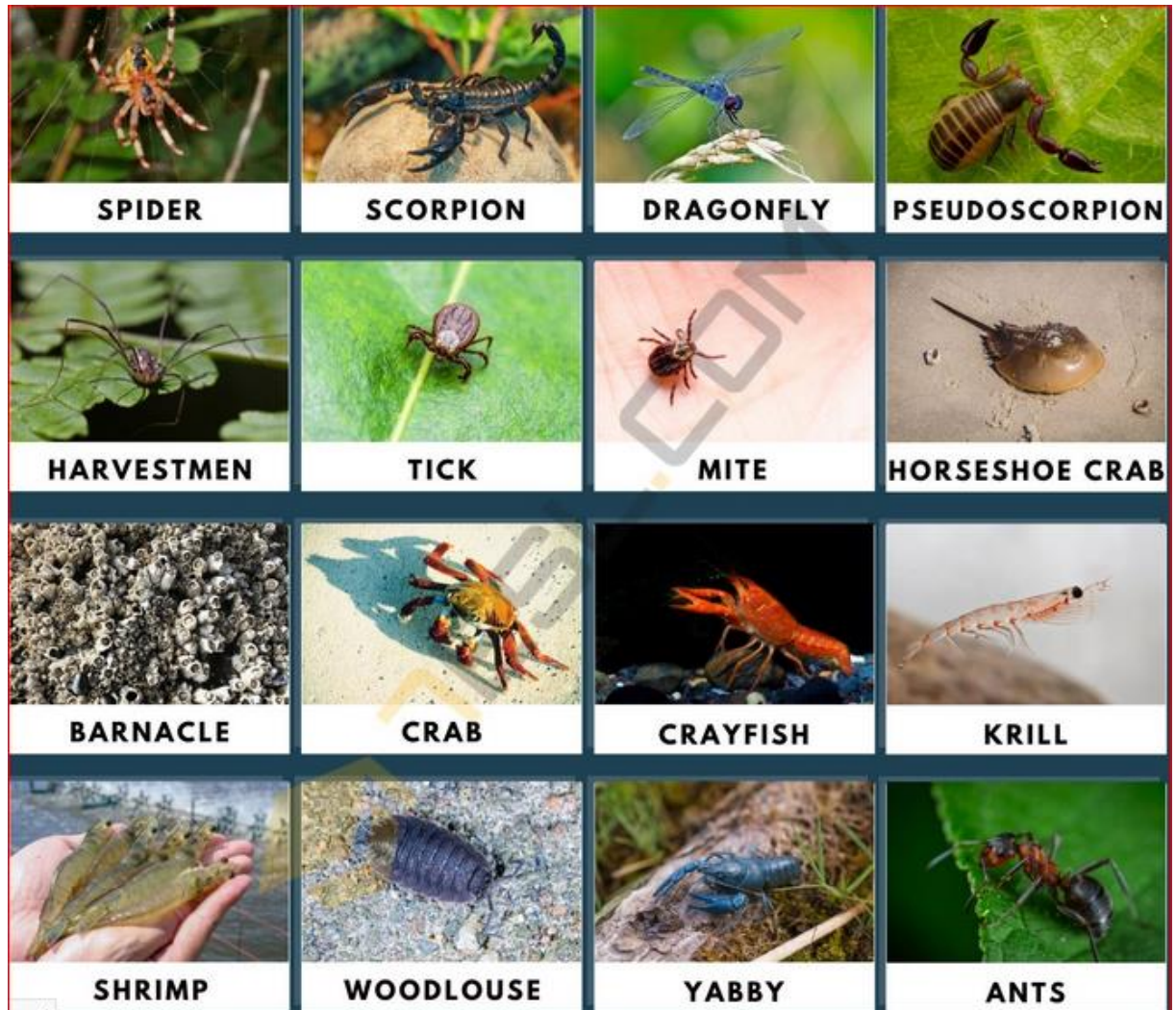
In mollusks. Most are dioecious (2 male and 2 female individuals)

- Several bivalves and gastropods are hermaphroditic (monoecious; only one individual)

Ecology (role of mollusks)

- Mollusks are present in all marine and terrestrial habitats; they are essential for maintaining trophic webs (food chains).
- Snails are pests that can cause damage to various crops.
- Some snails can be vectors of plant diseases. *Helix aspersa* could transmit a species of fungus to other plants.

3.8. Phylum Arthropoda



Morphology

General Information

Like all other arthropods, insects have an exoskeleton that covers the outside of their bodies and is formed of rigid plates called sclerites, whose cuticle is made of sclerotin, a very strong protein, and chitin. This shell is regularly replaced as the animal grows: this is called molting. The old, discarded cuticle is called an exuvia. (Vincent H. Resh et al. 2009)

Insects are, in their imaginal state, that is, imago (=adult insect), small terrestrial or freshwater animals (from 0.25 mm to exceptionally 30 cm long), with a body divided into three parts:

- the head, which, unlike chelicerates, has a pair of mandibles (insects belong to the subphylum Mandibulate) and a pair of antennae (this subphylum is also called Antennata);
- the thorax has three pairs of legs (the class Insecta is also called the class Hexapoda) and, most often, two pairs of wings
- abdomen

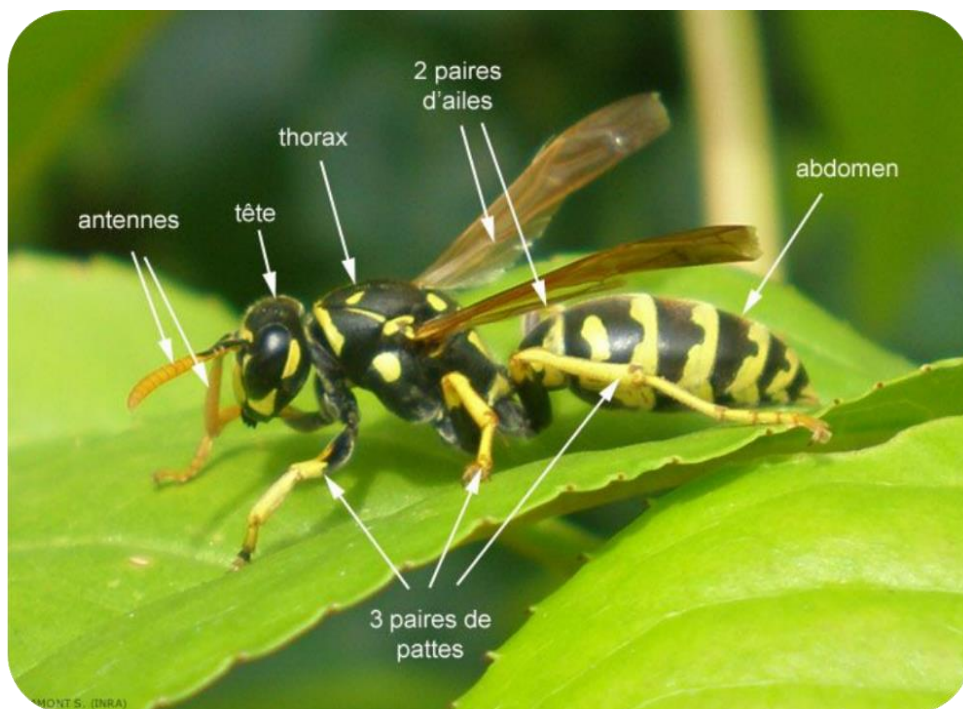


Figure 24 : insect Morphology (J.P.Lavigne.2002)

1. The head

The head contains the antennae, eyes, and mouthparts. The antennae are sensory organs for smell and touch. Their shape varies considerably depending on the species. Generally, female antennae are less developed than male antennae.

The compound eyes are composed of a large number of cells, each of which constitutes a simple, immobile eye (Launois-L., 1979).

Some insects also have ocelli (3), generally located on the forehead. These simple eyes are thought to be sensitive to variations in light intensity.

The mouthparts are organized into four different types:

- **The crushing or fundamental type**, recognizable by the pairs of highly developed and more or less toothed mandibles and maxillae. These are joined by an upper lip (labrum) and a lower lip (labium). The palps of the maxillaries are equipped with numerous sensory organs and, like the labium, serve to search for food.
- **The biting type**, where the parts of the fundamental type are modified to form a rostrum with which the insect pierces tissues and extracts liquid food (aphids, mosquitoes, etc.).
- **The licking type**, where the lower lip is transformed into a sort of tongue allowing it to mop up liquids by capillary action (bees, flies, etc.).
- **The sucking type**, where the jaws are modified into two long half-grooves which, when joined, form a flexible, hollow proboscis. The end of the latter has numerous pores allowing the absorption of liquids (Butterflies, etc.). In some species of butterflies, the mouthparts are atrophied and the insects are unable to feed.



(1)



(2)

Figure 25: Eyes of a locust (1) and a grasshopper (2)
(BRAHIMI ,2015)



Figure 26: Legs of two Pamphagidae (*insect*) (BRAHIMI 2015)



Figure 27: Antenna of a locust
2015). (BRAHIMI 2015).

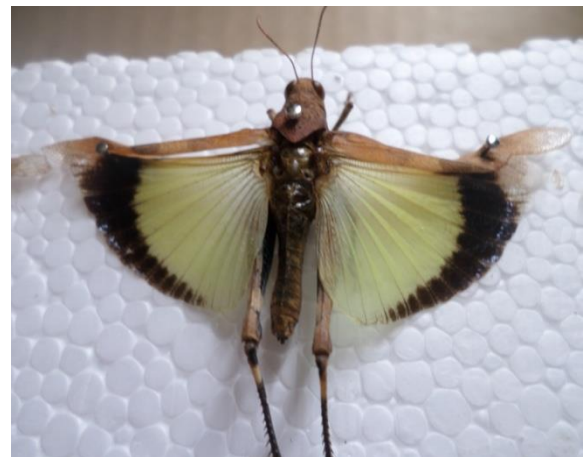
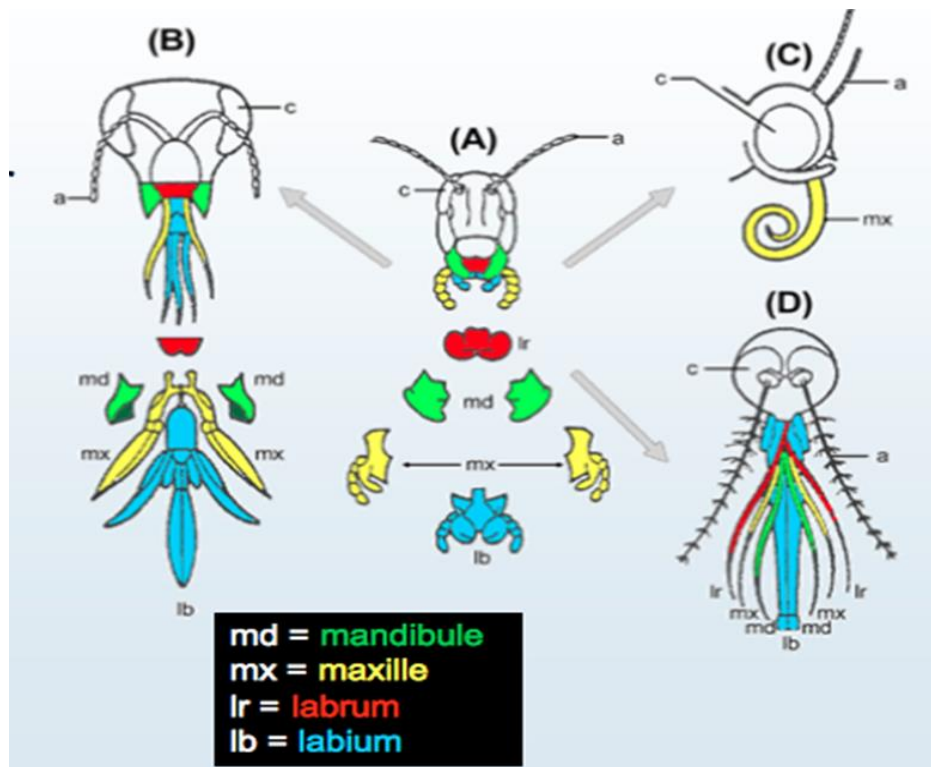


Figure 28: Wings of an Oedipoda (BRAHIMI



A : Crusher B : licker C : sucker D : piercer

Figure 29 : The different types of insect mouthparts

2. The Thorax

The thorax is often large because it contains the muscles that power the locomotor appendages. It is formed by the union of three segments: the Prothorax (anterior), the Mesothorax (medial), and the Metathorax (posterior). Respiratory openings (spiracles) may be visible (one pair per segment).

2.1. Legs:

Each thoracic segment has a pair of legs. These are organized as follows:

- the hip or coxa connects the leg to the thorax,
- the femur is generally the most developed segment, connected to the hip by the trochanter,
- the tibia articulates on the femur and extends into the tarsus, the latter having 3 to 5 small segments, the last of which often bears two claws

The legs can have morphological modifications adapted to specific functions:

- raptor legs (mantises, water mantises, etc.)
- jumping legs (grasshoppers, fleas, etc.)
- burrowing legs (mole crickets, dung beetles, etc.)

- swimming legs (diving beetles, etc.)

- foraging legs (bees, etc.)

. They can also emit sound signals or carry tympanic devices. Typical insect leg (walking beetle) and some adaptations to particular functions (Maurice R, 1980).

2.2. Wings

- The adult pterygote insect has two pairs of wings inserted respectively on the mesothorax and metathorax. The wings can be membranous (bees, aphids, flies, etc.), chitinous (elytra of cockchafer, semi-elytra of bugs, etc.), scaly (butterflies, etc.), pinnate (thrips, etc.), etc.

