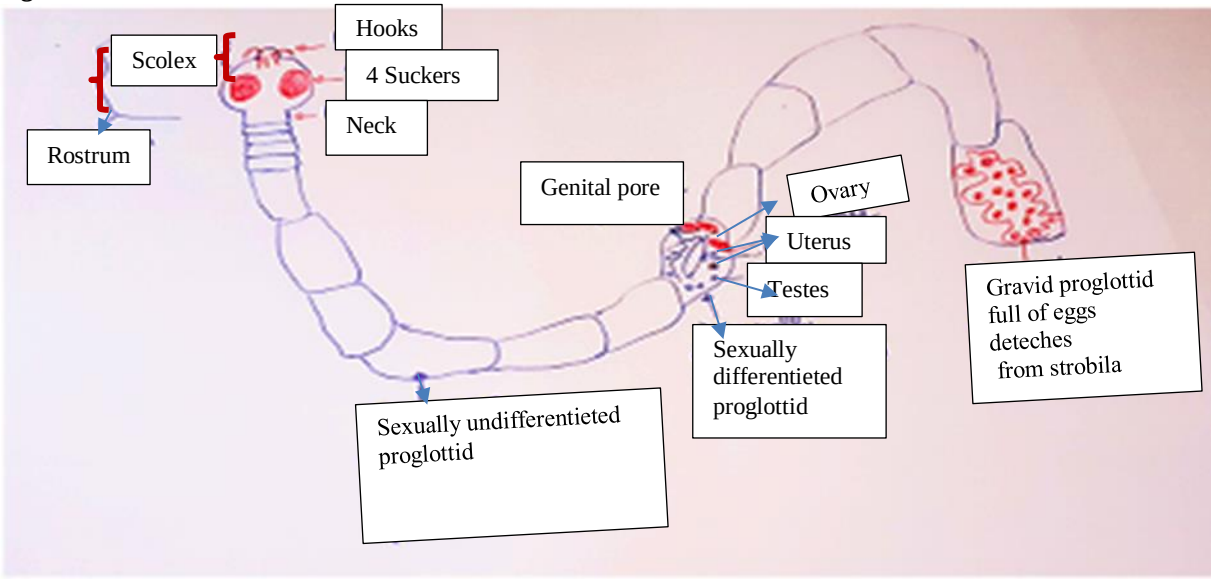
Systematics of Cestoda

1- Definition

--These are flattened, segmented worms in their adult stage; they possess an attachment organ at their anterior end known as the scolex.

--Cestodes are hermaphrodites, lack a digestive tract, and are always parasitic at all stages of their life cycle; adults live in vertebrates, whilst larvae live in both vertebrates and invertebrates.

2- Morphological and anatomical characteristics of Cestoda



2-1- External morphology of adult cestodes

The body of a cestode varies in length from 1 mm (or even less) and a fraction of a millimetre in width, to 8–10 metres in length and 1 or 1.5 cm in width.

The body of the cestode consists of three parts:

1- a attachment organ or scolex at the anterior end
2- a growth zone or neck behind the scolex
3- a chain of segments or strobile behind the neck.

2-1-1- The scolex

--a small bulge, of variable shape: spherical, ovoid, cubic, etc.

--always bearing attachment organs: suckers and hooks, themselves attached to the rostrum

-Attachment organs

a- The suckers

In the Cyclophyllidea, there are four of them; if one examines the scolex from above, they appear to occupy the four corners of a square; they are covered by a cuticle that extends to cover the worm itself

b- Bothria

There are two elongated structures (one dorsal and one ventral); unlike suckers, they lack muscle fibres and are characteristic of the Pseudophyllidea

c- The hooks

--Large and small but always microscopic, arranged in one or more rings on the rostrum, they vary in shape—dagger-shaped, fork-shaped, rose-thorn-shaped, etc.

--They consist of three parts: shaft, blade and guard.

2-1-2- The neck

A very short part of the worm located behind the scolex; all segments of the cestode's chain bud from the neck, which is only eliminated along with the scolex, hence its importance in deworming.

