Unit-VII

- Types of Parasitism. Commensalism, symbiosis and predatorism,
- Types of hosts. Immunity against parasitic infections.
- Standardized nomenclature of animal parasitic diseases.
- General description of helminth parasites, Classification, life cycle in relation to transmission, pathogenesis, epidemiology, diagnosis and control of various helminthes of animals and birds.
- General description, classification, life cycle, transmission, pathogenesis and control of various insects and arachnida affecting domestic animals and birds.

Parasitology

Definition & Scope

- **Parasitology:** The study of parasites and parasitism, including multidisciplinary aspects such as biochemistry, physiology, biology, immunology, etc.
- **Parasite:** An animal, organism, or plant that lives in or upon another organism (the host) and draws its nutrition directly from it.

Animal Associations and Relationships

1. Symbiosis

A close association between two individuals where both partners depend on each other.

- **Mutualism:** Both organisms benefit, with each partner being physiologically dependent on the other (one cannot live without the other).
- **Commensalism:** One partner benefits while the other is neither harmed nor benefited.

2. Other Types of Associations

- **Phoresis:** One organism (the phoront) is simply carried by a larger organism without any metabolic or nutritional relationship.
- **Predation:** One organism lives by eating another.
- **Parasitism:** An obligatory, intimate association between two different (heterospecific) organisms where the parasite benefits at the host's expense, often causing disease or harmful effects.
    - **Parasitosis:** A parasitic infection that produces a disease entity with clinical signs.
    - **Parasitiasis:** A parasitic infection that does not produce overt clinical signs despite the potential pathogenicity (e.g., Theileria annulata in indigenous animals).
    - **Parasitoidism:** Parasites lay eggs in other organisms; the larvae then feed on and destroy the host.
    - **Hyperparasitism:** One parasite parasitizes another parasite.
    - **Polyparasitism:** Simultaneous infection with multiple parasites.

Types of Parasites

Based on Life Cycle and Dependency

- **Obligatory Parasite:** Completely dependent on the host during its entire or a critical part of its life cycle.
- **Facultative Parasite:** Can live both within a host and freely in the environment.
- **Aberrant Parasite:** Migrates to and resides in an unusual or atypical location.

Based on Location in the Host

- **Ectoparasite:** Lives on the external surface (e.g., skin) of the host.
- **Endoparasite:** Lives within the body of the host.
- **Mesoparasite:** Enters and parasitizes external orifices/openings (e.g., Otobius megnini in the ears of dogs).

Based on Host Range

- **Monoxenous Parasite:** Does not require intermediate hosts or vectors to complete its life cycle.
- **Heteroxenous Parasite:** Requires one or more intermediate hosts for completion of its life cycle.
- **Stenoxenous Parasite:** Has a narrow host range.
- **Euryxenous Parasite:** Has a broad host range.
- **Autoheteroxenous Parasite:** A single vertebrate serves as both definitive and intermediate host (e.g., *Trichinella spiralis*).

Based on Tissue Location

- **Histozoic Parasite:** Lives in the tissues of the host.

Coelozoic Parasite: Lives within the lumen of the gastrointestinal tract or other hollow organs.

Based on Reproductive Mode

- **Oviparous Parasites:** Females lay eggs (e.g., *Ascaris*, *Ascridia*, *Ancylostoma*).
- **Ovo-viviparous Parasites:** Eggs contain fully developed larvae upon laying (e.g., *Habronema*).
- **Viviparous or Larviparous Parasites:** Eggs hatch inside the female; larvae are passed out (e.g., filarial worms).
- **Pupiparous Parasites:** Eggs hatch and develop into larvae inside the uterus; larvae are ready to pup upon exit.

Hosts and Their Roles

- **Host:** An organism that provides shelter, nutrition, and other factors for parasites.
- **Definitive Host:** The host in which parasites attain sexual maturity.

- **Intermediate Host:** The host in which a parasite undergoes part of its development (but does not reach sexual maturity).
- **Paratenic (Transport) Host:** A host that shelters the parasitic stage without any biological development occurring.
- **Reservoir Host:** Harbors the parasite without showing disease symptoms.
- **Vector:** Typically arthropods that harbor the parasitic pathogen and act as a constant source of infection.
    - **Mechanical Vector:** Transmits the parasite without allowing its multiplication or development (short-term carriage).
    - **Biological Vector:** Permits the development or multiplication of the parasite, making it infective for the host.

Modes of Infection and Transmission

- **Ingestion:** Infection via ingestion of infective stages (egg, cyst, oocyst, larva) through contaminated feed, water, meat, colostrum, milk, aquatic vegetation, or intermediate/paratenic hosts.
- **Transmammary Transmission:** Offspring become infected through the mother's colostrum or milk (e.g., *Toxocara canis*).
- **Skin Penetration (Percutaneous):** Infection by penetration of the skin (e.g., 3rd stage larva of hookworms, cercariae of *Schistosoma* spp., larvae of myiasis-causing flies, *Trypanosoma cruzi*).
- **Inoculation:** Direct introduction into the bloodstream via blood-sucking arthropod vectors (e.g., *Trypanosoma evansi*, *Leishmania* spp.).
- **Direct Contact:** Transmission through physical contact (e.g., infestation by mites, lice, fleas).
- **Venereal Transmission:** Spread through coitus (e.g., *Tritrichomonas foetus*, *Trypanosoma equiperdum*).
- **Congenital Transmission:** Transfer from an infected mother to her fetus through the placenta (e.g., *Toxocara canis*, *Ancylostoma caninum* in dogs).
- **Auto-infection:** Re-infection of the host due to reverse peristalsis or other routes (e.g., *Taenia solium* in humans, *Hymenolepis nana*, *Cryptosporidium* spp.).
- **Inhalation:** Infection through inhalation of infective particles (e.g., *Cryptosporidium* spp.)

Parasitic Life Stages

- **Prepatent Period:** The period from the initial infection to the first appearance of parasite stages (egg, larva, microfilaria, cyst) in the host.
    - *Example:* 19–22 days for *Eimeria bovis* in cattle.
- **Patent Period:** The time during which the parasite stages are demonstrable or discharged from the host.
    - *Example:* 2–3 weeks after the initial discharge of oocysts in *Eimeria bovis* infection in cattle.

Environmental Requirements and Dissemination

Bionomics of Parasites

- Study of external factors required for parasite survival (e.g., temperature, humidity, pH, nutrition for free-living stages).

Dissemination Methods

- **Water**
- **Aquatic Vegetation**
- **Arthropod Vectors**
- **Direct Contact**
- **Animal Transport**
- **Meat Export/Import**
- **Natural Calamities**

Nomenclature and Classification

Nomenclature Rules

- Governed by the **International Code for Zoological Nomenclature (ICZN, 1904)**.
- **Scientific Naming:**
    - Genus (uninomial) and species (binomial); subspecies are trinomial.
    - Names are derived from Latin or Greek.
    - Names are printed in italics (or underlined when handwritten).
    - The author's name (and year, if cited) follows the scientific name.
        - *Example:* **Taenia Linnaeus, 1758**

Classification Hierarchy

- Kingdom
- Subkingdom
- Phylum
- Subphylum
- Class
- Subclass
- Order
- Suborder
- Superfamily
- Family

- Subfamily
- Genus
- Subgenus
- Species and Subspecies

SNOPAD Guidelines

- Initially published in 1988 as Standardized Nomenclature of Animal Parasitic Disease (SNOAPAD) and later revised to SNOPAD.
- **Guidelines:**
    - Add the suffix **-osis** (plural: oses) to the stem of the parasite taxon by omitting the last one or two letters.
    - For taxa ending in **-x**, add **-osis** in the genitive form.
    - Add **-osis** to the full generic name of the parasite.

Parasitic Antigens and Immunity

Antigens from Parasites

Different parasite parts or stages used to prepare antigens include:

1. **Cuticle or Tegument:** The outer covering of the parasite.
2. **Subcellular Fraction:** e.g., Flagellar antigen of *Trypanosoma* spp.
3. **Excretory-Secretory Antigen:** Metabolic byproducts and secretory materials.
4. **Eggs:** Eggs themselves can be antigenic.
5. **Larva:** Antigens prepared from larval stages.
6. **Moulting Fluid:** Fluid released during the moulting process.