Wing venation plays a key role in determining families and genera. Their role is, of course, to ensure flight (long and rapid movement). The elytra protect the membranous wings, while the balancers ensure balance. **(Vincent H. Resh et al. 2009).**

3. Abdomen

The abdomen is normally composed of 10 or 11 segments, the most apical of which are often fused and indistinct. Each segment is formed of two chitinous half-cylinders, the tergite (dorsal) and the sternite (ventral). Unlike the thoracic segments, those of the abdomen are imbricated and connected by a flexible membrane, which allows a variation in volume in certain groups. **(Raccaud .1980).**

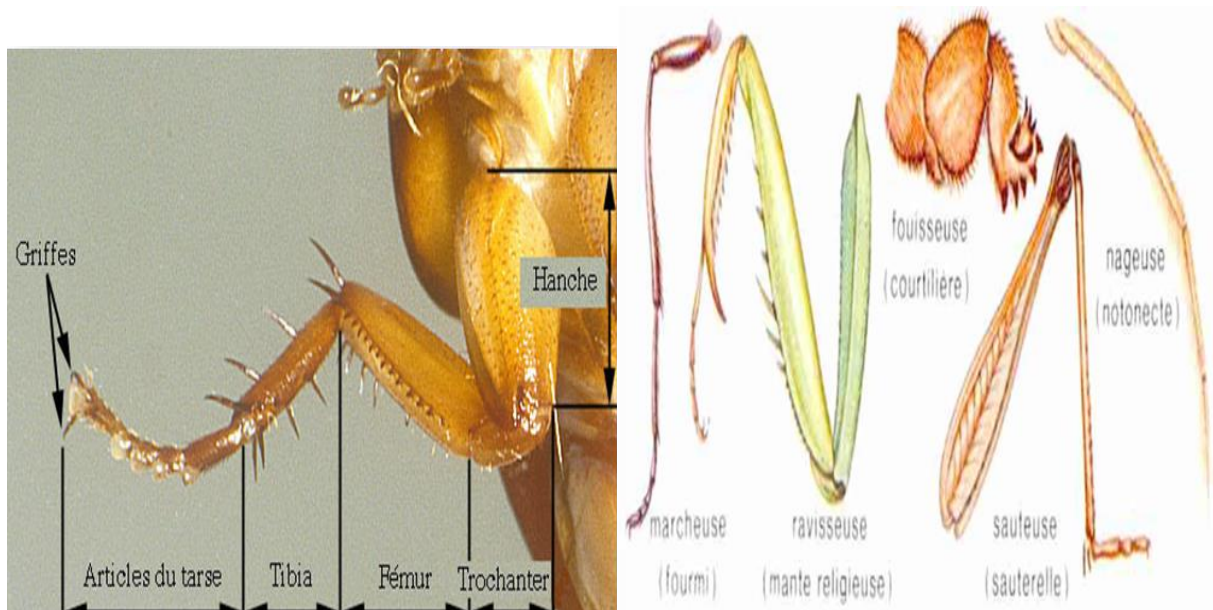


Figure 30 : The different types of legs in insects



Figure 31: Different wing colorations in insects (Brahimi 2015)

4. Internal organization of insects: The external skeleton delimits a general cavity extending from the head to the tip of the abdomen, in which the musculature and internal organs are arranged.

The digestive tract; includes the foregut, which receives food, the midgut, which digests it, and the hindgut, which rejects digestive waste.

The nervous system; consists of a group of centralizing ganglia located in the head and connected by the ventral nerve chain to the paired ganglia of the thoracic and abdominal segments. These paired ganglia constitute localized nerve centers, from which numerous nerve fibers branch off to the muscles and organs.

The reproductive organs are located in the abdomen.

Blood circulation occurs more or less freely within the general cavity. It is activated by a dorsal tube that pumps blood into the abdomen and forces it back toward the head.

The respiratory system; is of the tracheal type. Air enters each segment of the insect through the stigmata and irrigates the internal organs and musculature through a network of increasingly branched tracheae. This tracheal system also ensures the evacuation of stale air.

(Maurice R, 1980).

5. Dietary Variability in Insects

Food is one of the important ecological factors that plays a key role in various biological parameters of insect populations, namely, fecundity, longevity, development rate, and birth rate **(RAMADE F., 2003)**. The interest in studying the diet of locusts allows for a better understanding, among other things, of the phenomenon of competition and the existing relationship between the plant and the insect **(DAJOZ 1985)**.

The different diets of insects

Phytophagous

Carnivorous

Xylophagous

Melliphagous and nectarivorous

Hematophagous

Frugivorous

Coprophagous

Scavenging and saprophagous

Detritivorous

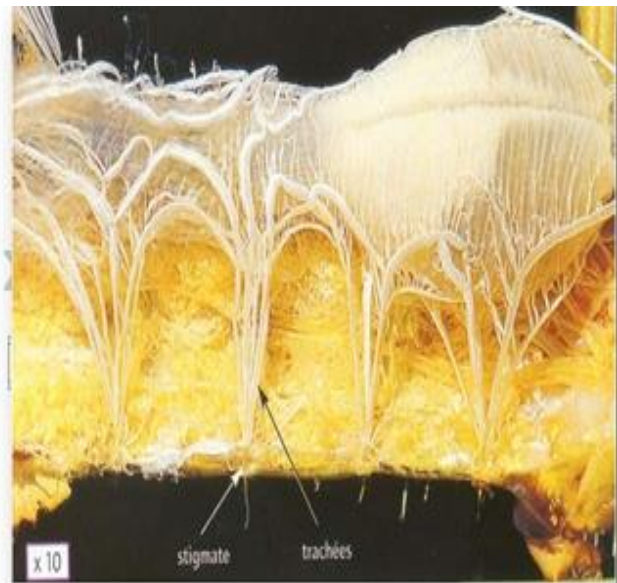
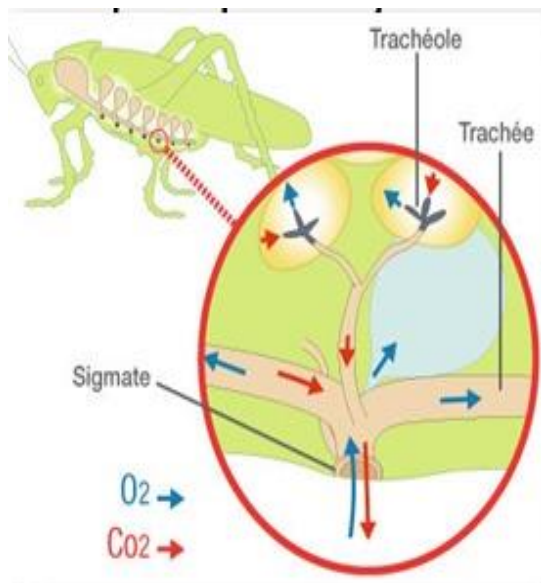


Figure 32: The respiratory system of insect . figure 33 :microscopic tracheal system

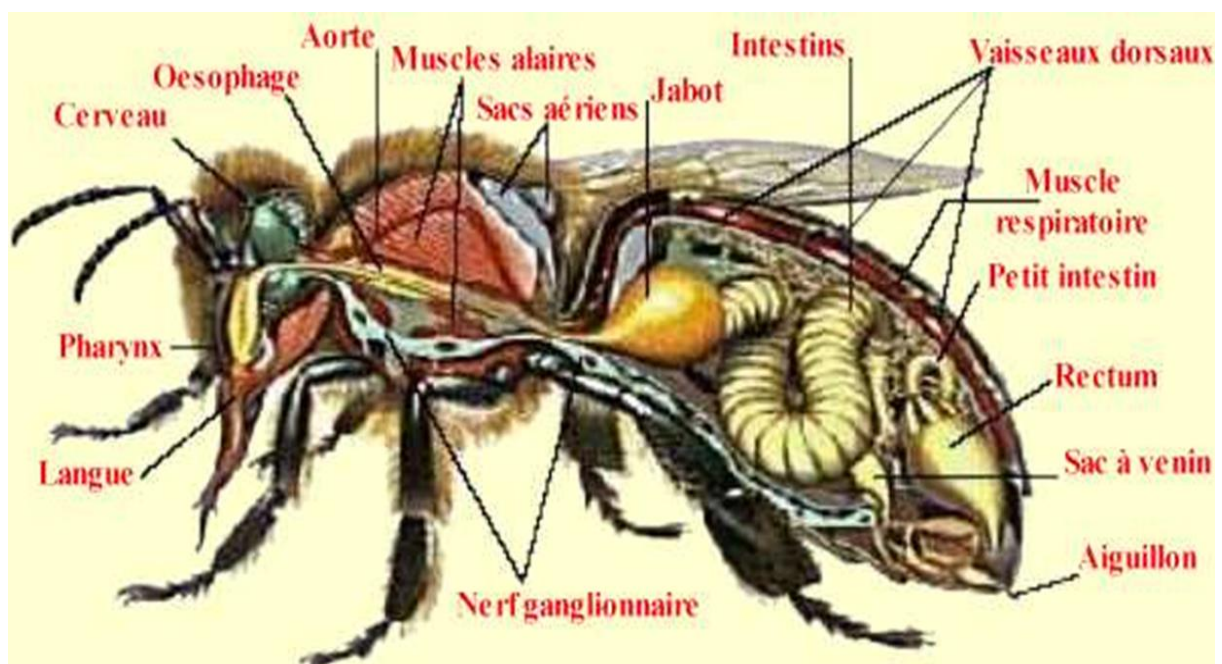


Figure34: insect Anatomy(Lavigne. J.P. (2002))

I. Classification

Systematics is the branch of biology that deals with the classification and scientific naming of organisms. The central principle of this discipline is to group species that share certain anatomical or developmental similarities and that come from the same evolutionary lineage **(Ramade 2003)**.

Arthropods are divided into two main groups:

- Chelicerates have pincer-like appendages; Arachnids (mites, spiders, scorpions)
- Antennates or Mandibulates: have chewing appendages, which are mandibles. This group includes the following classes:
 - Crustaceans: aquatic (crabs, shrimps, etc.)
 - Myriapods: e.g., millipedes
 - Insects

1. Taxonomy:

One of the tasks of taxonomists is to describe and name each species. Since Linnaeus, species have been named using binomial nomenclature (genus and species). Each species has a Latin name, consisting of two words. The first word is the genus (usually a noun), and the second the species (usually a qualifying adjective). For example, the scientific name for the earthworm is *Lumbricus terrestris* (the terrestrial earthworm).

2. The concept of species:

Species are groups of individuals or natural populations that are morphologically identical, capable of interbreeding, and reproductively isolated from other similar groups **(Dajoz 1970)**.

A pest insect is an insect that is harmful to agricultural crops, trees, and vegetation in general. Pests can be polyphagous (organisms that attack several genera of plants) or specific (organisms that attack a single genus or species of plants).

Species are grouped hierarchically into genera, genera into families, families into orders, orders into classes, classes into phyla, and phyla into kingdoms.

For example, the classification of the bee species is as follows:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Hymenoptera

Family: Apidae

Genus: *Apis*

Species: Mellifera

This classification is intended to reflect the degree of relatedness between species. Species of the same genus are more closely related than species of the same family. **(Maurice R, 1980).**

La Place des insectes dans le règne animal

Arthropods are divided into two major groups:

Chelicerates have pincer-like appendages; Arachnids (mites, spiders, scorpions) constitute the largest class. **(Maurice R, 1980).**

- Antennates or Mandibulates: have chewing appendages, which are the mandibles. This group includes the following classes:

I. Insect Biology

Insects change their appearance between the immature and adult stages (molts, metamorphoses), but development from egg to adult varies among groups **(Charles 2009).**

- In the most primitive insects, changes are gradual and metamorphoses are incomplete = heterometabolous insects. The young closely resemble adults, but without wings or reproductive organs (except for exceptions). **(Maurice R, 1980).**

e.g., Orthoptera, Phasmoptera, Isoptera, etc.

- In advanced insects, the changes are spectacular, and metamorphoses are complete = holometabolous insects **(Launois 1979).** The larvae have a very different appearance from the adult. After several molts, the larvae pupate and undergo a reorganization of their tissues. Ultimately, an adult insect emerges from the pupal exuvia;

e.g., Lepidoptera, Coleoptera, Diptera, etc.

Moulting is the process of producing a new cuticle and shedding the old one, which allows the insect to grow in size or change its morphology (metamorphosis) **(Maurice R, 1980).**

Insects pass through three biological stages during their lives:

- The embryonic stage: the egg,
- The larval stage: the larva.
- The imaginal stage: the winged or adult.

The embryonic stage is generally hypogeous (below the soil surface), the other two epigeous (above the soil surface). **(Raccaud 1980).**

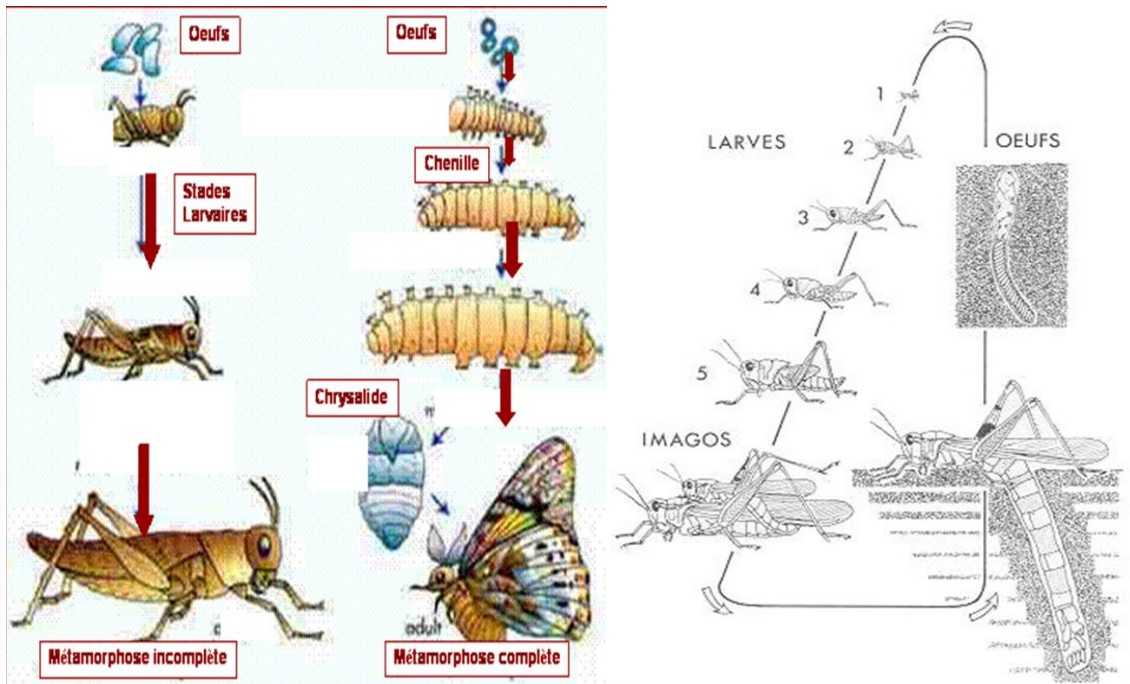


Figure 35 : Biologie des insectes

1. Insect Class

Insect Morphology

THORAX

- divided into three metameres: the prothorax, mesothorax, and metathorax carry the legs and wings

HEAD

- carries the sensory organs: eyes, ocelli, antennae, tactile setae
- carries the mouth, mouthparts, and mandibles

ABDOMEN

- composed of a variable number of segments
- contains the digestive and reproductive organs

Fundamental functions

Locomotion:

Winged insects (pterygotes)

Wingless insects (apterygotes)

Respiration;

Insects have a tracheal respiratory system. The cuticle is pierced with pores that lead to a network of tracheae.

Reproduction; Insect life cycles

Insects are oviparous

-development from egg to adult varies among groups;

Incomplete metamorphosis: The young closely resemble the adults, but without wings.

Ex: Orthoptera; grasshopper

Complete metamorphosis: The larvae are different from those of the adults.