2-1-3- The chain of segments or strobilus:

This chain is formed through the process of budding or strobilisation from the neck, giving rise to strobili

-The strobile

Consists of successive, aligned segments called proglottids; their number and size vary depending on the species and their position in the chain.

-The young segments

The first segments are wider than they are long; they are sexually undifferentiated.

-Mature segments

Called mature segments because they are sexually differentiated and therefore contain the male and female reproductive glands

-Ovarian segments

The posterior segments, which are longer than they are wide, are the oldest segments; their genital glands have degenerated, and they are described as gravid or oigerous because they contain eggs housed within a uterus; the final segments are shed either individually or in groups.

Note: in Anoplocephalidae, the segments along the length of the tapeworm are wider than they are long.

The ovigerous segments

Follow the mature segments; the male and female genital glands disappear, whereas the uterus undergoes significant development; the evolution of the uterus is variable:

*Production of lateral branches that are more or less branched (as in the Taeniidae)

*fragmentation of the uterine branches into closed pouches known as: egg capsules filled with eggs; these capsules may contain between one and several eggs depending on the species (in the case of the Dillepididae: several capsules; in the case of the Mesocestoididae: a single capsule)

*parouterine organs: these are thick-walled pouches into which the uterus, containing the eggs, extends.

2-2-Anatomical study

The body of the cestode can be divided into two parts: a peripheral belt and a central parenchyma.

The peripheral belt consists of:

A soft, permeable cuticle, equipped with papillae, which plays a role in the absorption of food and in the worm's resistance to expulsion.

A basal membrane

A muscular layer (which ensures mobility and keeps the tapeworm in a state of contraction, helping it to resist expulsion).

The central parenchyma

Loose tissue filling the body, containing **calcareous corpuscles** characteristic of cestodes, giving the worm an opaque appearance (clarified with HCl, CH_3, COOH, etc. for microscopic examination).

The osmoregulatory or excretory system consists of:

--Cells

--Four channels arranged longitudinally (2 ventral pairs and 2 dorsal pairs), opening onto the posterior edge of the last ring.

The nervous system

Within the scolex there is a central nervous system consisting of two ganglion masses, from which networks of nerves extend to the attachment organs and along the entire length of the strobilus.

The reproductive system

--Found only in the middle segments (mature rings) and the posterior segments (ovigerous rings)

Mature segments

--Contain fully developed genital glands; cestodes are hermaphrodites and therefore possess both male and female glands.

Male reproductive system

Develops before the female reproductive system; it comprises one to several hundred testicular masses throughout the segment. From the testes, fine efferent ducts extend, all converging into a single vas deferens: the sperm duct, which is either coiled upon itself or expands into an external seminal vesicle; it then enters a penial pouch or cirrus pouch, or expands into an internal seminal vesicle, continuing as an ejaculatory duct leading to the cirrus (copulatory organ), the cirrus pouch opens into the genital atrium, next to the female genital opening.

Female reproductive system

--The vagina extends from the genital atrium and, as it expands, forms a seminal receptacle before narrowing again. The ovary is bilobed; the oviduct receives the vitelloduct, which carries secretions from the vitellogenic glands, and then expands into an ootype surrounded by the Mehlis gland (coquillary gland).

--The egg is guided into the uterus, which acts as a reservoir for eggs; in Pseudophyllidea, this opens onto the ventral side of the segment via a tocostome (egg-laying opening).

Genital pores

These are diagnostic features; they vary in number and position

A single genital pore

* It may be unilateral, or irregularly alternating (family Taeniidae).

* It may be median (rare), but is more often ventral.

Two genital pores

* Lateral: one on the left and one on the right of each segment (family Dillepididae)

*Located on the ventral surface of each segment (family Mesocestoididae).

In their larval stage, cestodes exhibit a wide variety of morphologies, and each of these forms corresponds to a specific condition. Animals are the definitive hosts, whilst humans act as intermediate hosts.