Types of Immunity

- **Innate Immunity:** Naturally present, non-specific defense.
- **Acquired Immunity:** Developed by exposure to antigens, can be further classified as:
    - **Active Immunity:** Resulting from administration or exposure to an antigen.
    - **Passive Immunity:** Transfer of antibodies from an immune individual to a non-immune individual.
    - **Humoral Immunity:** Antibody-mediated (B lymphocytes are key).
    - **Cell-Mediated Immunity:** Involves lymphocytes, macrophages, NK cells, and others.
    - **Sterilising Immunity:** Immunity that persists even in the absence of the parasite (e.g., after coccidiosis infection).
    - **Premunity:** Immunity maintained only in the presence of the parasite (seen in *Babesia* and *Theileria* infections).

- **Cross Immunity:** Immunity elicited by one parasite that protects against another (e.g., immunity against *Fasciola* may protect against amphistomes).
- **Concomitant Immunity:** Immunity against invading larval stages but not against established infections.

Harmful Effects of Parasitism

General Harmful Effects

- **Nutritional:** Utilization of host's food (e.g., *Diphyllobothrium latum* absorbs Vitamin B12 leading to pernicious anemia).
- **Physiological:** Anorexia, decreased growth rate, poor milk yield, and anestrus.
- **Feeding Damage:** Direct feeding on host tissues.
- **Gastrointestinal Issues:** Diarrhea or dysentery.
- **Haemorrhage:** Can occur due to tissue damage.
- **Granuloma Formation:** e.g., *Schistosoma nasale* causes cauliflower-like growth in nasal mucosa.
- **Dermatological Reactions:** Itching, alopecia, and dermatitis.
- **Anaphylactic Reactions:** Rupture of hydatid cysts (e.g., *Echinococcus granulosus*) may trigger anaphylaxis.
- **Reproductive Issues:** Abortion can occur (e.g., *Tritrichomonas foetus* in cattle, *Toxoplasma gondii* in sheep and humans).

Specific Tissue Lesions

- **Submandibular Oedema (Bottle Jaw):** Seen in infections with *Fasciola*, amphistomes, *Haemonchus contortus*, hookworms.
- **Pipe Stem Liver:** Calcification and protrusion of bile duct walls (common in fasciolosis).
- **Granulomatous Lesions:** Cauliflower-like growths (e.g., *Schistosoma nasale*).
- **Cholangiocarcinoma:** Bile duct tumors due to *Clonorchis sinensis* infection.
- **Pimply Gut:** Nodular lesions from *Oesophagostomum* spp.
- **Milk Spot Lesions:** Liver lesions due to *Ascaris suum* in pigs.
- **Vascular or Structural Damage:** Stenosis of the aorta or esophageal tumors (e.g., lesions due to *Spirocerca lupi* in dogs).
- **Nurse Cell Formation:** *Trichinella spiralis* larvae encapsulated in skeletal muscle fibers form coiled "nurse cells."
- **Chronic Dermatitis (Hump Sore):** Caused by *Stephanofilaria assamensis* in cattle.
- **Lymph Node Enlargement:** Especially the prescapular nodes due to *Theileria* spp.
- **Ulceration:** Punched necrotic ulcers in the abomasum due to *Theileria annulata*.
- **Dollar Spot:** Lesions from *Trypanosoma equiperdum* in horses.

- **Haemorrhagic Typhlitis:** Due to *Eimeria tenella* infection in poultry.
- **Corneal Opacity:** Seen in dogs infected with *Trypanosoma evansi* and *Ehrlichia canis*.

Control Measures Against Parasitic Infections

1. Chemotherapy

- **Anthelmintics:** Drugs against parasitic worms.
- **Insecticides:** Used against insects such as flies, lice, ticks, mites (e.g., DDT, cypermethrin, deltamethrin).
- **Acaricides:** Target ticks and mites (e.g., amitraz, deltamethrin).
- **Antiprotozoal Drugs:** Specific drugs to treat protozoan parasites.

2. Immunoprophylaxis

- Development and use of vaccines or immune modulators to protect against parasitic infections.

3. Genetic Control

- Breeding for parasite-resistant animals.
    - *Examples:*
        - **N'Dama cattle:** Resistance to trypanosomosis.
        - **Red Maasai sheep:** Resistance to haemonchosis.
        - **Garole sheep:** Resistance to fasciolosis.
        - **Bos indicus (Desi cattle):** Resistance to theileriosis.

4. Biological and Managemental Control

Intermediate Host Control:

- Use of chemicals (e.g., $CuSO_4$ to kill molluscs).
- Use of biological agents (e.g., Gambusia fishes to control mosquito larvae).

- **Pasture and Managemental Control:** Adjustments in animal management and pasture hygiene to reduce parasite transmission.

Types of Life Cycles

1. Based on Reproductive and Propagation Methods

- **Simple Life Cycle:**
    - Parasite multiplies by binary fission in both its vertebrate host and insect vector.
    - *Example: Trypanosoma* spp.
- **Complex Life Cycle:**
    - Involves an alternation of asexual and sexual reproduction phases.

- *Examples:* All helminth parasites, malarial parasites, and many other parasitic protozoa.

2. Based on the Requirement of Intermediate Hosts or Vectors

- **Direct Life Cycle:**
  - No intermediate host is required for the parasite to complete its life cycle.
  - *Example:* Strongylid nematodes; also seen in *Eimeria* spp.
- **Indirect Life Cycle:**
  - One or more intermediate hosts or vectors are necessary.
  - *Examples:*
    - **One Intermediate Host:** *Taenia solium* (pig serves as the intermediate host).
    - **Two Intermediate Hosts:** *Diphyllobothrium* spp. (first intermediate host is cyclops; second is a fish).

3. Based on Development in the Environment

- **Homogonic Life Cycle:**
  - The parasite does not develop into the adult stage outside the host.
  - *Example:* The parasitic cycle of *Strongyloides* spp.
- **Heterogonic Life Cycle:**
  - The parasite develops to an adult (sexually mature) stage in the environment; its offspring then infect a host and later develop to the adult stage within that host.
  - *Example: Strongyloides* spp. (noting that some species may exhibit both cycle types).

4. Based on Transmission Between Species

- **Zoonotic Life Cycle:**
  - Parasites are transmitted between animals and humans (or vice versa).
  - *Example: Taenia solium*

Different Important Systems of Parasites

1. Digestive System

- **Cestodes (Tapeworms):**
  - No true digestive system; nutrition is absorbed through the entire body surface.
- **Trematodes:**
  - Possess an oral sucker, pharynx, oesophagus, and two blind caecae.
- **Nematodes:**
  - Have a mouth, buccal capsule, oesophagus, intestine, and anus.
- **Amoeba:**

- Ingests food material into a food vacuole and expels waste through a single opening (cytopyge).

2. Respiratory System

- Absent in cestodes, trematodes, nematodes, and protozoa.

3. Excretory System

- **Cestodes & Trematodes:**
  - Excrete through flame cells.
- **Nematodes:**
  - Use a pored osmoregulatory system for excretion.

4. Nervous System

- Present as a very simple system in cestodes, trematodes, and nematodes.

5. Reproductive System

- **Cestodes:**
  - Hermaphroditic (monoecious) – both male and female organs are present in the same individual.
- **Trematodes:**
  - Generally hermaphroditic, except for *Schistosoma* spp. which are unisexual; in these, the female is carried by the male during copulation.
- **Nematodes:**
  - Unisexual (dioecious).

Description of Intermediate Stages of Parasites

A. Trematodes

Mnemonic: **E-M-S-R-C-M**

1. **Egg:**
   - Usually oval; can be yellowish (e.g., *Fasciola* spp.), transparent or colorless (e.g., amphistomes), or grayish/brownish (e.g., *Dicrocoelium* spp.).
   - Some eggs are operculated; others may be elongated (e.g., *Schistosome*).
2. **Miracidium:**
   - The embryo within the egg develops into a miracidium, which is actively motile, ciliated, and features one prominent anterior spine.
   - Hatching can occur in the environment or after the egg is ingested by an aquatic snail (intermediate host).
3. **Sporocysts:**
   - The next developmental stage, where the miracidium transforms into sporocysts.

4. **Redia:**
    - Develops within the sporocyst, often producing many rediae. Rediae have several birth pores through which numerous cercariae are released.
5. **Cercaria:**
    - Typically tailed; the shape and tail length vary (tail may be short, long, or bifurcated, as in *Schistosoma* spp).
    - Some may contain pigment, termed “cercaria pigmentata.”
6. **Metacercaria:**
    - The encysted form of the cercaria; after losing its tail, it encysts on grass blades, aquatic vegetation, or within the intermediate host.