Ex: butterfly

Insect Systematics

- Coleoptera constitute the largest order in the animal kingdom: 350,000 described species
- Constitute 40% of known insect species, 30% of animal species (1/3)

29 orders, 949 families, and 1 million species

2.Class of Crustaceans

From the Latin crusta, "crust"

- 800 families of crustaceans, divided into 40,000 species, the diversity of this group can be 10 to 100 times greater.
- The body is covered with an exoskeleton called an exocuticle

Morphology

- The head is characterized by the presence of two pairs of antennae
- The thorax is covered with a shell containing the internal organs
- The abdomen
- The presence of gills for breathing.
- Their diet is very varied, carnivores, detritivores

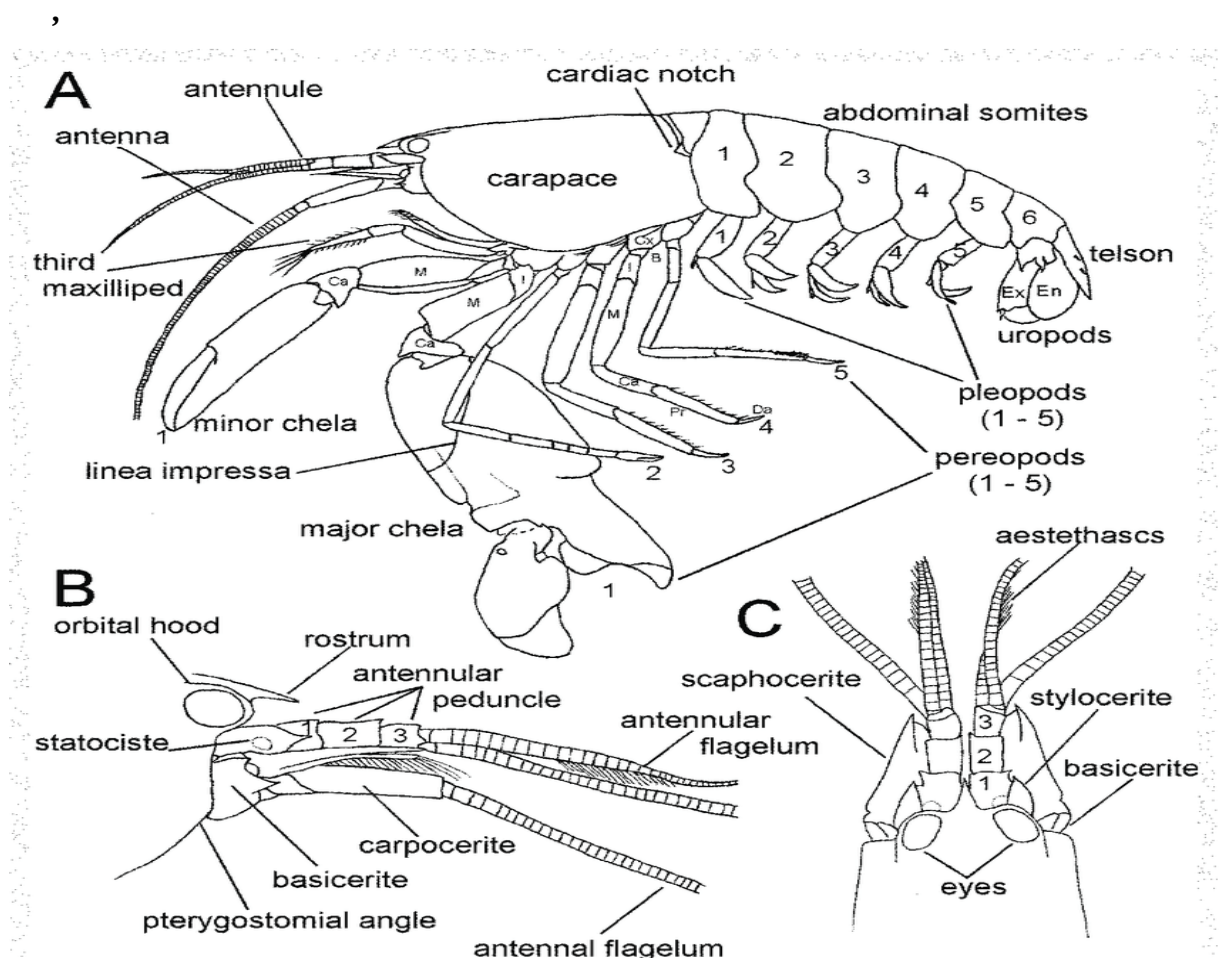
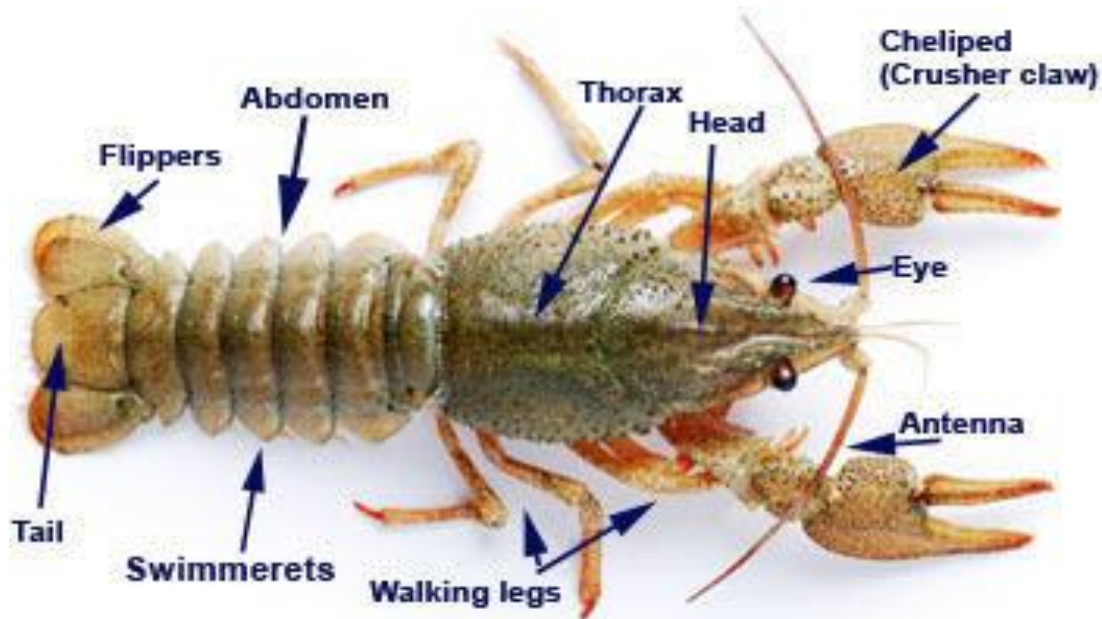


Figure36 : Morphology of snapping shrimp of the genus *Alpheus* Fabricius, 1798

Classification Of Crustaceans

Approximately two-thirds of crustaceans belong to the subclass Malacostraceae.

Among the Malacostraceae, the order Decapoda includes the majority of species, distributed across 16 orders and 18,000 species.

Within the Decapoda, there are two suborders:

Reptantia, "walking crustaceans" (such as crabs, crayfish, lobsters, and spiny lobsters)

Natantia, "swimming crustaceans," e.g., shrimp

Respiration

This is done through gills located either on the thorax, or "lungs" in terrestrial decapods.

Diet: Crustaceans are typically filter feeders (zooplankton) or detritivores.

Ecology; arthropods role and interaction

Arthropods play an important role in food chains in all environments.

-Insects are vectors of multiple parasites, such as Plasmodium, Leishmania, and trypanosomes.

-They are pollinators of plants, such as bees and butterflies.

-They are decomposers of organic matter.

-They are also insect pests of several plant species, such as locusts.

The great success of insects can be explained by several factors:

Their small size allows them to colonize all environments.

Flight is a means of defense and for finding food.

Their rigid, waterproof exoskeleton provides protection against predators and desiccation.

The high fecundity and rapid multiplication of insects

3.9. Phylum Echinoderms



Echinoderms have radial symmetry, and if this trait alone were used to group animals, one would think they were related to the Cnidarians. This is not the case. Although for a long time the best zoologists grouped all radially symmetrical animals into the phylum Radiata, this grouping is now obsolete. If we observe the life cycle of echinoderms, we realize that the larvae have bilateral symmetry, and that only the adult stage has radial symmetry.

In eucoelomates, there are two types of coelom development: schizocoel and enterocoel. In the schizocoel type, the mesoderm separates to form the coelom. This is characteristic of protostomes. In the enterocoel type, characteristic of deuterostomes, which include echinoderms, the coelom develops from mesoderm pouches in the digestive tract. In deuterostomes, the coelom is made up of three parts (tripartite coelom), one of which becomes an aquifer system in echinoderms..

Classification

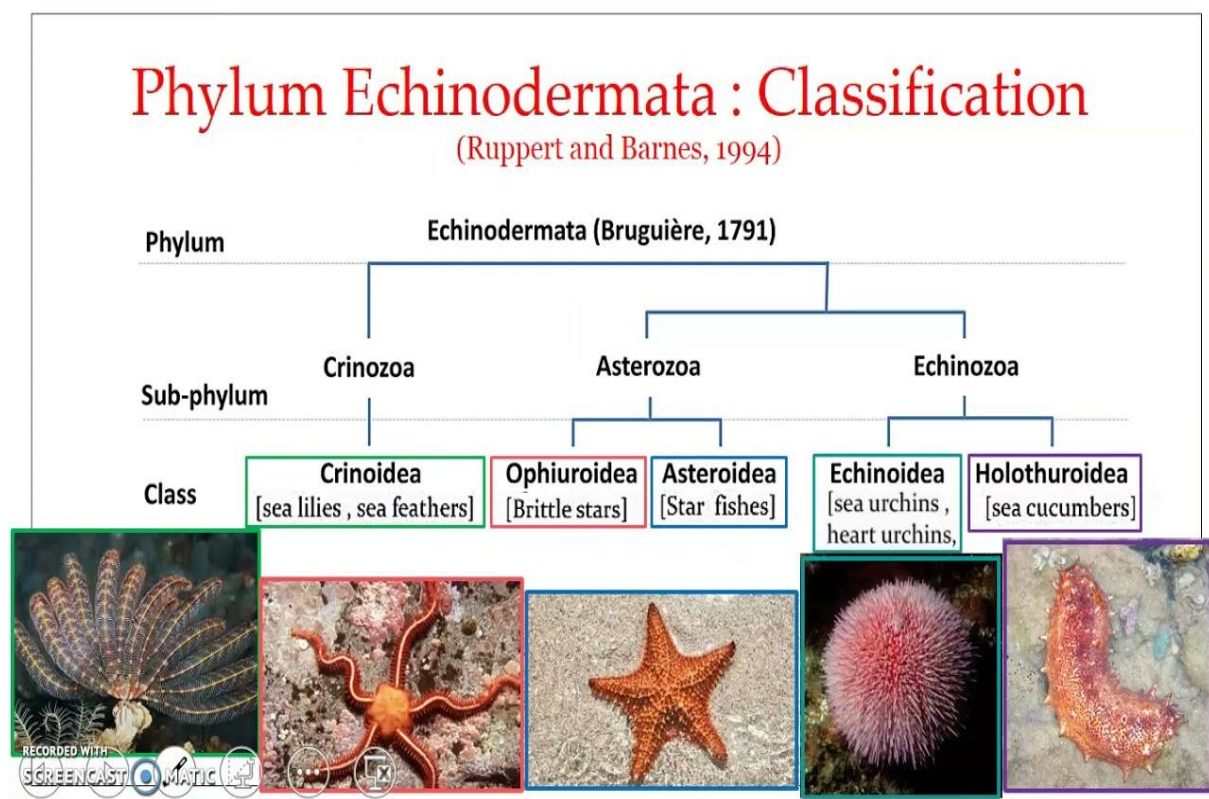


Figure 37 :phylum echinodermata classification Ruppert and Barnes 1994

Fundamental functions

Locomotion

The tube feet are the main locomotory structure. At the intersection of the lateral canal and the ampulla is a valve that traps water within the tube foot. The longitudinal muscles of the ampulla help push water into the foot, causing it to expand. At the tip of each foot is a suction cup that allows the tube foot to adhere to the substrate. Finally, the relaxation of the longitudinal muscles in the wall of the ampulla allows the foot to retract. The coordinated movement of hundreds of tube feet allows the starfish to move slowly forward. The fluid in the aquifer system is slightly hyperosmotic to seawater, reducing the chances of pressure loss within the system.

Respiration and Circulation

Diffusion plays an important role in echinoderm respiration. The epidermis bears ciliated dermal gills, where a countercurrent exchange takes place, allowing for greater diffusion. The tube feet also form an exchange surface. The internal tissues, however, are not in direct contact with seawater. The aquifer system,

whose internal surface is ciliated, serves as a circulatory system, allowing oxygen, nutrients, and wastes to pass from the epidermis to the internal tissues or vice versa.

Sea cucumbers have respiratory trees (tree-like organs) that communicate with the outside world through the cloaca.

Diet and Digestion

Starfish are predators. Their slow movements only allow them to catch prey that is even slower than themselves, such as mussels and oysters. They are able to crack open the shells of these mollusks using their tube feet, and then evaginate their cardiac stomach inside the shell of their prey. The digestive enzymes produced by the stomach digest and liquefy the prey's tissues, and the resulting "soup" is sucked into the starfish's digestive tract where digestion continues (in the pyloric stomach and ceca). The digestive tract branches into the starfish's arms, and this branching facilitates the transport of nutrients to all parts of the animal.

Sea urchins, belonging to the class Echinoidea, are grazers that feed on algae in the littoral zone of the oceans. Members of this class possess a characteristic structure, the Aristotle's

lantern, located in the mouth and formed of about forty ossicles forming five calcareous teeth connected by muscles. This structure is used to grind plant material.

Sea cucumbers are benthic and feed on sediment particles; they are suspension feeders. They have tentacles around their mouths that they spread over the surface of the sediment. The sediment particles stick to the mucus covering the tentacles, and the latter are regularly introduced into the digestive tract, allowing the animal to ingest the collected particles and re-coat the tentacles with mucus.

Excretion and Osmoregulation

Echinoderms lack an excretory system and expel their nitrogenous waste directly in the form of ammonia. They are exclusively marine animals, and their distribution is explained by the absence of a system ensuring osmoregulation

.

Senses and Nervous System

The sensory structures of echinoderms are dispersed throughout the animal, as one would expect from a radially symmetrical organism. The nervous system consists of two main elements: a central nerve ring and radial nerves. Starfish also have light-perceiving structures at the tips of their arms. These structures allow them to detect the surface, much like the statocysts of jellyfish.