Classification of tapeworms

The classification of tapeworms is based on the anatomy of the scolex and the position of the genital openings on the segments

3- Systematics of Cestoda

Phylum Helminthes	
Subphylum: Platyhelminthes (flatworms)	
Classes: Cestoda 2 orders Order Cyclophyllidea (true tapeworms) Order Pseudophyllidea	Trematoda

3-Characteristics of the two orders of Cestoda

Order Cyclophyllidea:	**Order Pseudophyllidea:**
-4 suckers: Tetracestodes -Rostrum often armed -Marginal genital openings (except Mésocestoides) -Unoperculated egg: hexacanthous embryo: 3 pairs of hooks -1 intermediate host -Families: Taeniidae, Dilepididae, Mesocestoididae, Anoplocephalidae, Hymenolipididae	2 bothria: Dicestodes Medio-ventral genital openings Tocostome: oviposition opening Operculated egg, incompletely differentiated embryo 2 intermediate hosts.

Classification of cestoda of carnivores

Order CYCLOPHYLLIDEA		
A) Family Taeniidea	B) Family Dilepididae	C) Family Mesocestoididae
A) Family Taeniidea *A-1) Genus Taenia* *A-1-1) Taenia pisiformis* *A-1-2) Taenia hydatigena* *A-1-3) Taenia ovis* *A-1-4) Taenia teniaformis* *A-1-5) Taenia multiceps* *A-1-6) Taenia serialis* *A-2) Genus Echinococcus* 3 species: *Echinococcus granulosus* *Echinococcus multilocularis* *Echinococcus polymorphus*	*B-1) Dipyllidium caninum* *B-2) Joyeuxella pasqualei* *B-3) Diplopyllidium*	*C-1) Mesocestoides lineatus*

I- Order Pseudophyllidea

Family Diphyllobothriidea

-Species: *Diphyllobothrium latum* (broad bothriocephalus or lake tapeworm)

-1.5 to 10 m / 10 to 15 mm

-Rectangular, greyish egg-bearing segment with a dark central spot (central uterus in a rosette)

-2 intermediate hosts: lower crustaceans and freshwater fish.

General biology of cestodes

Habitat

Cestode eggs are not parasitic, whereas the larvae and adults are.

-Adults are found in the small intestine of mammals and birds (*Echinococcus granulosus* in the small intestine of

dogs).
Some species are found in the bile ducts.

The larvae
They are found in various locations in:
Vertebrates (humans**, birds, reptiles, fish, amphibians):** the *Coenurus cerebralis* larva is found in the brain and spinal cord of small ruminants
Invertebrates: (lice, fleas, many molluscs and mites), the cysticercoid larva is found in fleas and lice
Nutrition
Tapeworms have a significant requirement for carbohydrates, proteins, lipids, minerals (primarily phosphates), and vitamins (B1 and PP for *H. dimunata),* (B12 for *Diphyllobotrium latum*), and (C for *H. dimunata)*

Method of nutrient absorption
-They obtain salts and soluble substances by osmosis,
-for proteins, this occurs via a metabolic process on the surface of the cuticle.

Resistance of cestodes
Tapeworms are resistant to their host's proteolytic enzymes; this resistance has been attributed to the presence of substances that inhibit these enzymes: in vitro, the action of trypsin is neutralised by the tapeworms' glyco-lipid-bile-protein complexes, as well as by oxidative processes that have a destructive effect on the enzymes.
Reproduction
Modes of fertilisation
-Cestodes usually mate at the level of each segment through self-fertilisation.
-Cross-copulation: this sometimes occurs between mature segments located at different levels of the strobilus. More rarely, it occurs between mature segments belonging to two different cestodes but of the same species**.**
Egg laying
Tapeworms are highly prolific and can lay several thousand eggs per day (*Taenia saginata* can lay up to 400,000 eggs per day
In the Cyclophyllidea
The eggs develop entirely within the worm's uterus; in the absence of an ovipositional pore, it is the egg-bearing segments that fragment and are passed in the stools; only the destruction of these segments releases the eggs into the external environment (**hence a negative coproscopy result**).
--Segments may be passed in the faeces: passive expulsion, or
active in cases where the eggs are expelled during defecation.
--Once the eggs have been fertilised inside the rings, they now consist of three layers; the outermost layer, which is very thick and sometimes striated, is called the embryophore. The embryo (encosphere) bears six hooks and is known as a hexacanth.
--In Taenidae, the egg may be reduced to the embryophore. In
Anoplocephalidae and Hymenolipididae,
the eggs are released into the host's intestine, hence a positive coproscopy.