B. Cestodes

1. **Egg:**
    - Eggs possess multiple coverings: an outer envelope, an inner envelope, and an oncospheral membrane.
    - In some species (e.g., *Taenia* spp.), an additional protective layer called an embryophore is present (which is striated).
    - The oncosphere (embryo) has six hooklets arranged in three pairs, earning it the name "hexacanth embryo."
2. **Post-hatching:**
    - The oncosphere migrates to various organs (e.g., lungs, liver, heart, diaphragm) where it forms cysts known as bladder worms or metacestodes.
3. **Types of Cysts/Metacestodes:**
    - Cysticercoid
    - Cysticercus
    - Hydatid cyst
    - Coenurus
    - Strobilocercus
    - Procercoid
    - Plerocercoid

C. Nematodes

- **Stages:**
    - Egg, larva, and adult.

D. Protozoa

1. **Oocysts/Cysts:**

- In some protozoa (e.g., coccidian parasites and amoeba), the infective stages are sporulated oocysts or cysts.
- Oocysts contain two or four sporocysts; each sporocyst further contains two or four sporozoites.

2. **Sporozoites:**
   - Elongated, motile forms capable of penetrating host cell membranes.
   - When the sporulated oocysts are ingested, enzymes (trypsin), bile, CO_2, and other factors facilitate the release of sporozoites.
3. **Trophozoites:**
   - Rounded-up forms of sporozoites.
4. **Schizonts:**
   - The trophozoite's nucleus divides into several parts; each portion acquires cytoplasm and eventually becomes an individual organism.
5. **Merozoites:**
   - The individual organisms produced within the schizont are called merozoites; they are released when the schizont bursts.
6. **Gametes:**
   - After the formation of second-generation schizonts, merozoites transform into macrogametes.
7. **Tachyzoites/Bradyzoites:**
   - These are developmental stages found in parasites such as *Toxoplasma* and *Sarcocystis* spp.

GENERAL CLASSIFICATION OF PARASITES

1. Broad Categories

- **Metazoan Parasites (Multicellular)**
  - **Helminth Parasites:**
    - Derived from the Greek "helmins" (or "helminthos") meaning worm.
    - Mainly endoparasites.
  - **Arthropod Parasites**
- **Protozoan Parasites (Unicellular)**
  - Classified under the sub-kingdom Protozoa.

2. HELMINTH PARASITES

Helminths (worms) are mainly divided into two groups:

- **Platyhelminths (Flatworms)**
- **Nematohelminths (Roundworms)**

A. Platyhelminthes (Flatworms)

- **General Characteristics:**
    - Dorso-ventrally flattened.
    - Body forms vary:
        - **Flukes:** Leaf-like or oval/globular; grouped under **Class Trematoda**.
        - **Tapeworms:** Very elongate and tape-like; grouped under:
            - **Class Eucestoda (True Tapeworms)**
            - **Class Cotyloda (Fish Tapeworms)**
    - All flatworms are **hermaphroditic** (monoecious) because both male and female reproductive organs are found in the same individual.
        - *Exception:* Blood flukes (Family Schistosomatidae) are unisexual.

B. Life Cycle of Trematodes (Flukes)

- **Nature of Life Cycle:**
    - Always **indirect**, requiring one or more intermediate hosts.
    - The **first (or only) intermediate host** is always a snail.
    - A **second intermediate host** (if present) may be an ant, grasshopper, fish, dragonfly, snail, frog, or some crustaceans.
- **Morphological Features:**
    - **Suckers:**
        - Generally two suckers (oral and ventral) serve as attachment organs.
        - Examples:
            - **Fasciola gigantica:** Ventral sucker is near the middle or upper half.
            - **Paramphistomum cervi (amphistomes):** Possess a muscular posterior sucker (acetabulum).
            - Some flukes have only an oral sucker (monostomes, e.g., *Notocotylus attenuatus*).
- **Body Systems:**
    - **Tegument:** A tough, syncytial body covering.
    - **Digestive System:**
        - Mouth opens into a muscular, pumping pharynx via a short oesophagus.
        - No anus is present; waste is egested through the mouth.
        - Some species have an excretory system with two or more protonephridia.
    - **Nervous System:**

        - Consists of a pair of ganglia in the head region with two or three pairs of nerve cords.
        - Generally lack specialized sense organs.
    - **Reproductive System:**
        - Most are hermaphrodites; however, *Schistosoma* spp. are an exception (unisexual).

- **Eggs:**
    - Generally operculated (with a lid at one pole) except for blood fluke eggs, which are non-operculated.

3. LIFE CYCLES OF TREMATODES

A. Life Cycle Stages (General Trematode Cycle)

1. **Egg:**
    - Excreted in the host's feces; varies in color (yellowish in *Fasciola*, transparent/colorless in amphistomes, grayish/brownish in *Dicrocoelium* spp.).
2. **Miracidium:**
    - The embryo hatches from the egg; actively motile, ciliated, with one prominent anterior spine.
3. **Sporocyst:**
    - Develops within the snail after the miracidium penetrates.
4. **Redia:**
    - Develops within the sporocyst (in many trematodes) and gives rise to numerous cercariae.
5. **Cercaria:**
    - Typically tailed; the tail length and shape can vary (bifurcated in some *Schistosoma* spp.).
    - Cercariae may be released to encyst on aquatic vegetation or invade a second intermediate host.
6. **Metacercaria:**
    - The encysted form, which becomes infective to the definitive host.

4. TAXONOMY AND IMPORTANT FAMILIES OF TREMATODES

- **Phylum:** Platyhelminthes
- **Class:** Trematoda
- **Subclass:** Digenea (of primary veterinary importance)

Key Families:

- **Fasciolidae**
- **Dicrocoeliidae**
- **Opisthorchiidae**
- **Paramphistomatidae**
- **Schistosomatidae**
- **Prosthogonimidae**
- **Paragonimidae**

5. IMPORTANT FLUKES

A. Fasciola spp. (Liver Flukes)

- **Hosts:**
    - Definitive: Cattle, sheep, goats, and other ruminants (also elephants, horses, pigs, dogs, cats).
- **Site of Infection:**
    - Bile duct and liver.
- **Diseases:**
    - Fasciolosis, liver fluke disease, liver rot.
- **Distribution:**
    - Cosmopolitan.
- **Intermediate Hosts:**
    - Lymnaea species (e.g., *L. truncatula*, *L. auricularia*, *L. bilimoides*, *L. nifescens*, *L. luteola*).
- **Pathological Features:**
    - Peritonitis, hepatitis, hyperplastic cholangitis, “pipe stem liver” condition, and hazelnut cyst formation.
    - **Bottle Jaw:** Due to massive hyperplasia of the bile duct epithelium leading to protein loss, reduced colloidal osmotic pressure, and resultant edema (notably submandibular).
- **Clinical Signs:**
    - **Acute Phase:** Sudden death (resembling anthrax), frothy blood from nostrils and rectum.
    - **Chronic Phase:** Loss of vigor, anemia, pale mucous membranes, constipation, and diarrhea.
- **Diagnosis:**
    - Fecal examination (oval, operculated, yellow eggs).
    - Enzyme estimation (Glutamate dehydrogenase, Glutamyl transpeptidase).

    - ELISA tests (using Cathepsin L as antigen via sandwich ELISA for early detection).
    - Note: Severity may be exacerbated by concurrent infection with *Clostridium oedematiens/novyi* (Black disease).
- **Additional Note:** Sometimes, Fasciola may accidentally enter the lungs, forming hazelnut-sized cysts; diarrhea may also be due to concomitant gastrointestinal nematode infections (e.g., *Oestertagia* spp.).

B. Fasciolopsis buski

- **Location:** Small intestine.
- **Hosts:** Humans and pigs.
- **Identification:**
    - Very large ventral sucker compared to the oral sucker.
    - Intestinal caeca are unbranched (differentiating it from *Fasciola hepatica* and *F. gigantica*).
- **Intermediate Host:**
    - Segmentina spp.

C. Fascioloides magna

- **Site/Location:** Liver.
- **Hosts:** Cattle, sheep.
- **Intermediate Host:**
    - Fossaria spp.