PHYLUM ECHINODERMATA

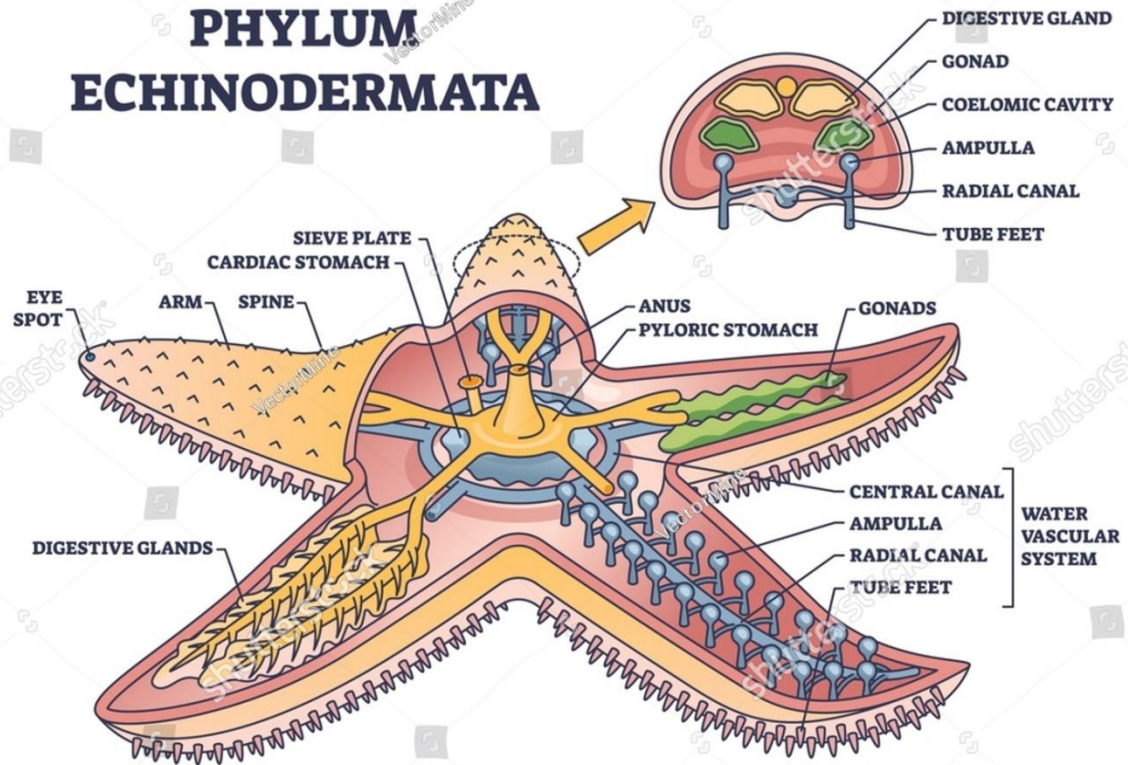
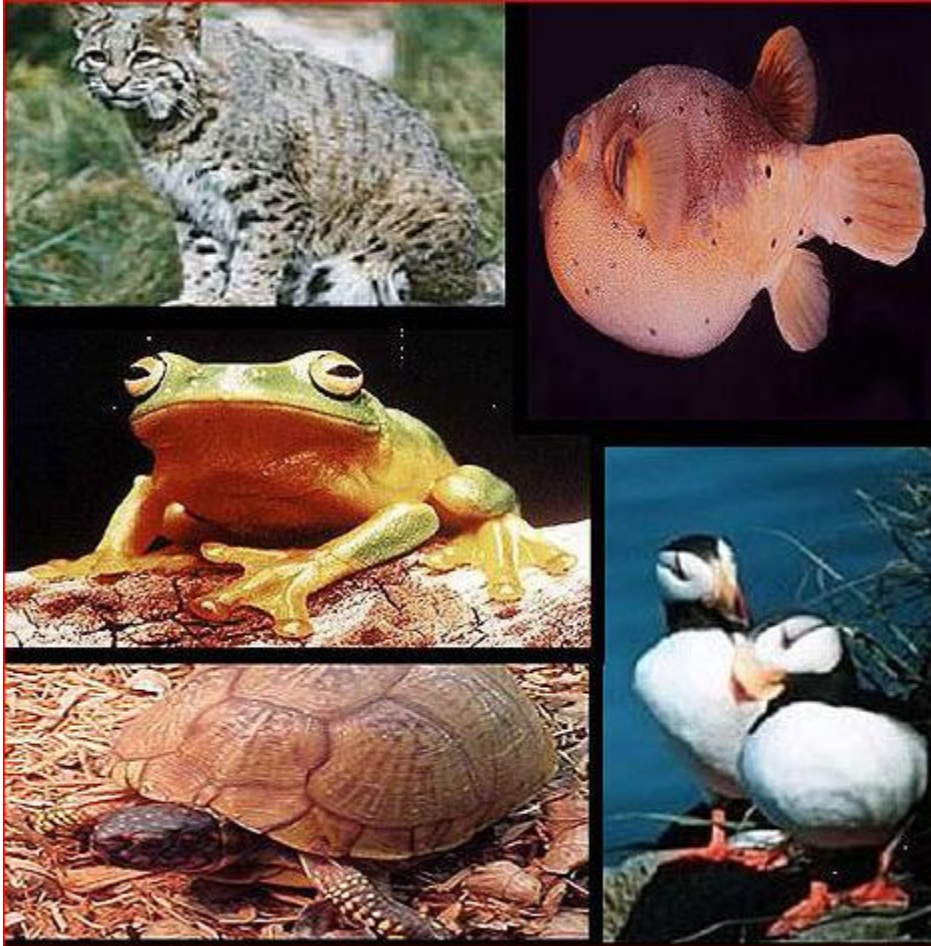


Figure38 : echinodermes anatomy

3.10. Chordate Phylum



Introduction

The Chordate Phylum (chordates) includes fish, mammals, reptiles, amphibians, and birds.

Chordates are higher metazoans, coelomates, triblastic, deuterostomes with bilateral symmetry.

The Chordate Phylum has over 45,000 species.

Triblastic; organisms have three tissues: ectoderm, mesoderm, and endoderm.

Protostomes: the mouth derives from the blastopore, which is the first opening to appear.

Deuterostomes: the mouth of these organisms appears second, hence the name deuterostome, second, -stome, mouth.

Classes of Phylum Chordata

Phylum Chordata is divided into three subphylas:

1. Urochordata (tunicates),
2. Cephalochordata (lancelets)
3. Vertebrata (vertebrates).

Subphylum Urochordata along with Cephalochordata are collectively referred to as protochordates. These are marine invertebrates. They are invertebrates, but they have the characteristics of chordates.

Urochordata

- The adults are attached to the substratum.
- It's also known as Tunicate since the adult's body is enclosed in the tunic, which is made of cellulose, a substance that is also known as tunicin.
- Notochords are only visible during the larval stage, and disappear when adults are born.
- The nerve that is present in the larva gets replaced by a dorsal-ganglion in adults.
- The larva moves and undergo a metamorphosis.
- For e.g., Ascidia, Salpa, Doliolum.

Cephalochordata

- The atrium is visible.

- The larval stage and the adult stage are both motile.
 - The tail is present all through the course of.
 - They display the progression of metamorphosis.
 - The notochord can be found in all aspects of all of.
 - Many well-developed pharyngeal gill openings are found.
 - For e.g., Lancelets possess the nerve cord and notochord throughout their lives.
- However, they don't have bone vertebral columns and brains similar to Branchiostoma.

Vertebrata

The distinctive features of vertebrates are:

- They are advanced chordates and contain craniums around the brain.
- The notochord is replaced with the vertebral column in adulthood. This is the reason why it's claimed that all vertebrates are chordates, but all chordates aren't vertebrates'.
- A high level of cephalization can be observed.
- The epidermis has multiple layers.
- They are composed of three kinds of muscles: unstriped, stripes and cardiac.
- They have a developed coelom.
- The alimentary canal has been made completely complete.
- The heart is a three-chambered or four-chambered.
- They have developed respiratory and excretory systems.

Subphylum Vertebrata It is also divided into 5 classes. They include:

- Fish
- Amphibia
- Reptilia
- Aves
- Mammalia

1. Class of fish



Fishes (class Pisces) are an **incredibly diverse superclass of cold-blooded, aquatic vertebrates** distinguished by a **streamlined body, fins** for propulsion and steering, and **gills** for respiration. Comprising over **36,100 described species**, they account for more than half of all known vertebrate life on Earth [7].

These fascinating creatures possess a unique suite of external characteristics that set them apart, including a lateral line system—a specialized sensory organ used to detect movement and pressure changes in the water—as well as a protective layer of scales. This broad group is organized into numerous orders, each with its own specialized adaptations and ecological niche, demonstrating a remarkable evolutionary success story spanning hundreds of millions of years.

The behavioral and reproductive strategies of fish are as varied as their physical forms, ranging from solitary hunters to species that form massive, coordinated schools. Their reproductive methods encompass a range of strategies, from laying vast numbers of eggs to giving birth to live young, demonstrating a remarkable adaptability to diverse aquatic environments.

Due to their critical position in aquatic food webs, both as predators and prey, fish are a cornerstone of ecosystem stability. This comprehensive guide will explore the diverse species, intricate characteristics, and many amazing facts that define this ubiquitous class of animals, providing an authoritative resource for enthusiasts, educators, and researchers alike.

The main types of fish are classified into three distinct superclasses: Agnatha, Chondrichthyes, and Osteichthyes, with over 36,100 species in total.

Osteichthyes (Bony Fishes): Comprising over 95% of all fish species, this is the largest group. They have a bony skeleton and a rigid operculum covering their gills, allowing them to breathe while stationary.

Chondrichthyes (Cartilaginous fishes): This class comprises about 3% of all fish species and includes sharks, rays, and skates. Their skeleton is made of cartilage, not bone. They have placoid scales, an oily liver for buoyancy, and are mainly found in marine environments.

Agnatha (jawless fish): This ancient group, representing less than 1% of all fish species, lacks jaws and features a cartilaginous skeleton. They include lampreys and hagfish, characterized by unique traits such as parasitic mouths and the production of slime.

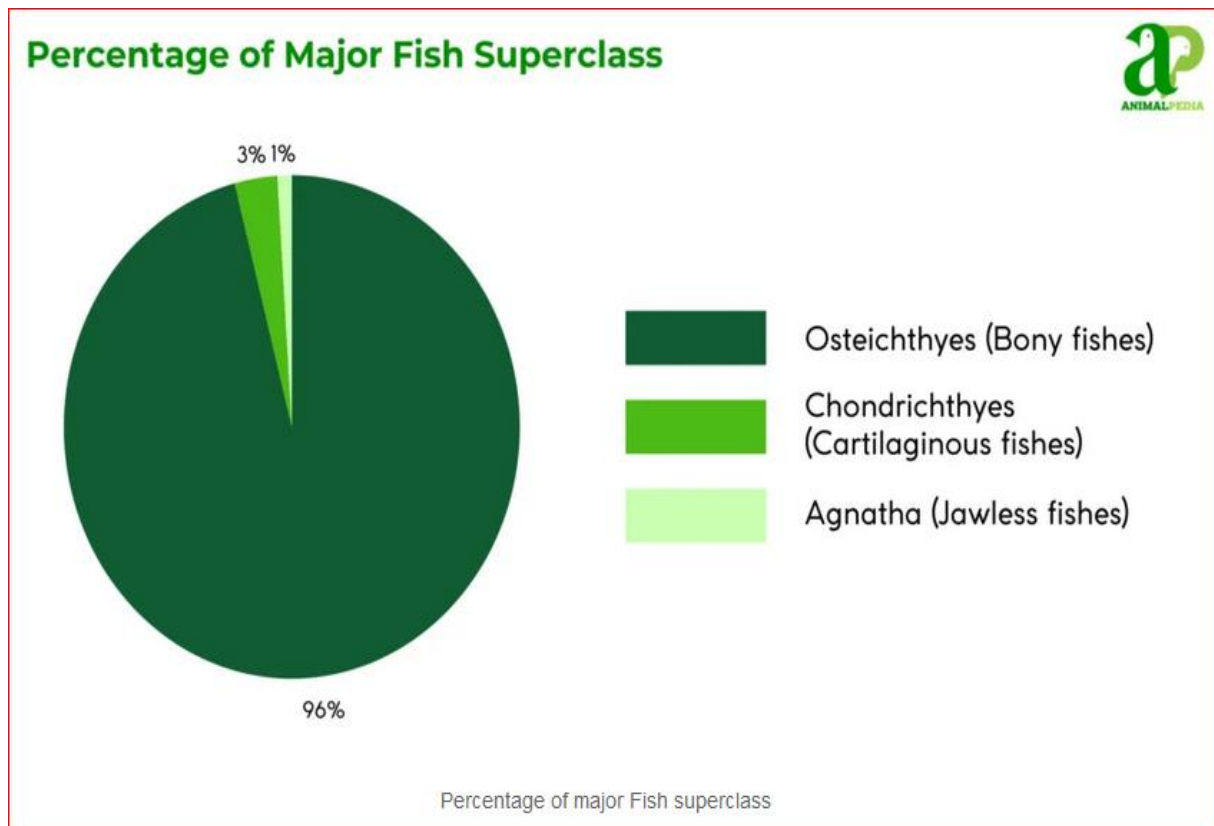


Figure 39 ; percentage of major fish superclass

Superclass Osteichthyes (Bony fishes)

The vast majority of fish, comprising over 33,000 species, fall into the superclass Osteichthyes, also known as bony fish. These are distinguished by a skeleton of bone and a rigid operculum that covers their gills.

This evolutionary innovation allows them to breathe without having to constantly swim, a significant advantage over their cartilaginous counterparts. Their physical characteristics are incredibly varied, from the torpedo-shaped bodies of tuna to the flattened form of flounder, all united by a bony internal structure.

This superclass is further divided into two major groups: the ray-finned fishes (Actinopterygii) and the lobe-finned fishes (Sarcopterygii). Bony fish occupy nearly every aquatic habitat imaginable, from shallow reefs to deep ocean trenches, and their ecological roles are equally diverse, from herbivorous grazers to formidable predators.



Figure40 ; Osteichthyes (Bony fishes) are vertebrates with bony skeletons, jaws, and paired fins, comprising most modern fish species

Superclass Chondrichthyes (Cartilaginous fishes)

Chondrichthyes are characterized by a skeleton composed of cartilage rather than bone, which gives them a lighter and more flexible body plan.

This group includes well-known predators such as sharks, rays, skates, and chimaeras, comprising about 1,200 species globally .A key physical trait is their unique placoid scales, often referred to as dermal denticles, which give their skin a rough, sandpaper-like texture and reduce drag.