In Pseudophyllidea
In the Pseudophyllidae: The eggs, which are surrounded by a thick, operculated shell and are non embryonated (syncytium), are laid into the digestive tract of the definitive host via the tocostome of each ring (thus without destroying the ring).

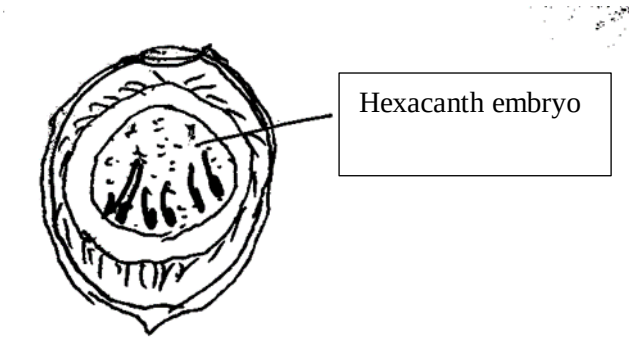


Figure: representation of a Pseudophyllidea egg

Hatching of the eggs:
In the Pseudophyllidae:
--In water, a small swimming coracidium emerges from the egg, consisting of an embryo equipped with three pairs of hooks (hexacanth embryo or oncosphere), itself surrounded by a ciliated membrane or embryophore.
--The coracidium disappears rapidly unless ingested by a receptive intermediate host (IH), a small copepod crustacean, and then develops into a procercoid larva; in the second IH, represented by a fish, it develops into an

infective plerocercoid larva; if the fish is ingested raw by a mammal (dog, cat, human) or a bird, the adult worm then develops in the intestine.

In the Cyclophyllidae:

--Embryonic development takes place entirely within the worm's body; there is no ovipositional opening, so the complete egg-bearing segments are passed in the stool, and when these segments are broken down, the eggs are released into the external environment.

--Intermediate hosts become infected by ingesting either the egg-bearing segments or eggs that have emerged from the segments, and it is only within the intermediate host that the eggs hatch.

--After hatching, the embryo migrates before developing into larvae in specific tissues.

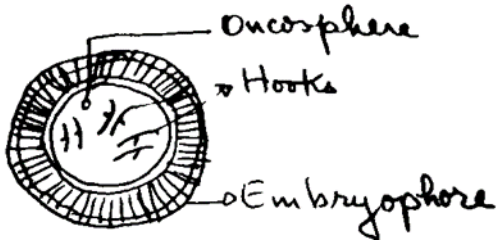


Figure : representation of a Cyclophyllidea egg

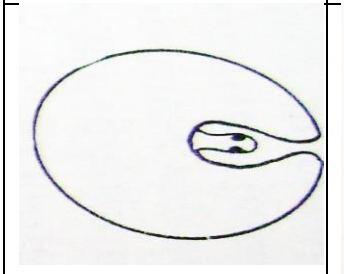
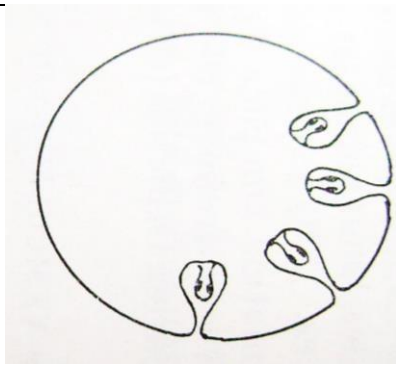
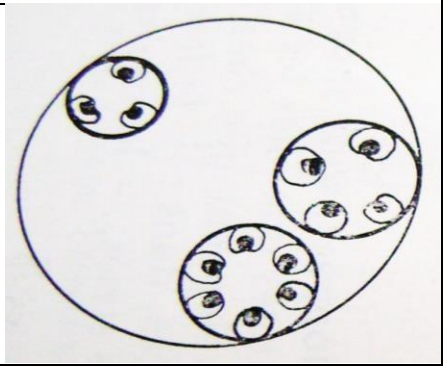
The different larvae of cestodes:

When there is a single intermediate host (as in the case of the Cyclophyllidea), there is only one infective larva. When there are two intermediate hosts (as in the case of the Pseudophyllidae), there are two larvae, but only the second larva (in the second intermediate host) is infective to the definitive host.

a- Cystic larvae: family Taenidae

-Found in the Cyclophyllidae, cysticercoid larvae, coenure larvae, echinocoid larvae,

-These are well-developed vesicles without a caudal appendage and are parasitic to the definitive host.

Cysticercoid larva	**Coenure larva**	**Echinococcus larva**
Vesicular larva (pea to walnut-sized), thin-walled, containing a clear, transparent fluid, with an invaginated scolex (white spot on the wall) --the larva is monosomatic (a single scolex) and monocephalic (a single invagination). **Examples** --*Cysticercus bovis* **larva** of *Taenia saginata* --*Cysticercus tenuicollis* larvae *of Taenia hydatigena*	Several cephalic invaginations, each containing a scolex. --ranging in size from a walnut to an orange –the larva is monosomatic and polycephalic Example – *Coenurus cerebralis* larva in a sheep from the tapeworm *T. multiceps* (dog)	–Vesicle under tension as it is full of fluid; vesicle with several cephalic invaginations, each containing several scolex --the cuticle is thick and stratified; sometimes daughter vesicles (proligera vesicles) form, attached to the wall of the mother vesicle. --the larva is of the polysomatic polycephalic type. Example Hydatid larva of the tapeworm *Echinococcus granulosus*
		

Strobilocercus larva: Characterised by the presence within the vesicle, in addition to the scolex, of a rudimentary strobilus.
--Example: *Cysticercus fasciolaris* larva, *T. taeniaformis* larva in cats.

Figure: **Strobilocercus larva**

b- Cysts with a caudal appendage

Cysticercoid larva: A small, thick-walled cyst containing little fluid, which develops in arthropods or poikilothermic lower vertebrates (with the exception of *Hymenolepis nana*)

Figure: **Cysticercoid larva**

Tetrathyridium larva: A larva of the Cyclophyllidea (particularly the family Mesocestoididae), 2 mm to 7 cm in length, flattened, wrinkled and warty, with a cephalic invagination bearing a scolex. It infests the definitive host (reptiles, birds, small mammals, etc.).

Figure: **Tetrathyridium larva**

Solid or full-bodied larvae found mainly in the Pseudophyllidea
Procercoid larva: Anterior section with a cephalic invagination and an incompletely differentiated scolex **(non-**

infesting); the tail, where the hooks are concentrated, subsequently degenerates. **It is found in the first intermediate host (crustacean),** within the general cavity (160–200 µm)

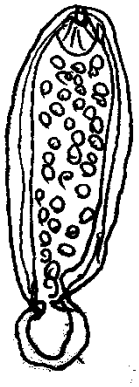


Figure: Procercoid larva

Plerocercoid larva

Found in the second intermediate host (poikilothermic vertebrate, small mammal), it is ribbon-shaped or subcylindrical and measures 1 to 20 mm. The anterior part is thick and opaque, with an invaginated scolex; the posterior part is thin and translucent and degenerates.

It infests the definitive host.

Figure: Plerocercoid larva

Infection of the definitive host and development of the adult tapeworm

This occurs through ingestion of the second intermediate host harbouring the infective form:

For the **Pseudophyllidae,** this will be the intermediate host (represented by fish, reptiles, etc.)

For the **Cyclophyllidae**, there is only one intermediate host; infection occurs through the ingestion of parasitised viscera

-In the definitive host, encystment is broken down by the action of intestinal secretions and bile salts

-Bile then plays an important role in the evagination of the scolex

-Thus, the scolex attaches itself to the intestinal mucosa and develops segment