D. Dicrocoelium spp. (Lancet Flukes)

- **Species:** *Dicrocoelium dendriticum*, *D. hospes*
- **Common Name:** Lancet fluke.
- **Distribution:** Worldwide.
- **Site of Predilection:**
    - Bile duct, liver, gall bladder, and pancreas (most commonly bile duct and liver).

Morphology:

- Small, lancet-shaped (about 1 cm long).
- Soft, partially transparent with dense genital parts.
- Two suckers (the oral sucker is smaller than the ventral sucker).
- Possess tandem testes, an ovary posterior to the testes, and lateral vitelline glands.
- Eggs are operculated and brown.

Life Cycle:

- **Definitive Hosts:** Sheep, goats, and cattle.

- **1st Intermediate Host:** Land snails (e.g., *Zebrina detrita*, *Cionella lubrica*; in India, also *Macrochlamys cassida* and *Luastenia*).
- **2nd Intermediate Host:** Ants (e.g., *Formica fusca*).

Developmental Stages:

1. Eggs are passed in the host's feces.
2. Eggs hatch after ingestion by the land snail.
3. In the snail, the miracidium transforms into a sporocyst in the hepatopancreas.
4. A second generation sporocyst forms and produces cercariae directly (the redia stage is absent). The cercaria, called "Cercaria vitrina," has a stylet and tail.
5. Cercariae are released within a gelatinous "slime-ball" containing 200–400 individuals.
6. Ants are attracted to the slime-ball and ingest it.
7. Within ants, metacercariae form.
8. The definitive host becomes infected upon ingestion of the infected ants along with feed.

Pathological Features:

- Cholangitis, cholangiectasis (biliary stasis due to parasite aggregation), and portal cirrhosis.
- In the chronic phase, fibrous tissue deposition leads to hyperplasia of the bile duct.
- Portal cirrhosis typically begins at the portal triad and later affects the entire liver.
- Note: Unlike Fasciola, immature fluke migration into the liver is absent.

E. Eurytrema pancreaticum (Pancreatic Fluke)

- **Life Cycle:**
  - **First Intermediate Host:** Snail.
  - **Second Intermediate Host:** Grasshopper.
  - Life cycle is similar to that of *Dicrocoelium* spp.
- **Disease:** Causes pancreatitis.

FAMILY – OPISTHORCHIIDAE

General Features:

- Small to medium-sized distomes found in the bile duct and gall bladder of mammals, birds, and other hosts.
- In terms of pathology, they rank third after Fasciola and Dicrocoelium.

History / Discovery:

- The Chinese liver fluke (*Chlonorchis sinensis*) was first recorded in Calcutta in 1875 by McConnellin in the bile duct of a Chinese carpenter.

Taxonomy and Species:

- **Genus:**
  - *Opisthorchis* and *Chlonorchis*
- **Species of Opisthorchis:**
  - *O. tenuicollis*
  - *O. viverrini*
  - *O. caninus*
  - *O. felineus*
  - *O. noverca*
- **Species of Chlonorchis:**
  - *C. sinensis* (commonly known as the Chinese liver fluke)

Morphology & Life Cycle:

1. **Egg Expulsion:**
   - Eggs are expelled from the final host in the feces.
2. **Snail Stage:**
   - Eggs are ingested by a suitable snail host (commonly of the genus *Bithynia*).
   - Inside the snail, the egg hatches and releases a miracidium that transforms into a sporocyst.
   - The sporocyst produces one generation of rediae.
3. **Cercarial Stage:**
   - From the redia, tailed cercariae develop with pigmented eye-spots.
4. **Fish Stage:**
   - The cercaria penetrates a fish host (typically of the Cyprinidae family) and transforms into a metacercaria, usually encysting at the base of the fin.
5. **Final Host:**

Infection occurs when a final host (mammal or bird) ingests raw, undercooked, or uncooked infected fish.

Pathological Features / Lesions:

- **Cholangitis:** Inflammation of the bile duct.
- **Cholangiocarcinoma:** Bile duct cancer linked to chronic infection.
- **Biliary Stasis:** Impaired bile flow due to obstruction or parasite aggregation.

Control Measures:

- **Treatment:** Appropriate anthelmintic treatment for infected animals.
- **Food Safety:** Prevent consumption of raw or undercooked fish.
- **Snail Control:** Use of molluscicidal agents to reduce intermediate host populations.

FAMILY – PARAMPHISTOMATIDAE

General Overview:

- These flukes are primarily found in ruminants.
- Commonly known as “ruminal flukes” or “conical flukes” when located in the rumen and reticulum.

One species (Gigantocotyle explanatum) may also be found in the bile duct (mainly of buffalo) and rarely in cattle.

Clinical Significance:

- Amphistomosis: Immature amphistomosis is a major disease in ruminants in India, second only to fasciolosis.
- Eight genera of veterinary importance include:
    - *Paramphistomum*, *Cotylophoron*, *Gastrothylax*, *Fischoederius*, *Carmyerius*, *Gastrodiscus*, *Gastrodiscoides*, and *Pseudodiscus*.

Morphology:

Typically, these flukes have a thick, fleshy, conical or oval body that is circular in transverse section.

Reproductive System:

    - Testes are usually lobed and located anterior to the body cavity.
- **Digestive System:**
    - The intestine caeca are simple.
    - In some species (e.g., *Paramphistomum explanatum*), the pharynx is absent.
- **Eggs:**
    - Oval, operculated; color may vary (whitish to transparent; eggs of *Gigantocotyle explanatum* tend to be yellowish transparent similar to Fasciola eggs).

Life Cycle:

- The cycle is indirect, involving aquatic snails as the intermediate host.
- **General Stages:**
    1. Eggs are passed in the feces of the definitive host.
    2. In the aquatic environment, eggs hatch and infect snails.
    3. Development in the snail produces cercariae, which are then released.
    4. Cercariae encyst as metacercariae on vegetation or in the environment.

- **Key Intermediate Hosts:**
    - *Indoplanorbis exustus* and *Planorbis* for species such as *Paramphistomum cervi*, *P. epiclitum*, and *P. microbothrium*.
    - Other genera have specific snail hosts such as *Gyraulus convexiusculus*, *Lymnaea luteola*, or *Helicorbis coenosus*.

Genus-Specific Notes:

Paramphistomum:

- *Paramphistomum cervi*, *P. epiclitum*, *P. microbothrium*
- **Hosts:** Cattle, sheep, goats
- **Site:** Rumen, reticulum, and sometimes small intestine.

Gigantocotyle explanatum (Paramphistomum explanatum):

- Found primarily in the bile ducts, gall bladder, and liver of buffaloes (rarely in cattle, sheep, goats).
- The life cycle involves the snail *Gyraulus convexiusculus*.

Cotylophoron:

- *Cotylophoron cotylophorum*
- **Hosts:** Cattle, sheep, goats
- **Site:** Rumen and reticulum
- **Intermediate Host:** Species of *Indoplanorbis*.

Gastrothylax:

- *Gastrothylax crumenifer*
- **Hosts:** Sheep, cattle, buffalo
- **Site:** Rumen and reticulum
- **Intermediate Host:** *Gyraulus convexiusculus*.

Fischoederius:

- *Fischoederius elongatus*, *F. cobboldi*
- **Host:** Cattle
- **Site:** Rumen, reticulum
- **Intermediate Host:** *Lymnaea luteola*.

Gastrodiscus:

- *Gastrodiscus aegyptiacus*
- **Host:** Equines
- **Site:** Intestine

- **Intermediate Host:** *Cleopetra* spp.

Gastrodiscoides:

- *Gastrodiscoides hominis*
- **Hosts:** Pigs and humans
- **Site:** Caecum and colon
- **Intermediate Host:** *Helicorbis coenosus*.

Pathogenesis & Clinical Features:

Immature Amphistomosis ("Plug Feeder"):

- Immature flukes cause mechanical damage by drawing a plug of the mucosa into their acetabula, leading to necrosis and sloughing of tissue.
- **Consequences:**
  - Protein loss through a damaged intestinal wall (hypoproteinemia)
  - Edema (due to loss of plasma protein and altered osmotic pressure)
  - Mucosal erosion and petechiae, resulting in intestinal discomfort.

Clinical Signs:

- Severe abdominal pain
- Profuse watery diarrhea and increased thirst (due to fluid loss)
- Anorexia, weight loss, and emaciation.