Unlike other fish, they lack a swim bladder, instead relying on an oily liver for buoyancy. Their primary distribution is in marine environments, where many species, like the great white shark, are apex predators that play a vital role in maintaining the health of ocean ecosystems .(ferron *et al* 2019)



Figure 41 ; superclass chondrichthyes are jawed fishes with cartilaginous skeletons, including sharks, rays, and skates

Superclass Agnatha (Jawless fishes)

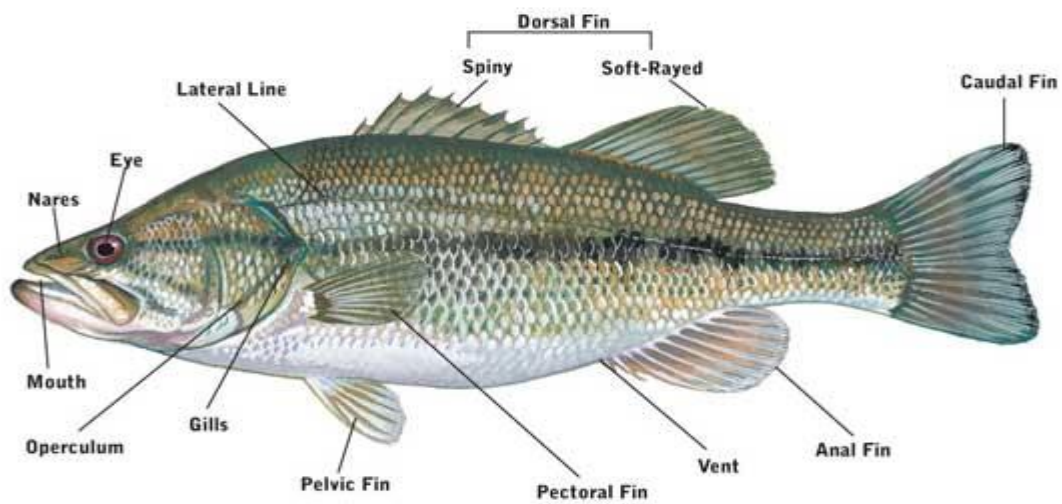
This ancient group represents the earliest vertebrates, characterized by the absence of jaws and a skeleton composed entirely of cartilage. Despite their primitive appearance, these fish are highly adapted to their specific ecological niches. With fewer than 130 extant species, they are a minor yet crucial group in the phylogenetic tree of vertebrates (Kolmann A *et al* 2020).

The two main suborders are the parasitic lampreys and the scavenging hagfish. For instance, a sea lamprey (*Petromyzon marinus*) uses a sucker-like mouth filled with sharp teeth to attach to and feed on other fish.

Hagfish are renowned for their ability to produce copious amounts of slime as a defense mechanism, a truly unique physical trait. Their distribution is global, with them inhabiting both marine and freshwater environments



Figure 42; Agnatha (Jawless fishes) are primitive fishes without jaws, paired fins, or stomachs, such as hagfish and lampreys



Fish Skeletal System

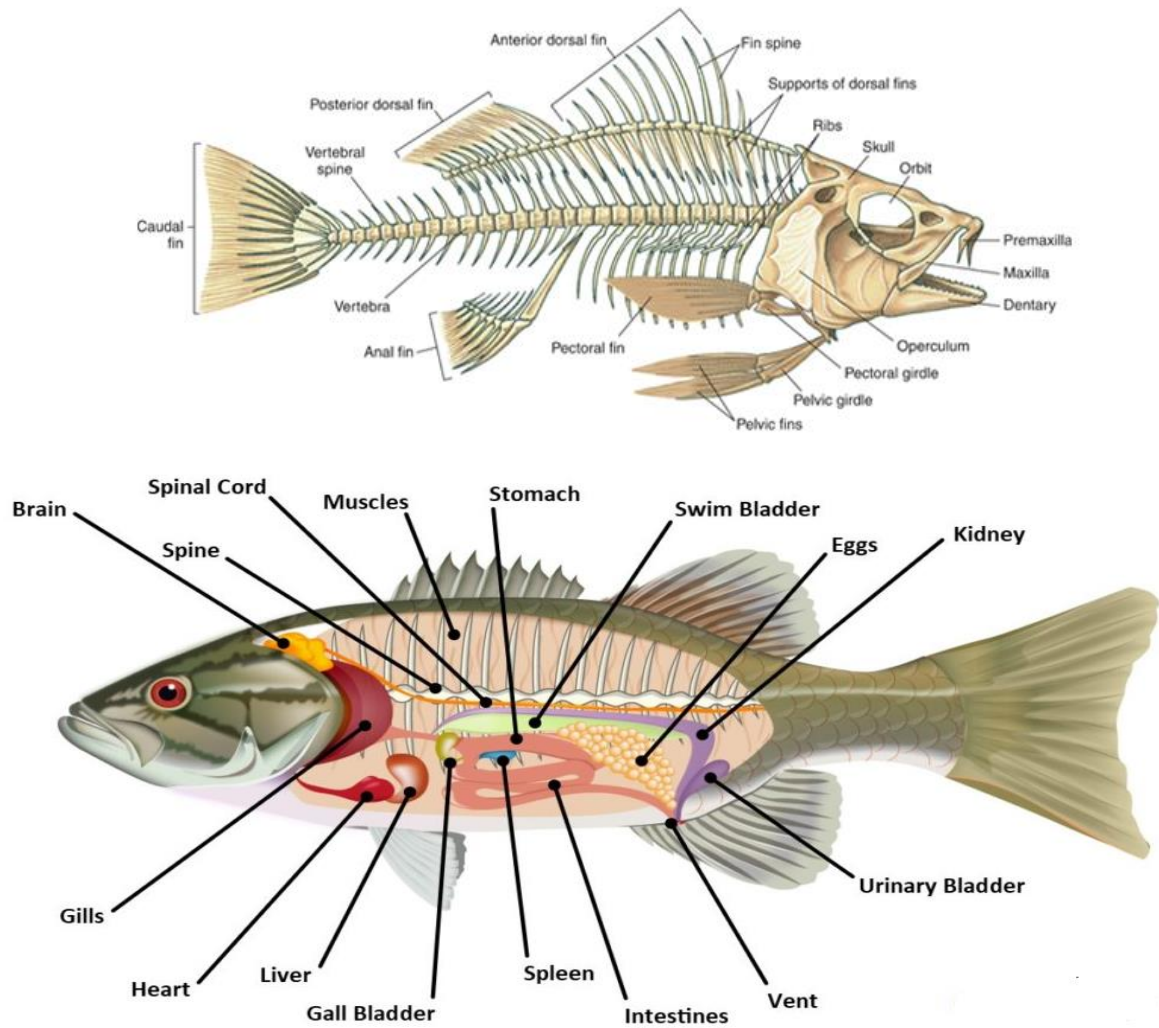


Figure 39: Fish morphology ,skeleton and anatomy

2. CLASS MAMMALS



General Characteristics

- Most evolved tetrapod vertebrates
- Presence of hair (reduced in some forms)
- Homeothermic
- Heart with 4 lobes, respiration with lungs
- Highly developed brain
- Separate sexes
- Embryonic development in the uterus with placenta

Mammals are therefore endothermic, homeothermic vertebrates, covered with hair, and characterized by the presence of mammary glands.

Locomotion

The locomotory limbs of mammals have a surprising variety of forms. Burrowing animals, such as moles, have short, powerful limbs that allow them to dig quickly in the ground.

Hopping animals, such as kangaroos, have hypertrophied hind legs. Running animals or those that move around a lot (caribou) have slender limbs that allow them to take large strides.

Respiration and Circulation

The skin of mammals is formed of several layers of dead cells, which reduces water loss in terrestrial environments but limits gas exchange through the skin. Air is drawn into the lungs through the action of the diaphragm and intercostal muscles. The air first passes through the nasal passages where it is warmed and moistened, then into the trachea and bronchi, which are covered with cilia that repel particles.

Food Habits

As a group, mammals eat an enormous variety of organisms. Many mammals can be carnivores (e.g., most species within Carnivora), herbivores (e.g., Perissodactyla , Artiodactyla), or omnivores (e.g., many primates). Mammals eat both invertebrates and vertebrates (including other mammals), plants (including fruit, nectar, foliage, wood, roots, seeds, etc.) and fungi. Being endotherms, mammals require much more food than ectotherms of similar proportions. Thus, relatively few mammals can have a large impact on the populations of their food items.(Wilson, D et a 1993) .

Development

There are three major groups of mammals, each is united by a major feature of embryonic development. Monotremes (Prototheria) lay eggs, which is the most primitive reproductive condition in mammals. Marsupials (Metatheria) give birth to highly altricial young after a very short gestation period (8 to 43 days). The young are born at a relatively early stage of morphological development. They attach to the mother's nipple and spend a proportionally greater amount of time nursing as they develop. Gestation lasts much longer in placental mammals (Eutheria). During gestation, eutherian young interact with their mother through a placenta, a complex organ that connects the embryo with the uterus. Once born, all mammals are dependent upon their mothers for milk. Aside from these few generalities, mammals exhibit a diversity of developmental and life history patterns that vary among species and larger taxonomic groups. (Vaughan, T et al 2000).

Reproduction

Generally, most mammalian species are either polygynous (one male mates with multiple females) or promiscuous (both males and females have multiple mates in a given reproductive season). Because females incur such high costs during gestation and lactation, it is often the case that male mammals can produce many more offspring in a mating season than can females. As a consequence, the most common mating system in mammals is polygyny, with relatively few males fertilizing multiple females and many males fertilizing none. This scenario sets the stage for intense male-male competition in many species, and also the potential for females to be choosy when it comes to which males will sire her offspring. As a consequence of the choices females make and the effort males put into acquiring matings, many mammals have complex behaviors and morphologies associated with reproduction. Many mammal groups are marked by sexual dimorphism as a result of selection for males that can better compete for access to females. (Wilson, D et al 2005).

About 3 percent of mammalian species are monogamous, with males only mating with a single female each season. In these cases, males provide at least some care to their offspring. Often, mating systems may vary within species depending upon local environmental conditions. For example, when resources are low, males may mate with only a single female and provide care for the young. When resources are abundant, the mother may be able to care for young on her own and males will attempt to sire offspring with multiple females.

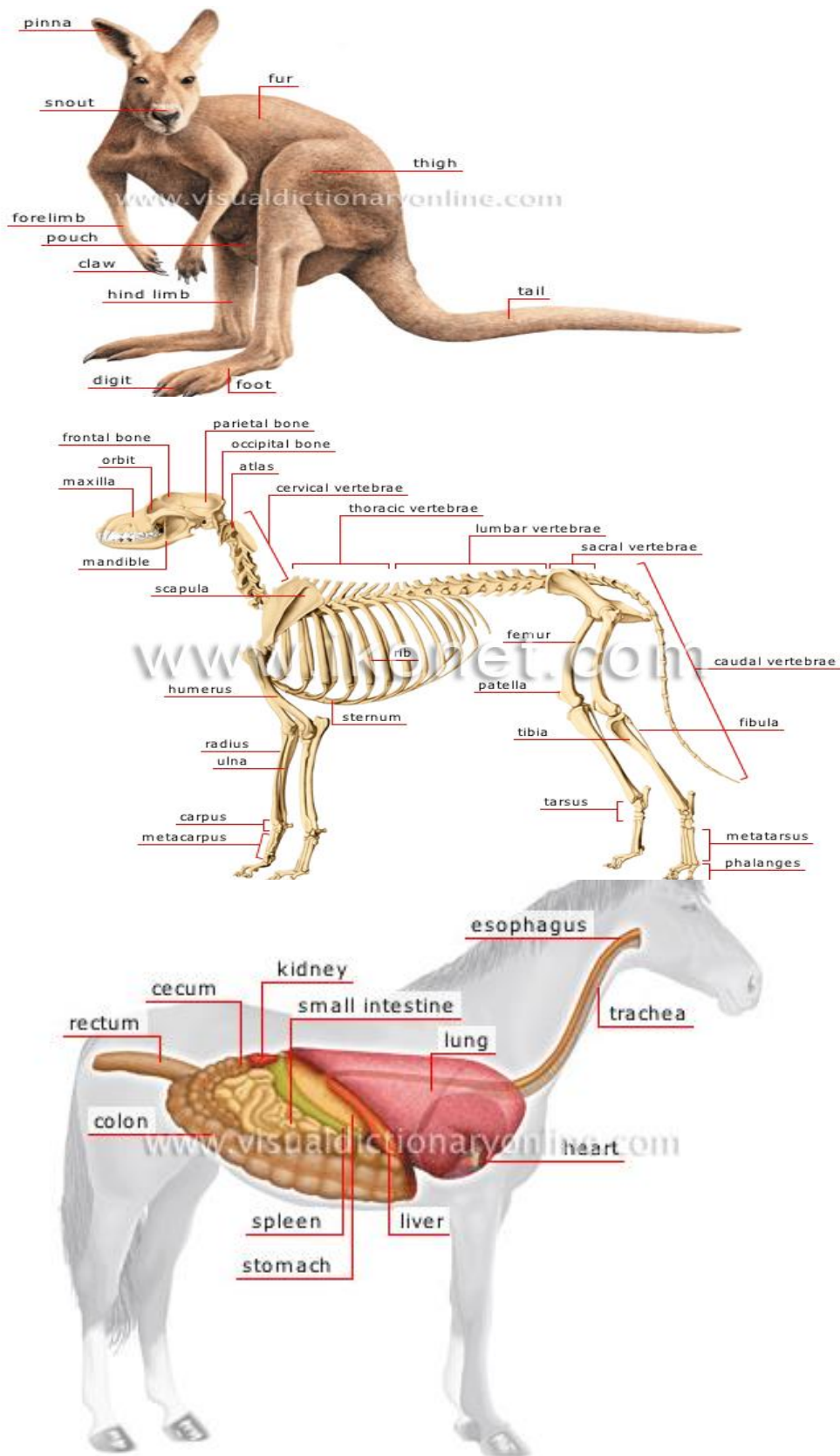


Figure 44 : mammals morpholog, skeleton and anatomy

Class: Mammalia

- | — **Subclass Prototheria** (Egg-laying mammals)
 - | — **Order Monotremata** (5 species, including Platypus and Echidnas)
 - | — Family: Ornithorhynchidae (Platypus)
 - | — Family: Tachyglossidae (Echidnas)
- | — **Subclass Metatheria** (Marsupials)
 - | — **Order Diprotodontia** (~143 species, including Kangaroos, Koalas)
 - | — Family: Macropodidae (Kangaroos, Wallabies)
 - | — Family: Phascolarctidae (Koalas)
 - | — Family: Vombatidae (Wombats)
 - | — **Order Dasyuromorphia** (~71 species, including Tasmanian Devil)
 - | — Family: Dasyuridae (Marsupial carnivores)
- | — **Subclass Eutheria** (Placental mammals)
 - | — **Order Rodentia** (~2,277 species, including Rats, Squirrels)
 - | | — Family: Muridae (True Mice and Rats)
 - | | — Family: Sciuridae (Squirrels)
 - | | — Family: Cricetidae (Hamsters, Voles)
 - | — **Order Chiroptera** (~1,400 species, including Bats)
 - | | — Family: Pteropodidae (Fruit Bats)
 - | | — Family: Vespertilionidae (Evening Bats)
 - | — **Order Carnivora** (~286 species, including Lions, Wolves)
 - | | — Suborder: Feliformia (Cat-like carnivores)
 - | | | — Family: Felidae (Cats)
 - | | | — Family: Herpestidae (Mongooses)

- | | | └─ Family: Hyaenidae (Hyenas)
- | | └─ Suborder: Caniformia (Dog-like carnivores)
- | | | └─ Family: Canidae (Dogs, Wolves, Foxes)
- | | | └─ Family: Ursidae (Bears)
- | | | └─ Family: Mustelidae (Weasels, Otters)
- | └─ **Order Primates** (~511 species, including Humans, Gorillas)
- | | └─ Suborder: Strepsirrhini (Lemurs and Lorises)
- | | | └─ Family: Lemuridae (Lemurs)
- | | └─ Suborder: Haplorhini (Monkeys and Apes)
- | | └─ Family: Hominidae (Great Apes, including Humans, Gorillas)
- | | └─ Family: Cercopithecidae (Old World Monkeys)
- | └─ **Order Cetacea** (~90 species, including Whales, Dolphins)
- | | └─ Family: Balaenopteridae (Rorquals, including Blue Whale)
- | | └─ Family: Delphinidae (Dolphins)
- | └─ **Order Artiodactyla** (~349 species, including Deer, Cattle)
- | | └─ Family: Bovidae (Cattle, Antelopes)
- | | └─ Family: Cervidae (Deer)
- | └─ **Order Perissodactyla** (~17 species, including Horses, Rhinos)
- | | └─ Family: Equidae (Horses, Zebras)
- | | └─ Family: Rhinocerotidae (Rhinoceroses)
- | └─ **Order Proboscidea** (3 species, including Elephants)
- | └─ Family: Elephantidae (African and Asian Elephants)

2. Class of Birds



Birds can almost be defined as specialized reptiles because their architecture is similar to that of reptiles, and the modifications can be related to flight. Birds are endothermic homeotherms that have feathers. Their forelimbs are modified for flight, and their hindlimbs for walking, swimming, or perching.