Biliary Amphistomosis:

- Occurs with *Gigantocotyle explanatum* where juvenile flukes migrate from the duodenum into the bile ducts, gall bladder, and liver.
- **Pathological Features:**
  - Extensive thickening (fibrosis) of the bile ducts, mucosal erosions, and hemorrhages.

Diagnosis:

- Based on clinical signs and history of infection in endemic areas.
- Observation of immature amphistomes in fluid feces.
- At postmortem, signs include enteritis with numerous brownish pink parasites on the mucosal surface.
- Eggs are examined in fecal samples: oval, operculated with knob-like thickening at the broader end.

Treatment, Prevention, and Control:

- **Drugs:** Resorantel and Oxyclozanide are effective against these flukes.
- **Management:**

- Timely treatment based on clinical diagnosis.
- Preventive measures include controlling snail populations (the intermediate hosts) and managing pasture hygiene.

FAMILY – SCHISTOSOMATIDAE

Schistosomatidae, commonly known as blood flukes, are a group of trematodes that inhabit the blood vessels of their definitive hosts.

1. General Characteristics

- **Habitat:**
  - Found in the blood vessels (e.g., mesenteric, portal, nasal veins) of mammals, birds, and other hosts.
- **Common Name:**
  - Blood flukes or Bilharzia worms.
- **Sexual Dimorphism and Unisexuality:**
  - **Unisexual:** The sexes are separate.
  - **Dimorphic:** Males and females differ in morphology and size.
    - **Male:** Stout, short, with a tuberculated (rough) tegument; possesses a ventral gutter-like groove (gynaecophoric canal) to carry the female during copulation.
    - **Female:** Longer and more slender, with a smooth tegument.

2. Morphology

- **Suckers:**
  - Both oral and ventral suckers are located anteriorly.
- **Digestive System:**
  - Begins with the oral sucker, followed by a short oesophagus.
  - Two intestinal caeca that reunite and terminate as a blind tube.
- **Reproductive System:**
  - Well developed in both sexes.
  - **Male:**
    - Testes number varies from 2 to 10, located dorsal and posterior to the ventral sucker.
  - **Female:**
    - Elongated, compact ovary located in front of the posterior union of intestinal caeca.
    - Uterus occupies the anterior half of the body.
- **Eggs:**

- Thin-shelled, non-operculated, embryonated, transparent.
- Bear a terminal spine.

- **Cercariae:**
  - Furcocercous (fork-tailed); tails are bifurcated.

3. Taxonomy & Hosts

- **Genus:**
  - *Schistosoma* is the most important genus.
- **Hosts:**
  - Definitive hosts include cattle, sheep, goats, pigs, dogs, and humans.
- **Intermediate Hosts:**
  - Aquatic snails such as *Indoplanorbis* spp., *Bulinus* spp., and *Planorbis* spp.
- **Site/Location in Host:**
  - Commonly in the mesenteric veins, portal veins, or nasal veins (as seen in *S. nasale*).

4. Life Cycle and Development

A. Developmental Stages

1. **Egg:**
   - Laid by the female fluke in the blood vessels.
   - Eggs migrate across tissue walls into the lumen of the intestine, urinary, or nasal passages, then passed out with feces, urine, or nasal discharge.
2. **Miracidium:**
   - Embryonated eggs hatch immediately upon contact with water.
   - A ciliated, pyriform miracidium is released; it has a short lifespan (12–20 hours) and does not feed.
3. **Sporocyst:**
   - After penetrating a suitable aquatic snail, the miracidium loses its cilia and transforms into a sac-like sporocyst.
   - Two generations of sporocysts develop within the snail.
4. **Cercaria:**
   - Germ cells within the sporocyst develop into forked-tailed, furcocercous cercariae.
   - Redia stage is absent.
   - Cercariae are liberated from the snail (typically in the morning) and swim actively in search of a definitive host.
5. **Schistosomula:**
   - Upon contact, cercariae penetrate the host's skin.

- During penetration, they lose their tails and transform into a globular body called schistosomulum (young fluke).

6. **Adult:**
    - Schistosomula migrate via systemic circulation to the lungs and then to the liver.
    - In the liver, pairing and further development occur.
    - Adults finally reside in the mesenteric (or other specific) veins where they become sexually mature and begin egg laying.

Note:

- Metacercaria and redia stages are absent in the schistosome life cycle.

B. Timeline

- The complete transformation from penetration to the production of eggs generally takes about 6–7 weeks.

5. Pathogenesis and Clinical Syndromes

A. Role of Eggs in Pathogenesis

- **Mechanisms:**
    - Eggs are responsible for most of the damage through both mechanical disruption and immune-mediated reactions.
- **Types of Schistosomosis:**
    - **Hepato-intestinal Schistosomosis (Visceral):**
        - **Acute Intestinal Syndrome:**
            - Begins with egg laying; egg transit through the intestinal wall produces severe inflammation and hemorrhagic lesions, particularly in the posterior small intestine.
            - Features include blood-stained mucous surfaces and formation of granulomas or abscesses.
        - **Chronic Hepatic Syndrome:**
            - Due to migration of eggs to the liver, provoking a cell-mediated immune response.
            - Leads to granuloma formation and portal fibrosis.
    - **Nasal Schistosomosis:**
        - Typically caused by *S. nasale*.
        - Eggs in the nasal mucous glands evoke fibrosis and cauliflower-like growths.
        - Clinical signs include rhinitis, mucopurulent discharge, sneezing, dyspnea, and “snoring disease.”
    - **Urinary Schistosomosis:**

        - Seen in species such as *S. haematobium*.
        - Eggs cause delayed-type hypersensitivity reactions, resulting in extensive granuloma formation and obstructive lesions in the urinary bladder and ureters.

6. Clinical Signs

A. Nasal Schistosomosis

- Sneezing and snoring.
- Difficulty in breathing due to granulomatous growth and mucopurulent discharge.
- Coryza (inflammation of the nasal mucosa).

B. Hepato-intestinal Schistosomosis

- **Acute Phase:**
    - Diarrhea and dysentery with blood and mucus.
    - Slight fever, anemia, emaciation, anorexia, and thirst.
- **Chronic Phase:**
    - Ascites, eosinophilia, and hypoalbuminemia.
    - Phlebitis in mesenteric veins due to adult parasites.

C. Urinary Schistosomosis

- Obstructive lesions in the urinary tract due to granuloma formation.
- Signs related to impaired urinary flow.

7. Diagnosis

- **Clinical Examination:**
    - Observation of typical clinical signs (e.g., nasal discharge with boomerang-shaped eggs in *S. nasale*).
- **Laboratory Tests:**
    - Fecal and urine examination for eggs.
    - Serological tests including:
        - Cercarial Mullen Test (CHR)
        - IHAT, CFT, DID
        - Ring precipitation test, ELISA, and Dot-ELISA.

8. Treatment

- **Drugs Used:**
    - **Praziquantel** is the treatment of choice.
    - Other agents include:

        - Sodium antimony tartrate
        - Potassium antimony tartrate
        - Lithium antimony thiomate
        - Tartar emetic, Antimosan, Stibophen, Lucanthone, Hycanthone, Niridazole, and Trichlorophon.

9. Additional Considerations

- **Cercarial Dermatitis:**
    - An occupational hazard in humans who contact water containing non-human schistosome cercariae.
    - Characterized by erythema, and with repeated exposure, papules or pustules may develop.
    - Also known by various synonyms:
        - Schistosome dermatitis, Gale des nageurs, Plumber's itch, Lakeside disease, Fisherman's itch, Collector's itch, Swamp itch, Swimmer's itch, Clam digger's itch, Dhobi itch, Hunter's itch, Rice paddy itch.

Other Genera in the Family:

- **Ornithobilharzia:**
    - Notable for numerous testes and a short uterus containing a single egg at a time.
- **Orientobilharzia bomfordi:**
    - Occurs in the mesenteric veins of buffaloes in India.
- **Bivitellobilharzia nairi:**
    - Found in elephants.
- **Heterobilharzia americanum:**
    - Infects dogs and other mammals.
- **Australobilharzia variglandis, Gigantobilharzia:**
    - Found in water fowl.
- **Trichobilharzia:**
    - Primarily parasites of birds.

Trematode Families

A. Family – PROSTHOGONIMIDAE

General Features:

- Small distomes inhabiting the bursa of Fabricius and oviducts of fowl and ducks.
- Considered one of the most pathogenic trematode parasites of poultry in Europe and America.

Taxonomy & Hosts:

- **Genus:** Prosthogonimus
- **Affected Hosts:** Fowl, pea fowl, guinea fowl, etc.

Life Cycle:

1. **Egg:**
    - Eggs are typically dark brown and operculated.
2. **Larval Stages:**
    - **Miracidium → Sporocyst → Cercaria → Metacercaria (infective stage) → Adult**
    - *Note:* Redia stage is absent.
3. **Intermediate Hosts:**
    - **1st Intermediate Host:** Aquatic snail (e.g., *Bithynia tentaculata*).
    - **2nd Intermediate Host:** Dragon fly; in India, the species *Sympetrum decoloratum* acts in this role.
    - Cercariae enter the naiad stage of the dragon fly, aided by the insect's breathing movements that facilitate penetration (often through the anus).

Pathological Features:

- **Peritonitis:** Continuous irritation of the oviduct.
- Egg passage is affected—eggs may be expelled without full shell formation due to increased oviduct movement and lime secretion by associated glands, which leads to a characteristic white discharge.

B. Family – PARAGONIMIDAE

General Features:

- Distomes that inhabit the lungs of humans and dogs.
- Significant due to their zoonotic importance.

Taxonomy & Hosts:

- **Genus:** Paragonimus
- **Important Species:** *P. westermani*, *P. kellicotti*
- **Common Name:** Lung fluke or Oriental lung fluke.
- **Site/Location:** Lungs.
- **Definitive Hosts:** Dogs, cats, foxes, pigs, and humans.

Life Cycle:

- Requires two intermediate hosts:
    - **1st Intermediate Host:** Snails (e.g., of the genus *Melania*).

    - **2nd Intermediate Host:** Crab or crayfish.
- **Developmental Stages:**
    - Miracidium, sporocyst, redia, daughter redia, cercaria, metacercaria.
- Immature flukes reach the lung via the peritoneal cavity.

Pathogenesis:

- Eosinophilic granulomatous lesions in the lungs.
- **Drug of Choice:** Bitonol.

C. Family – ECHINOSTOMATIDAE

General Features:

- Elongate flukes with a characteristic head-collar around the oral sucker.
- The head-collar is usually armed with a single or double row of hooks (spines); the cuticle often bears spines or scales.
- A well-developed ventral sucker is found in the anterior third of the body.
- The excretory vesicle is Y-shaped with many side branches.
- Eggs are large.

Hosts & Sites:

- Parasites in the intestine and sometimes in the bile ducts of birds and mammals.

Examples:

- **Genus Echinostoma:**
    - *Echinostoma revolutum* – found in the rectum and caeca of domestic duck, goose, partridge, fowl, and other aquatic birds.
    - In India, *Lymnaea auricularia* serves as an intermediate host.
    - The cercaria is known as "Cercaria echinata."
- **Genus Hypoderaeum:**
    - *Hypoderaeum conoideum* – inhabits the posterior part of the intestine.
    - **Intermediate Hosts:**
        - 1st intermediate host: snail.
        - 2nd intermediate host: kidneys of tadpoles (e.g., *Rana temporaria*).

D. Family – NOTOCOTYLIDAE

General Features:

- These flukes lack a ventral sucker (monostomes).
- **Internal Anatomy:**
    - Testes and vitellaria lie laterally to the intestinal caeca.

    - The ovary is located between the testes and vitellaria.
- **Habitat:** Mainly found in the intestine of birds.
- **Eggs:** Possess polar filaments at both ends.

Examples:

- *Notocotylus attentatus*
- *Ogmocotyle indica*

E. Family – HETEROPHYIDAE

General Features:

- Very small trematodes found in the intestines of birds and mammals.
- **Example:**
    - *Heterophyes heterophyes* – inhabits the small intestine of dogs, cats, and humans.

II. Cestodes (Tapeworms)

General Characteristics:

- **Body Form:**
    - Elongated, tape- or ribbon-like body; dorsoventrally flattened.
    - Lack an alimentary canal.
- **Segmentation:**
    - Highly segmented; each segment (proglottid) contains complete male and female reproductive systems.
    - The entire chain of segments is called the strobila.
- **Reproduction:**
    - Hermaphroditic.
- **Life Cycle:**
    - Most exhibit an indirect life cycle, but some (e.g., *Hymenolepis* spp.) can have both direct and indirect cycles.
    - Intermediate stages are commonly referred to as cysts or bladder-worms.
- **Classes:**
    - **Eucestoda:** True cestodes.
    - **Cotyloda:** Primarily cestodes of fish.

Morphology:

- **Scolex (Head):**
    - Bears attachment organs such as suckers and hooks.

    - May possess a protrusible cone (rostellum) armed with hooks.
    - In some cestodes (Cotyloda), the scolex has two long muscular grooves called bothria.
- **Neck:**
    - A short, unsegmented region following the scolex.
- **Proglottids:**
    - Segments that make up the strobila.
    - Three main types:
        - **Immature:** Reproductive organs not fully developed.
        - **Mature:** Fully developed and functional reproductive organs (located in the middle of the strobila).
        - **Gravid:** Terminal segments where fertilized eggs fill the uterus; reproductive organs are often reduced.

Egg and Larval Forms:

- **Egg Characteristics:**
    - Contain a hexacanth (six-hooked) embryo.
    - **Oncosphere:** A hexacanth embryo enclosed by one or two embryonic envelopes.
    - **Coracidium:** A motile oncosphere with a ciliated inner envelope (sometimes called the "ciliated embryophore").
- **Larval (Cyst) Forms:**
    - **Cysticercus:** A bladder-like cyst containing a single invaginated scolex (protoscolex); typically found in vertebrates.
    - **Cysticercoid:** A small vesicle with a non-invaginated scolex; found in invertebrate intermediate hosts.
        - *Cryptocystis* is a type of cysticercoid (e.g., in *Diphyllobothrium latum* with early tail remnants in *D. caninum*).
    - **Strobilocercous:** Scolex evaginated and attached by a chain of proglottids.
    - **Hydatid Cyst:** A large, fluid-filled cyst lined with a germinal layer producing multiple invaginated scolices ("hydatid sand").
    - **Coenurus:** A large cyst with numerous invaginated scolices budded from the cyst wall (e.g., *Multiceps multiceps* formerly known as *Taenia multiceps*).
    - **Tetrathyridium:** A worm-like, elongate larval stage with an invaginated scolex.
    - **Procercoid:** A solid-bodied larva bearing hooks.
    - **Pleurocercoid:** An elongated larva with an adult scolex; seen in *Diphyllobothrium latum*.

General Life Cycle of Cestodes:

1. **Egg Stage:**
    - Eggs are released in feces from gravid proglottids.
2. **Intermediate Host Infection:**
    - In vertebrate hosts, eggs hatch under the influence of gastric and intestinal secretions. The oncosphere penetrates the intestinal wall, enters the blood/lymph stream, and reaches its predilection site where it develops into a cyst (metacestode).
    - In invertebrates, the oncosphere reaches the body cavity.
3. **Cyst (Metacestode) Development:**
    - The oncosphere loses its hooks and forms a bladder-like cyst with an outer cuticle and inner germinal layer.
    - Within the cyst, one or more invaginated scolices develop.
4. **Infection of Final Host:**
    - Final hosts become infected by ingesting cyst-infected tissues.

In the intestine, the scolex evaginates to attach to the intestinal wall and then grows **into an adult tapeworm.**

III. Summary

- **Trematode Families:**
    - *Prosthogonimidae* affect the oviduct of birds via a snail–dragon fly cycle.
    - *Paragonimidae* (lung flukes) have zoonotic significance and require snails and crabs/crayfish.
    - *Echinostomatidae* are intestinal (or biliary) flukes with a characteristic head-collar armed with hooks.
    - *Notocotylidae* lack a ventral sucker and are found in bird intestines.
    - *Heterophyidae* are very small intestinal trematodes infecting birds and mammals.
- **Cestodes (Tapeworms):**
    - They are elongated, segmented, and lack a digestive tract.
    - Their life cycle usually involves intermediate (often cystic) stages, and drugs (e.g., Praziquantel) are aimed at the scolex to prevent regeneration.