Characteristics of Aves

Birds are warm-blooded animals.

Their forelimbs are modified into wings.

They have well-developed flight muscles that help during the flight.

Their hind limbs are adapted for walking, hopping, perching, grasping, wading and swimming.

There are epidermal scales on their legs.

The endoskeleton is bony with long hollow bones filled with air cavities. known as pneumatic bones.

Their spindle-shaped body minimizes resistance of the wind.

The feathers help in preventing heat loss and reduce air friction by providing passage to the air.

There is no skin gland except the oil gland.

The lower and upper jaws are modified into a beak.

They have no teeth.

They have sharp eyesight.

The alimentary canal has a crop and a gizzard. The crops help in softening food, and the gizzard helps in crushing the food.

Pigeons and other seed-eating birds lack a gall bladder.

They have spongy and elastic lungs for respiration.

The special vocal organ called syrinx is present at the base of trachea.

Their heart is four-chambered.

RBCs are oval, nucleated and biconvex.

12 pairs of cranial nerves are present.

They have a single ovary and oviduct on the left side

All the birds are oviparous and exhibit sexual dimorphism. The eggs have four embryonic membranes- amnion, chorion, allantois, and yolk sac

Modifications Associated with Flight

Flight requires a very high metabolic rate, and the forces exerted by the wing muscles are also significant. Therefore, birds have adaptations to increase the metabolic rate that can be sustained, to reduce unnecessary metabolic expenditure (weight reduction), to increase the efficiency of the cardiovascular system (to maintain a high metabolism), and to strengthen the skeleton.

Respiration and Circulation

The presence of feathers reduces epidermal ventilation and prevents birds from breathing through their skin.

Their high metabolic needs (6 to 10 times those of a reptile of similar size) have led to changes in their respiratory and circulatory systems.

Diet and Digestion

Birds have high metabolic needs and must therefore feed on rich foods. The first birds were probably insectivores, but the diet of modern birds is very varied (granivores, piscivores, carnivores, scavengers, frugivores). Dietary specialization is accompanied by modifications to the beak and digestive tract. For example, granivorous birds, such as chickens, have a robust beak for breaking seeds, a crop for storing them, and a gizzard that typically contains pebbles for grinding them (birds have no teeth).

Excretion and Osmoregulation

Seabirds have salt glands similar to those of iguanas to excrete excess ions.

Nervous System

Flight requires very good vision and coordination; The areas of the brain responsible for these aspects are therefore particularly developed in birds. The eyes are highly developed, and their position is linked to diet. In herbivorous birds, the eyes are located on either side of the head, allowing them to have a very wide field of vision and see predators approaching. In birds of prey, the eyes are located at the front, allowing for better binocular vision and better judgment of distances and speeds.

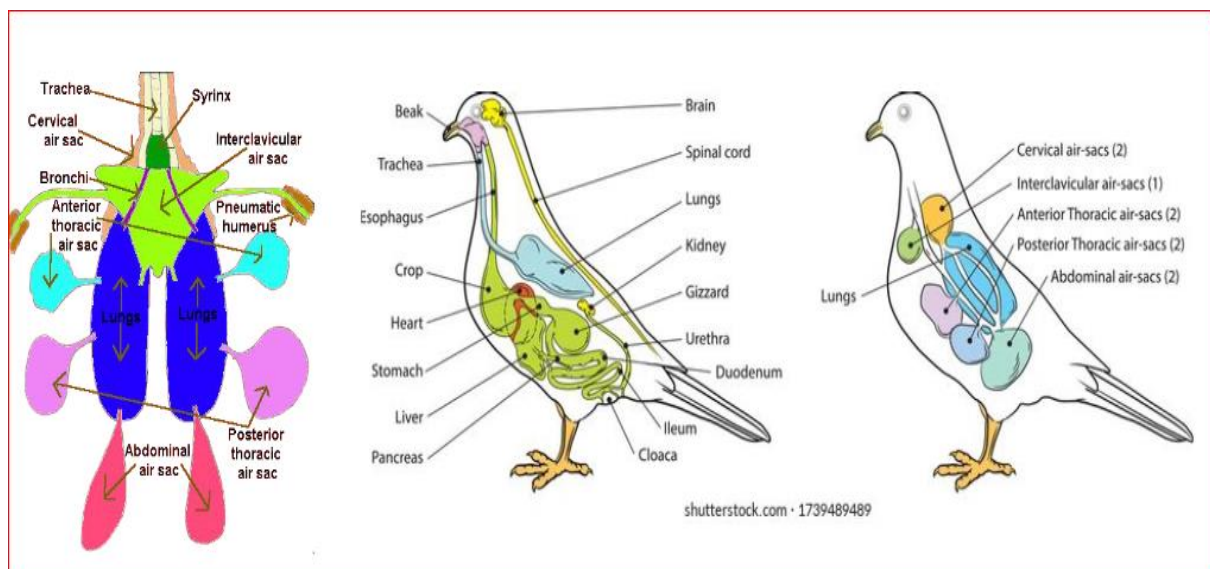
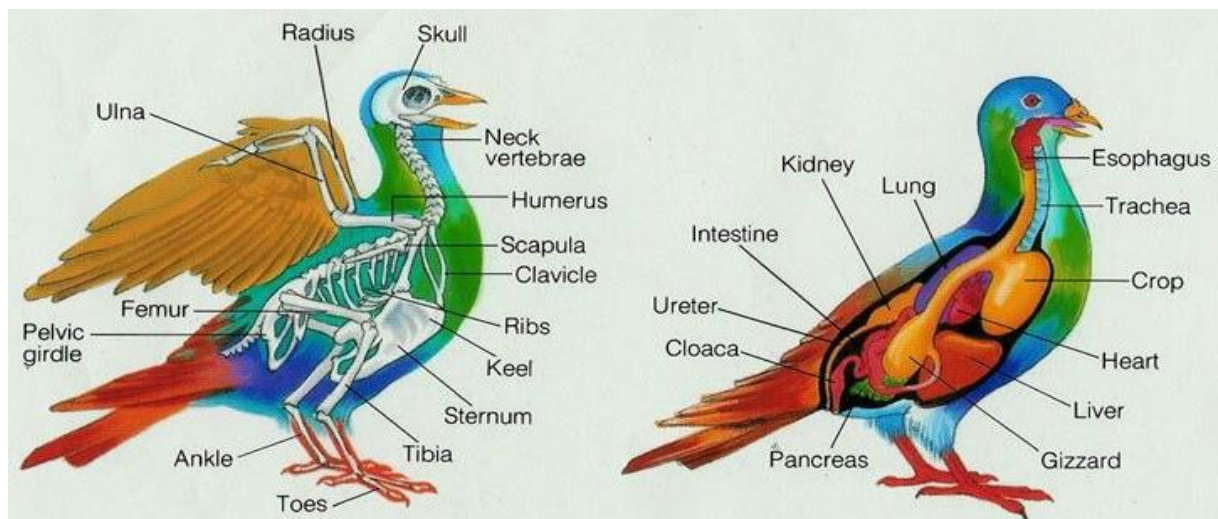
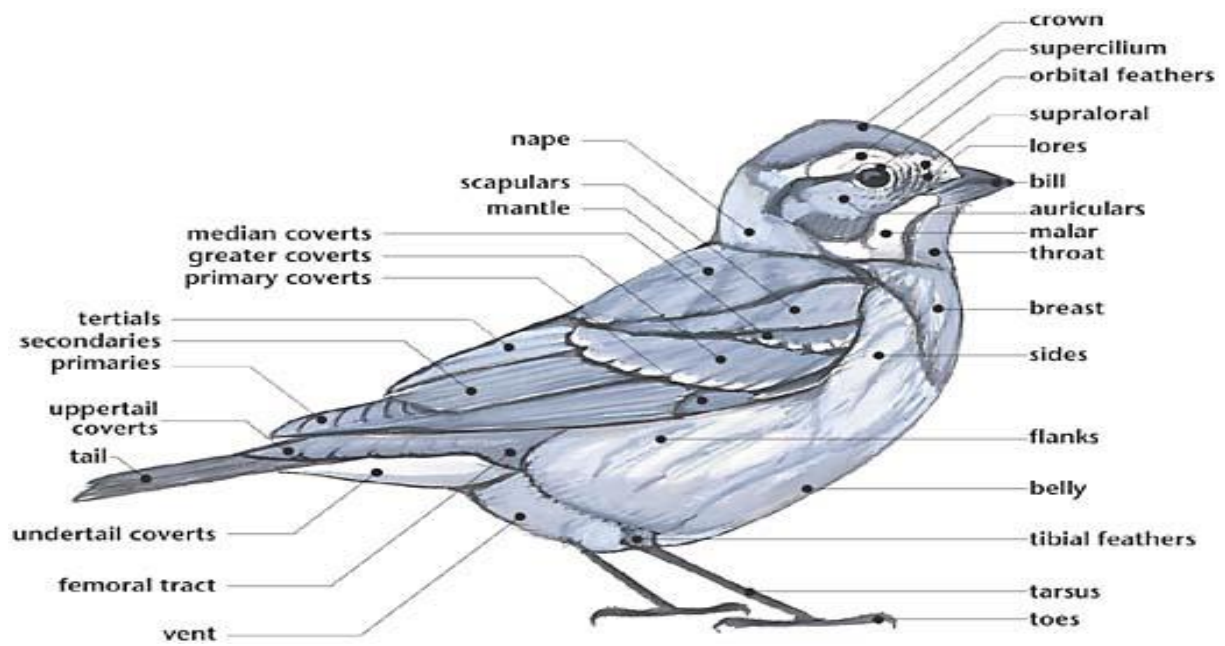


Figure 45: Birds morphology ,skeletonand anatomy

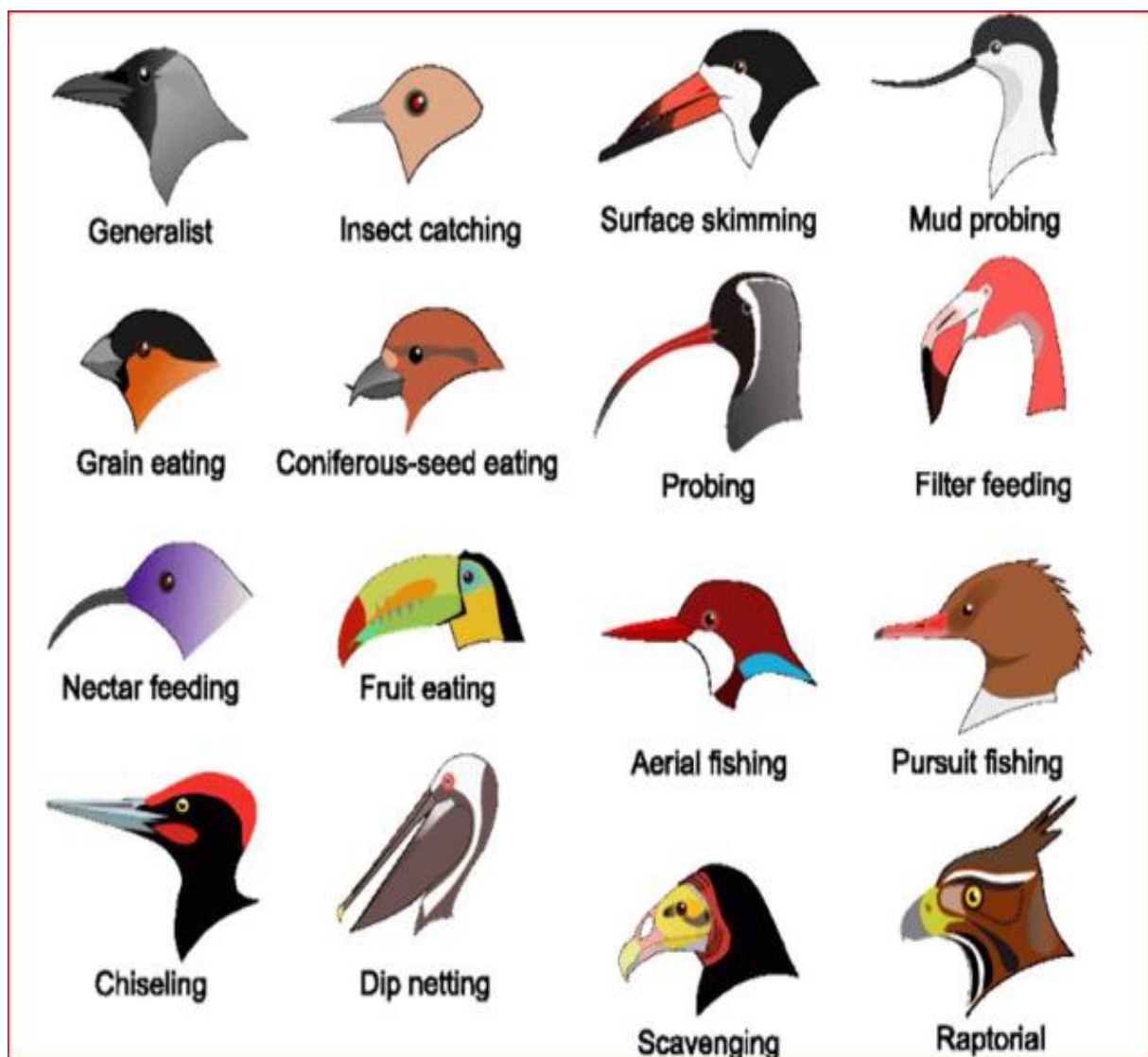
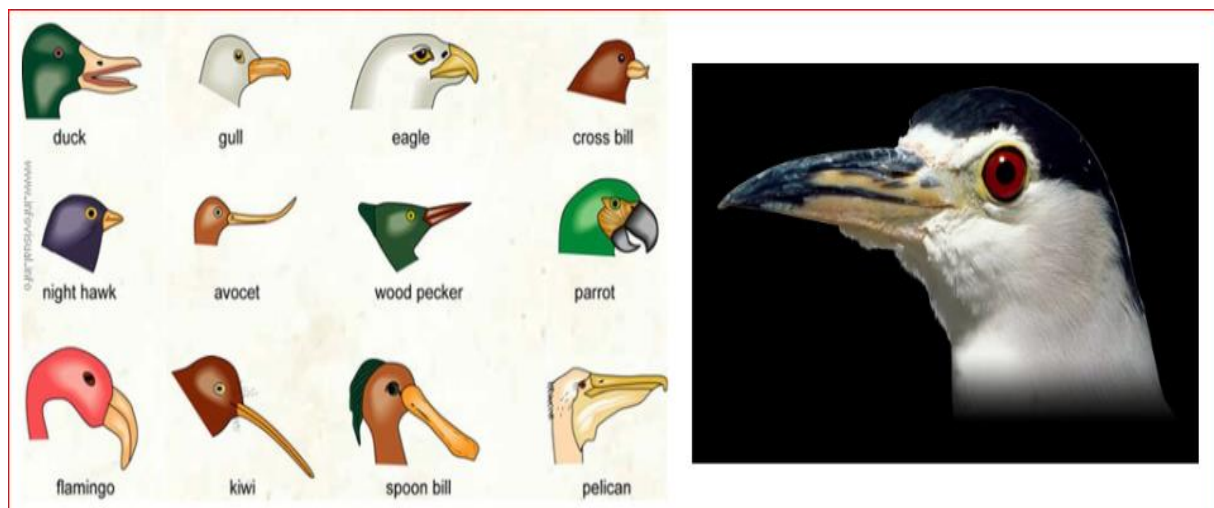


Figure 46: Birds Beaks morphology

3. Class of Amphibians



Amphibians illustrate the architecture of vertebrates in transition between aquatic and terrestrial environments. It is among amphibians that the important characteristics of terrestrial vertebrates appear: tetrapod architecture, modifications to the axial skeleton, and the development of lungs and a dual circulatory system. However, adaptations to life in a terrestrial environment are not complete among amphibians, as demonstrated by their need to return to the aquatic environment to reproduce.