I. Equine Tapeworms (Family Anoplocephalidae)

A. Genus: Anoplocephala

1. Species and Their Features

- **Anoplocephala magna**
    - **Size:** Up to 80 cm long × 2.5 cm wide
    - **Habitat:** Mainly in the small intestine (SI; jejunum); rarely found in the stomach

- **Host:** Equines
- **Remarks:** Lappets (flap-like outgrowths under the suckers) are absent; this is the largest cestode found in equines.

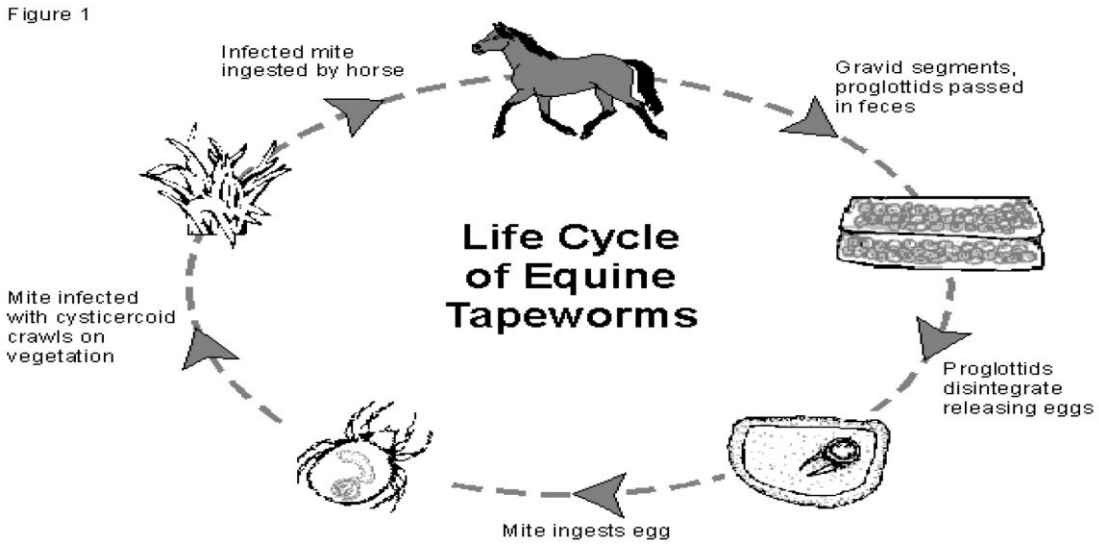
- **Anoplocephala perfoliata**
  - **Size:** Approximately 8 cm long × 1.5 cm wide
  - **Habitat:** Small and large intestines (SI and LI) of horses and donkeys
  - **Host:** Equines
  - **Remarks:** Lappets are present; these outgrowths under each sucker are thought to aid in attachment and may contribute to perforation.
- **Paranoplocephala mamillana**
  - **Size:** 6–50 cm long × 4–6 mm wide
  - **Habitat:** Small intestine (SI)
  - **Host:** Equines
  - **Remarks:** Known as the "dwarf tapeworm" of equines; lappets are absent.

Genus	Size	Habitat	Host	Remarks
Anoplocephala magna	80 x 2.5 cm	Small intestine (jejunum), rarely stomach	Equines	Lappets absent; Largest cestode of equines
Anoplocephala perfoliata	8 x 1.5 cm	Small and large intestine of horse and donkey	Equines	Lappets present (outgrowth under each sucker aids in perforation)
Paranoplocephala mamillana	6–50 x 4–6 mm	Small intestine	Equines	Dwarf tapeworm of equines; Lappets absent

B. Life Cycle (Anoplocephala and Paranaplocephala)

Life cycle of equine tapeworm

Figure 1



Pathogenesis

1. **Stages:**
    - **Egg → Cysticercoid → Adult**
2. **Cycle Details:**
    - **Adult tapeworms** reside in the small intestine of the definitive host (DH).
    - **Eggs** are released from shed gravid segments and disseminated in feces.
    - **Intermediate Host (IH):**
        - Oribatid mites (e.g., genera *Scheloribates* and *Galumna*) ingest the eggs.
        - Cysticercoids develop in these mites over a period of 2–4 months.
    - **Transmission:**
        - Infected mites are found on grass in grazing fields.
        - When horses ingest contaminated herbage, the mites are digested, releasing cysticercoids.
        - Adult tapeworms develop in the intestine within 4–6 weeks.

C. Pathogenesis (Equine Tapeworms)

- **Light Infections:** Often subclinical; may have no overt clinical signs.
- **Heavy Infections:**
    - May cause ill health and unthriftiness.
    - **A. perfoliata:**
        - Attachment near the ileocaecal orifice can produce depressed ulcerative lesions.
        - Excessive granulation tissue may partially occlude the ileocaecal opening, possibly contributing to intussusception.

    - **A. magna:**
        - Heavy infections may result in catarrhal or hemorrhagic enteritis in the small intestine.
    - **Both Species:**
        - Intestinal perforation has been recorded.
- **Paranoplocephala mamillana:**
    - Generally considered non-pathogenic (rarely produces clinical disease).

D. Diagnosis and Treatment (Equine Tapeworms)

1. Diagnosis

- **Fecal Examination:**
    - Identification of eggs, which are characterized by:
        - Three distinct coverings: an outer vitelline membrane, a middle albuminous coat, and an inner chitinous membrane.
        - The egg is frequently pear-shaped and bears a pair of hooked projections (together forming the "pyriform apparatus").
- **Postmortem (PM) Findings:**
    - Ulcerative lesions at the ileocaecal junction may be noted.

2. Treatment

- **Anthelmintics and Dosages (mg/kg b.wt.):**
    - Micronized mebendazole: 15–20
    - Bithionol: 7
    - Niclosamide: 88
    - (Note: Benzimidazoles are effective at higher doses; narrow-spectrum anthelmintics are preferred for tapeworms.)

II. Tapeworms of Ruminants

A. Common Genera within Family Anoplocephalidae

1. Genus: Moniezia

- **Species:**
    - *Moniezia expansa* (commonly affects sheep)
    - *Moniezia benedeni* (commonly affects cattle)
- **Key Features:**
    - **Habitat:** Small intestine of sheep, goats, cattle, and buffalo.
    - **Size:** Can reach up to 6 m in length.

- **Morphology:**
  - Proglottids are broader than long.
  - Gravid segments possess two sets of genital organs.
  - Body is creamish white; the scolex is unarmed.
  - Characteristic “horseshoe-shaped” ovary and vitelline glands form a ring-like structure.
  - Lobed testes are scattered in the medial field.
  - Interproglottidal glands are present along the posterior margin.

- **Life Cycle:**
  - Eggs from gravid segments are passed in feces.
  - Ingestion of oribatid mites (acting as the intermediate host) containing the developing cysticercoid leads to infection.

- **Pathogenesis:**
  - More common in young animals (lambs, kids, calves under 6 months).
  - Extensive tapeworm surface may reduce nutrient availability.
  - Can cause emaciation, depressed production, intestinal obstruction, constipation, diarrhea, and even death.
  - High incidence of enterotoxemia may be associated with Moniezia in lambs.

2. Diagnosis and Treatment (Ruminant Tapeworms)

- **Diagnosis:**
  - Identification of characteristic eggs in feces.
  - Observation of “cooked rice grain”–like gravid segments.
  - Postmortem examination can reveal the large, coiled tapeworm mass.

- **Treatment (mg/kg b.wt.):**
  - Praziquantel: 15
  - Albendazole: 10
  - Fenbendazole: 5
  - Cambendazole: 20
  - Resorantel: 65
  - Niclosamide: 75–150
  - Bithional: 200

B. Family: Thysanosomidae (Tapeworms with Paruterine Organs)

1. General Features

- In these tapeworms, the gravid uterus is replaced by paruterine organs or capsules.
- Important genera include **Avitellina**, **Stilesia**, and **Thysaniezia**.

2. Genus: Avitellina

- **Species:**
  - *Avitellina centripunctata*
- **Features:**
  - **Habitat:** Small intestine of cattle, sheep, and goats.
  - **Scolex:** Unarmed with a distinct neck; rostellum is absent.
  - **Proglottids:**
    - Mature segments show indistinct segmentation.
    - Only one set of genital organs, arranged in an alternating, irregular pattern.
  - **Vitelline Glands:** Absent (as indicated by the genus name).
  - **Ovary and Testes:**
    - Ovary is spherical, located near the genital pore.
    - Testes occur in groups on either side of the excretory canal.
  - **Eggs:** Lack a pyriform apparatus.
- **Life Cycle:**
  - Indirect cycle involving an intermediate host that is likely a psocid (bark, book, or dust lice).
  - Ingestion of eggs leads to cysticercoid development in the IH; digestion of the arthropod in the DH liberates the cysticercoid, which develops into the adult tapeworm.
- **Diagnosis:**
  - Presence of characteristic gravid proglottids and eggs in feces.
  - Postmortem: Unsegmented worm with a distinct dark opaque line in the center of each segment may be observed.