Characteristics of Class Amphibia

The characteristics of the organisms present in class amphibia are as follows:

1. These can live both on land and in water.
2. They are ectothermic animals, found in a warm environment.
3. Their body is divided into head and trunk. The tail may or may not be present.
4. The skin is smooth and rough without any scales, but with glands that make it moist.
5. They have no paired fins. Unpaired fins might be present.
6. They have two pairs of limbs for locomotion.
7. They respire through the lungs and skin. Gills might be present externally in some adults.
8. The heart is three chambered.
9. The kidneys are mesonephric. The excretory material includes ammonia and urea.
10. They possess ten pairs of cranial nerves.
11. The lateral line is present during their development.
12. The sexes are separate and fertilization is usually external. However, in salamanders, the fertilization is internal.
13. Development is indirect with metamorphosis.
14. Breeding occurs in water. The copulatory organs are absent in males.
15. Eg., Frogs, Salamanders.

Classification of Amphibia

The Amphibians are divided into three orders. The classification of amphibia is given below:

Apoda (Gymnophiona or Caecilia)

- Apoda means “without legs”. These are limbless organisms with scales on their body.

- They are also known as “blind-worms” because their eyes are covered by skin or bone.
- The tentacles on their head are the chemosensory organs that help them to detect the underground prey. Eg., Caecilians
- They possess venom glands.
- They secrete mucus to reduce water loss.

Urodela (Caudata)

- These are the organisms with a tail.
- The body is elongated with four equally sized limbs.
- The skin is smooth with poison glands.
- Fertilization is internal.
- They feed on insects and worms. Eg., Salamanders
- They are found under leaf litter, in the soil, or in water.
- In the southern US, they reproduce primarily in winters.
- Very little differences between male and female.
- Spermatophores are utilized for internal fertilization.
- They possess hidden gills.

Anura (Salientia)

- There are around 3400 species of Anura in the world.
- They have four limbs. The front limbs are elongated and modified to jump.
- The head and trunk are fused together.
- The tail is present only in the larval stage and is lost in the adults.
- Fertilization is external and the eggs are laid in water. Eg., frogs and toads.

Respiration and Circulation

Aquatic forms of amphibians have gills. These gills can be external, as in the newt, or internal, as in the tadpole.

In frogs, the metamorphosis from tadpole to frog is accompanied by significant respiratory changes. The gills disappear and are replaced by simple but well-vascularized lungs. These lungs are ventilated by a mouth pump powered by the throat muscles. This ventilation mechanism is relatively inefficient compared to that of mammals, especially birds.

Diet and Digestion

Most adult amphibians have teeth, which they use primarily to hold their prey, which is swallowed whole. Frogs capture their prey (usually insects) using their tongue, which is attached to the front of the mouth and folded back when at rest.

Excretion and Osmoregulation

Excretion is accomplished by the kidneys. Aquatic larvae and adults usually excrete ammonia. Most terrestrial adults excrete their nitrogenous wastes as urea. Metamorphosis in frogs is accompanied by changes in kidney physiology and a shift from excreting wastes as ammonia to excreting urea.

Reproduction

Amphibian eggs cannot withstand desiccation. Reproduction therefore occurs in aquatic environments, and the distribution of these animals is limited by water availability. Gametes are released into the water, and fertilization occurs externally.

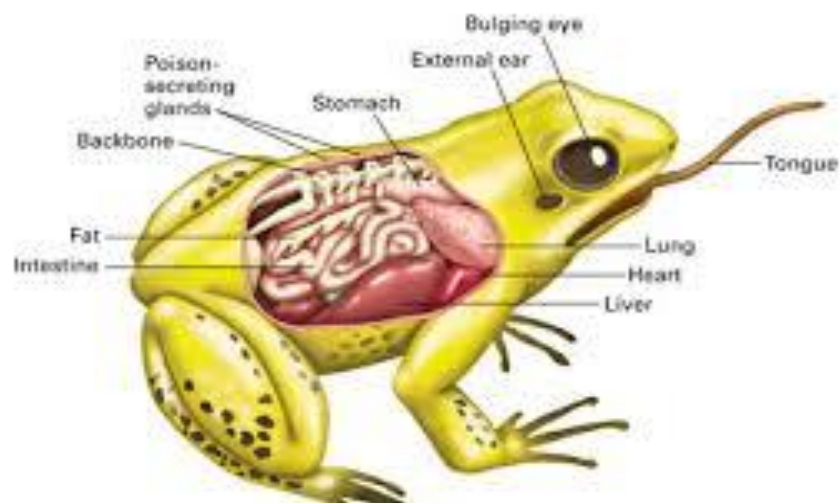
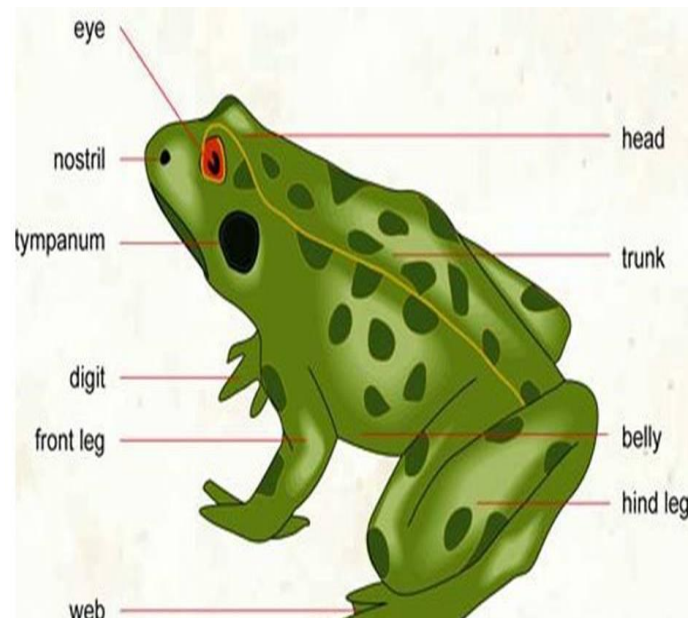
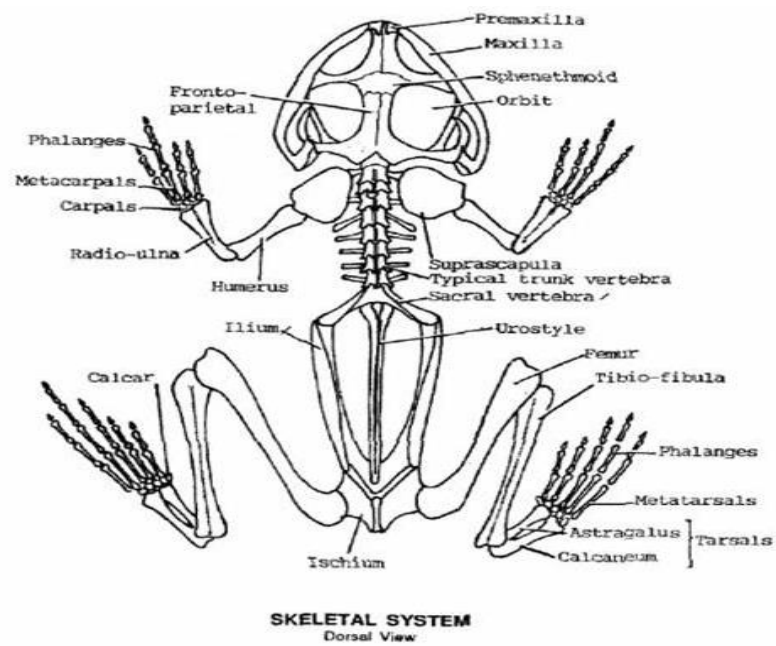


Figure 47: Amphibians skeleton, morphology and anatomy-

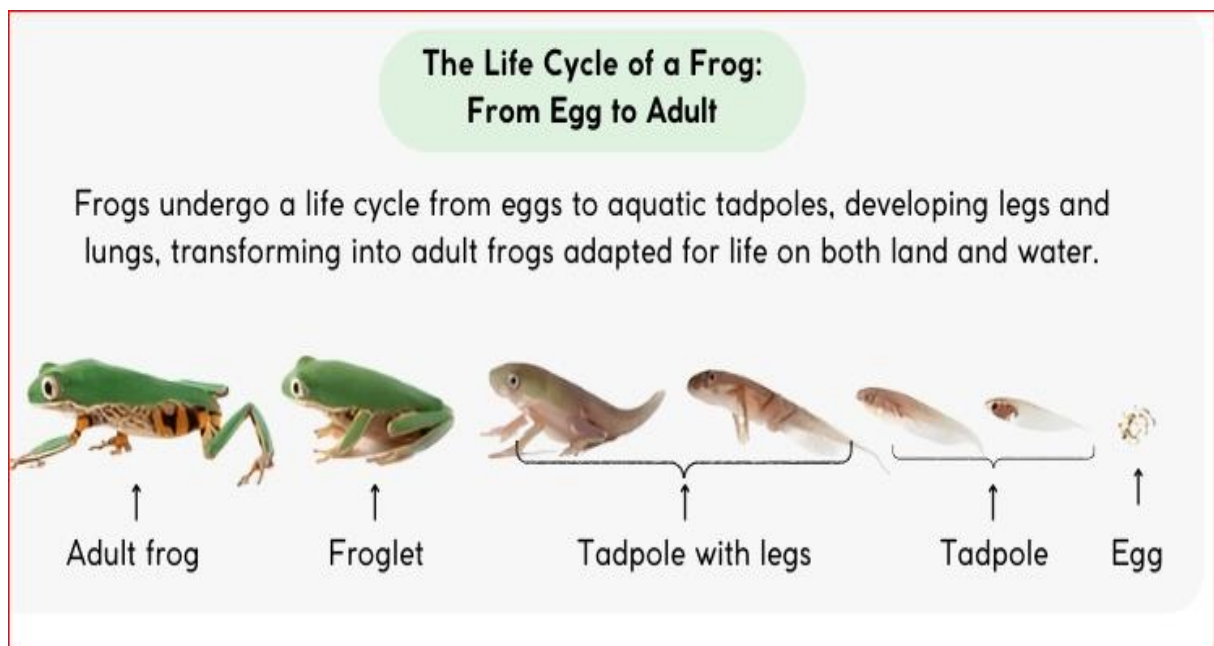


Figure48 ; life cycle of frog

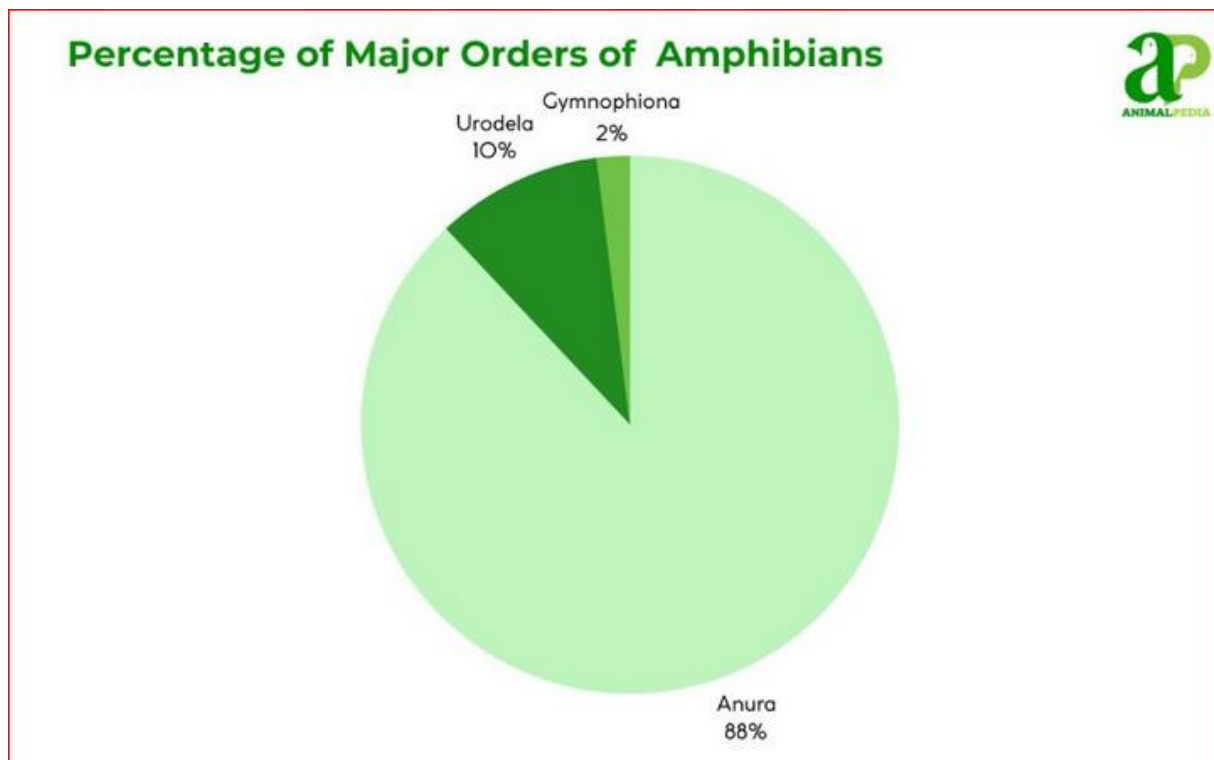
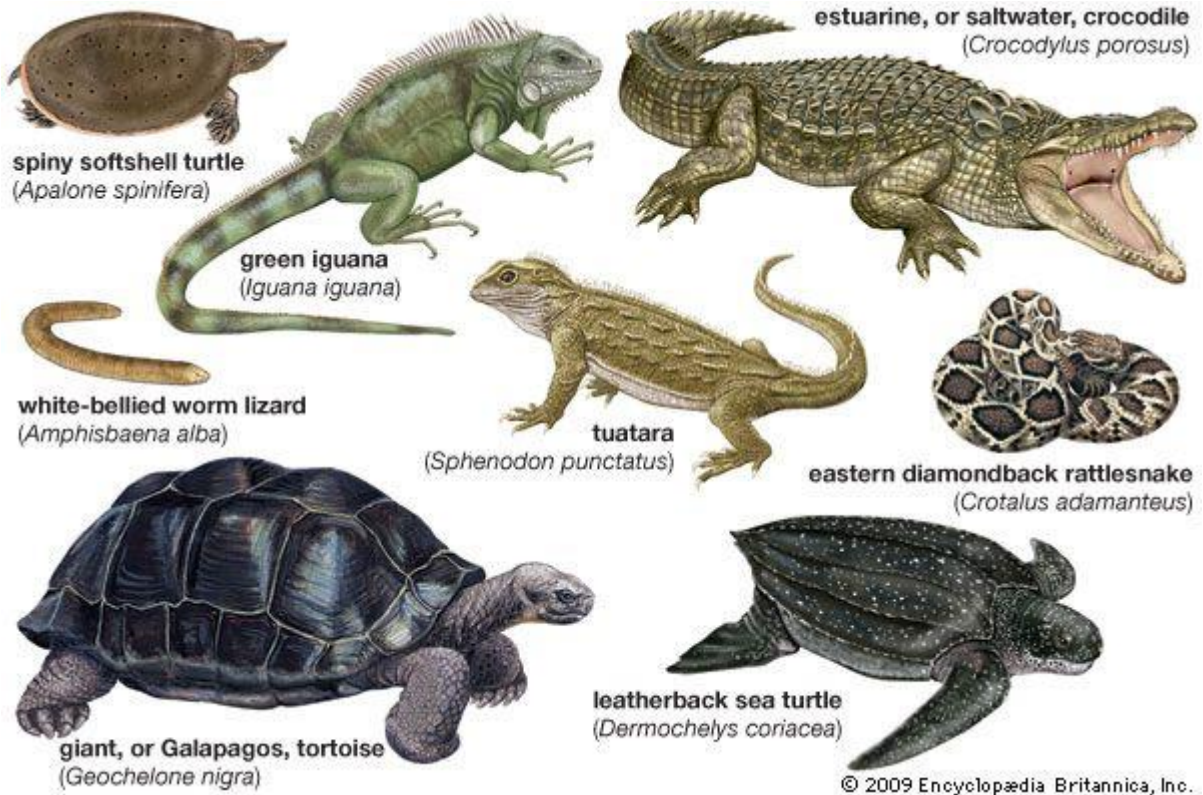


Figure 49 ; percentage of major orders of amphibians

4. Class of Reptiles



Reptiles (Class Reptilia) are a diverse group of cold-blooded, ectothermic, vertebrate animals characterized by breathing with lungs and possessing scaly skin . This ancient lineage, comprising over 11,000 extant species, distinguishes itself from other animal classes through several key external features, notably the presence of epidermal scales or scutes that provide protection and prevent desiccation, a unique adaptation for terrestrial life(Pough, F et al 2019)

Unlike amphibians, reptiles typically lay amniotic eggs with leathery or calcareous shells, freeing them from aquatic environments for reproduction, a significant evolutionary advancement

The class Reptilia is broadly divided into four main extant orders: Crocodilia (alligators, crocodiles, gharials, and caimans), Squamata (lizards, snakes, and amphisbaenians), Testudines (turtles and tortoises), and Rhynchocephalia (tuataras) (Uetz, P et al 2024)

These animals exhibit a vast array of behavioral features, from the highly social dynamics of some crocodilians to the solitary hunting strategies of many snakes, and their reproductive methods vary from oviparity (egg-laying) to viviparity (live-bearing), playing crucial ecological roles as both predators and prey across diverse biomes . This comprehensive guide will delve into the myriad species, distinctive characteristics, and fascinating facts that define this group.

Classification

1-Testudines

Turtles are a very ancient group of reptiles, which today includes approximately 330 species spread across 14 families. They are characterized in particular by their shells, which protect them from predators.

2.Order of Squamata

The group of squamates is the group with the greatest diversity 9,000 species

- *Gecko* Legs allow them to climb on surfaces.
- Iguanas and chameleons are semi-arboreal tetrapod reptiles, terrestrial or marine, which feed mainly on plants and insects.
- *Snakes*;

Legless animals move along the ground by crawling using the contractions of their ribs.

Venom fangs

3-Crocodylians

4.Order - Rhynchocephala

Represented by two species belonging to the genus Sphenodon

Reptiles Class Reptilia are classified into **four primary orders: Squamata, Testudines, Crocodilia, and Rhynchocephalia**, containing over 11,000 species worldwide as documented in global assessments (1).

- **Squamata**, which includes lizards, snakes, and amphisbaenians, is the most successful group. With over 10,000 species, they make up about 93% of all living reptiles.
- **Testudines** is the order for turtles and tortoises. There are around 360 species, accounting for 4% of reptile diversity.
- **Crocodilia** includes alligators, crocodiles, caimans, and gharials. This group has 28 species, representing 2% of the total.
- **Rhynchocephalia** is a very special group, with only two surviving tuatara species. They are found exclusively in New Zealand.

The overwhelming dominance of the Squamata highlights their evolutionary success and adaptive radiation, allowing them to occupy nearly every terrestrial and many aquatic habitats globally. This broad classification provides a framework for understanding the incredible array of forms and functions within the reptilian lineage, leading us to a more detailed examination of each distinct order.

Squamata represents the largest order of reptiles, comprising the majority of all reptile species. Reptiles Class Reptilia are classified into four primary orders: Squamata, Testudines, Crocodilia, and Rhynchocephalia, containing over 11,000 species worldwide as documented in global assessments (1).

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Crocodylia includes alligators, crocodiles, caimans, and gharials. This group has 28 species, representing 2% of the total.

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percentage of major orders of reptiles

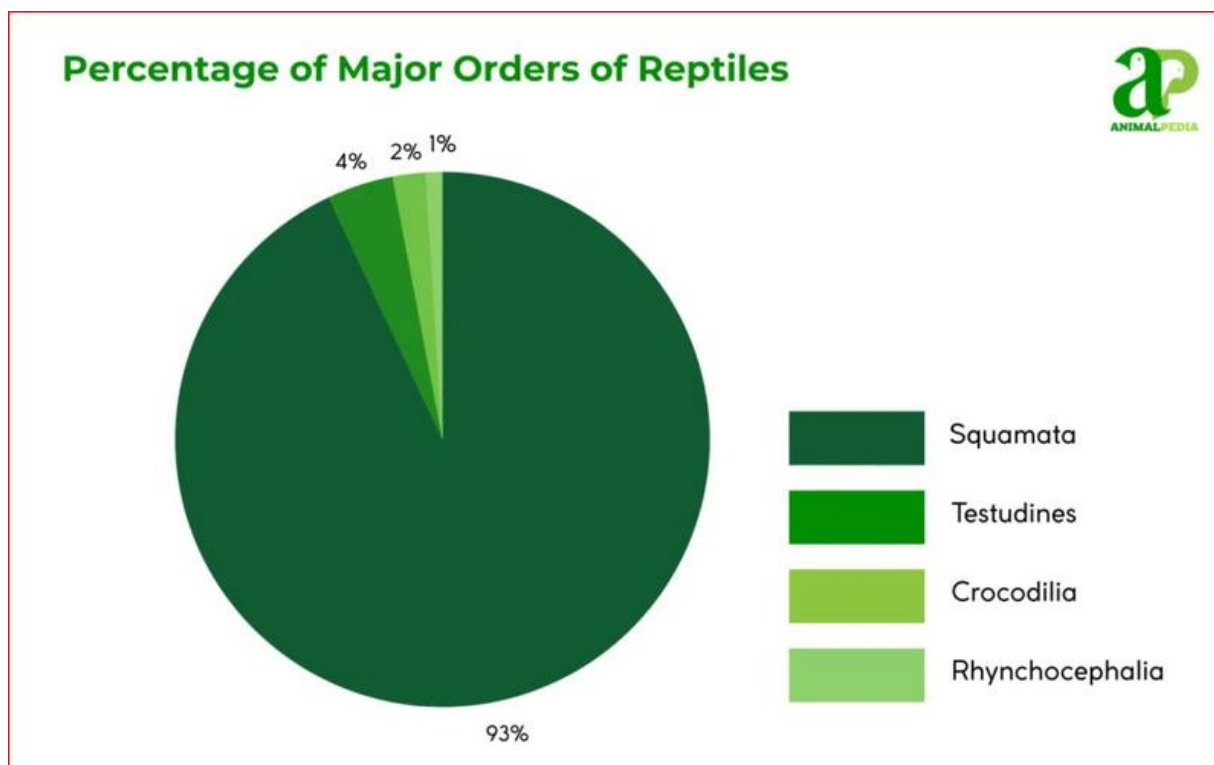


Figure 50; Squamata represents the largest order of reptiles, comprising the majority of all reptile species

Respiration and Circulation

The presence of impermeable skin prevents cutaneous respiration in reptiles. This loss is compensated for by an improvement in the efficiency of the lungs and circulatory system. Lung ventilation is ensured by the contraction of the intercostal and abdominal muscles in

most reptiles. In turtles, the dorsal carapace and ventral plastron prevent movement of the rib cage, and the movements of the pectoral and pelvic girdles ensure inflation and deflation of the lungs.

Diet and Digestion

Most reptiles are carnivores. Their main adaptations are teeth and jaw modifications that allow them to swallow large prey.

Crocodiles and most lizards have multiple similar teeth (they are homodonts). In crocodiles, these teeth are deeply embedded in the jaw, reducing the chances of them being torn out during a fight with prey.

Excretion and Osmoregulation

Reptiles excrete their nitrogenous waste in the form of uric acid, which allows them to conserve precious water in dry environments. Marine reptiles have salt glands on their heads to get rid of excess ions.

Reproduction

Fertilization is internal in reptiles. Gametes are therefore not exposed to the harsh conditions of the terrestrial environment. Reptiles lay amniotic eggs. The embryo is surrounded by a membrane (the amnion) containing the amniotic fluid. Two membranous sacs are attached to the embryo: the yolk sac and the allantois. The yolk sac contains the yolk (yolk) that nourishes the embryo. The allantois stores waste until hatching. The whole thing is surrounded by another membrane, the chorion, which is permeable to gases but not to water. The chorion is surrounded by a flexible shell in reptiles.

Defenses and Adaptations

Reptiles are heterotherms (ectotherms).

Their body temperature varies (heterothermic), and these temperature variations are related to those of their environment (ectothermic).

However, these animals manage to regulate their temperature somewhat by modifying their behavior.

Some biologists believe that the largest dinosaurs were homeothermic and endothermic, meaning they maintained their temperature constant by controlling their metabolism.

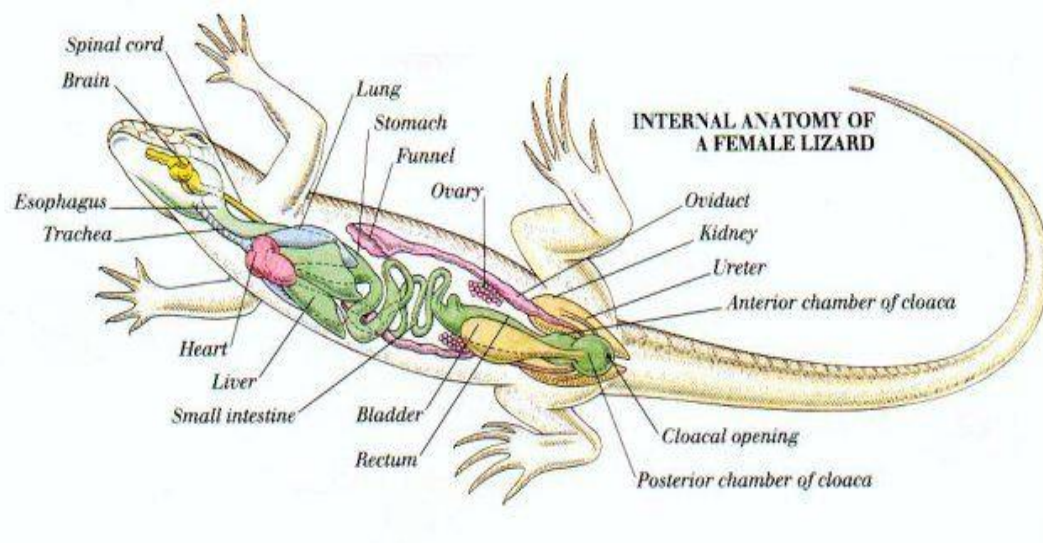
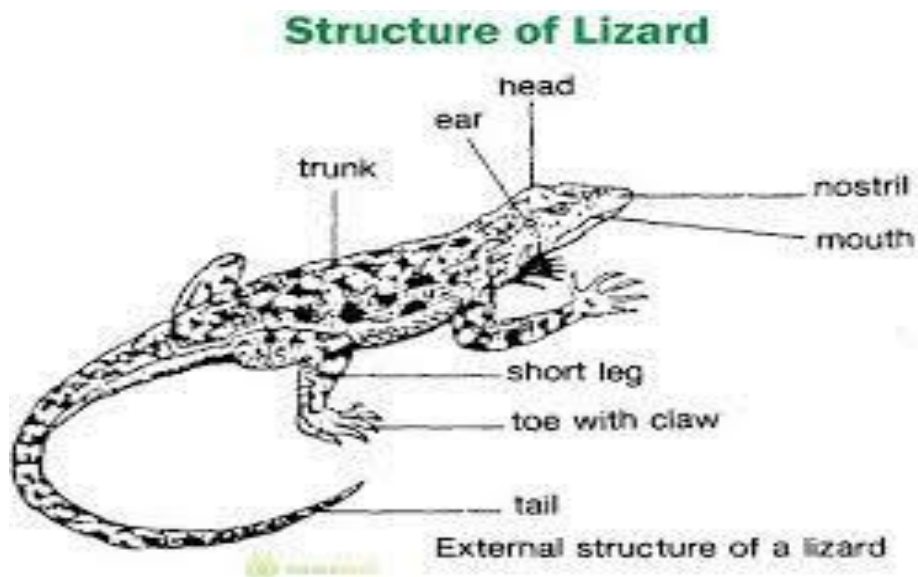


Figure 51: Reptiles morphology and anatomy

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