3. Genus: Stilesia

- **Species:**
  - *Stilesia hepatica* – occurs in the bile duct of ruminants.
  - *Stilesia globipunctata* – found in the small intestine.
- **Features:**
  - Strobila is very thin and membranous; margins appear wrinkled.
  - Morphologically resembles Avitellina, but vitelline glands are absent.

- Testes are arranged medially to the excretory canals.
- The uterus is characteristically dumbbell-shaped (two bulging parts connected by a transverse duct) and later forms two paruterine organs in gravid proglottids.

- **Remarks:**
  - May be associated with thickening of the bile duct in affected animals.

4. Other Notable Genera

- **Helicometra giardi (also known as Thysaniezia giardi):**
  - **Habitat:** Small intestine of sheep, goats, and cattle.
  - **Features:**
    - Scolex unarmed with a distinct neck.
    - Short segments, each with a single set of genital organs; genital pores are irregularly alternate.
    - Testes lie lateral to the excretory canal.
    - Uterus is transversely placed in an "M" shape.
    - Gravid segments contain many small paruterine organs.
- **Thysanosoma actinioides:**
  - **Hosts:** Sheep, goats, and cattle.
  - **Site/Location:** Bile duct, pancreatic duct, and small intestine.
  - **Common Name:** Fringed tapeworm or double-pored tapeworm.
  - **Remarks:**
    - Segments are "fringed" posteriorly.
    - Associated with digestive disorders and unthriftiness.
    - The intermediate host is suspected to be psocids (book or bark lice).

Poultry Tapeworms

Poultry tapeworms belong to several families and are important parasites of fowl and other gallinaceous birds. The main families include:

- **Family Davaineidae**
- **Family Dilepididae**
- **Family Dipylidiidae**
- **Family Hymenolepididae**

Each family has distinct genera and species with unique biological and pathological characteristics.

II. Family Davaineidae

This family includes genera such as **Davainea, Raillietina,** and **Cotugnia**.

A. Davainea proglottina

- **Common Name:** Dwarf tapeworm of poultry
- **Habitat:** Small intestine of fowl, pigeon, and other gallinaceous birds
- **Size & Morphology:**
    - Very small (approximately 4 mm in length).
    - Adults are microscopic, comprising 4–9 segments.
    - The scolex is armed with a rostellum and suckers; hooks are thorn-shaped and hammer shaped.
    - Neck is almost absent.
    - Possesses a single set of reproductive organs with irregularly alternating genital pores.
    - In gravid segments, the uterus is replaced by an egg capsule, with each capsule containing one egg.
    - Segments are narrow anteriorly and widen posteriorly, forming a triangular profile.
- **Life Cycle:**
    - **Eggs:** Gravid proglottids are voided in droppings; egg capsules and eggs are released.
    - **Intermediate Host (IH):** Gastropod molluscs (snails or slugs such as *Limax, Arion, Cepoea, Agriolimax* spp.) ingest the eggs.
    - **Development:** Cysticercoids develop within the molluscs in about 3 weeks.
    - **Transmission:** Birds acquire infection by swallowing infected molluscs; adult worms develop in the small intestine within approximately 14 days (prepatent period).
- **Pathogenesis:**
    - Can cause haemorrhagic enteritis, reduced growth, emaciation, and weakness.

B. Genus Raillietina

About 200 species are described, but the major ones in poultry include:

Species	Suckers	Rostellum	Uterus (Eggs per Capsule)	Additional Remarks
R. tetragona	Oval in shape	Armed with a single row of hooks (100 spines)	6-12	Gravid proglottids frequently separate in the middle, forming windows in the strobila.
R. echinobothrida	Circular in shape	Armed with 2 rows of hooks (200 spines)	8-10	-

R. cesticillus	Inconspicuous, i.e., not clear	Armed with 400-500 small hooks	Single egg per capsule	

1. Raillietina tetragona

- **Habitat:** Small intestine of poultry.
- **Morphology:**
  - Large tapeworm; reaches up to 25 cm in length.
  - Oval suckers armed with 3–4 layers of spines.
  - The rostellum is armed with a single row of hooks (around 100 spines).
  - Mature proglottids have one set of genital organs with a unilaterally placed, irregularly alternating genital pore.
  - The ovary is median; gravid segments have egg capsules each containing 6–12 eggs.
- **Life Cycle:**
  - **IH:** Various ants (e.g., genera *Pheidole* and *Tetramorium*) serve as intermediate hosts.
  - **Prepatent Period:** Approximately 13–21 days.
  - **Stages:** Egg → Oncosphere → Cysticercoid in ant → Adult.

2. Raillietina echinobothrida

- **Features:**
  - Similar to R. tetragona but with differences:
    - Suckers are circular.
    - Rostellum is armed with two rows of hooks (about 200 spines).
    - Each egg capsule contains 8–10 eggs.
- **Pathogenesis:**
  - Most pathogenic among the Raillietina spp.
  - Forms nodules at attachment sites; causes hyperplastic enteritis (nodular tapeworm infection).
  - Nodules may mimic tuberculosis nodules with central necrosis and surrounding fibrosis.

3. Raillietina cesticillus

- **Features:**
  - Suckers are inconspicuous.
  - Rostellum is heavily armed with 400–500 small hooks.
  - Each egg capsule contains a single egg.

- **Life Cycle:**
    - **IH:** Beetles (various types) act as intermediate hosts.
    - **Prepatent Period:** Around 20 days.

C. Genus Cotugnia

- **Species and Hosts:**
    - *Cotugnia digonophora* – found in the small intestine of fowl.
    - *Cotugnia fastigata* – found in ducks.
    - *Cotugnia cuneata* – reported from pigeons.
- **Morphology:**
    - Adult tapeworms are around 10 cm long.
    - Scolex has unarmed suckers with a rostellum armed with two rows of spines.
    - Mature proglottids have two sets of genital organs (double-pored); numerous testes extend across the segment.
    - Gravid proglottids contain egg capsules with a single egg in each.

III. Order Dilepididea

This order comprises two families affecting poultry:

A. Family Dipylidiidae

- **Genera:**
    - **Dipylidium** and **Choanotaenia**
- **Example: Choanotaenia infundibulum**
    - **Habitat:** Upper half of the small intestine of fowl and turkey.
    - **Morphology:**
        - Scolex provided with armed suckers.
        - Rostellum armed with 16–20 elongated spines.
        - Mature proglottids have one set of reproductive organs; the genital pore alternates irregularly and opens near the posterior margin.
        - Ovary is lobed; testis lie below the ovary.
        - Vitellaria are arranged in two branches.
        - Proglottids are funnel-shaped (wider posteriorly, narrow anteriorly).
    - **Intermediate Hosts (IH):**
        - Beetles (e.g., genera *Aphodius, Calathus, Tribolium*) and house flies support the development of the cysticercoid.

B. Family Dilepididae

- **Genus:** Amoebotaenia
    - **Example: Amoebotaenia cuneata (or A. sphenoides)**
    - **Habitat:** Small intestine of domestic fowl.
    - **Morphology:**
        - Rostellum armed with 14 elongated, bottle-shaped hooks.
        - Suckers are oval and unarmed.
        - Strobila is triangular, comprising about 20 segments.
        - Mature proglottids contain a single set of reproductive organs with an alternating genital pore located at the extreme anterior margin.
        - Testes are located along the posterior margin.
        - Gravid proglottids contain a transverse uterine sac filled with eggs; the ovary appears bilobed.
    - **Life Cycle:**
        - **IH:** Earthworms (genera *Eisenia* and *Pheretima*) serve as the intermediate host.
        - Cysticercoid development takes approximately 2 weeks.
        - Birds ingest earthworms (especially after rain when worms surface).
        - Prepatent period in birds is around 4 weeks.
        - Cysticercoids are protected by secretory substances against digestive enzymes.

IV. Family Hymenolepididae

This family includes the genus **Hymenolepis**, with species infecting various hosts including poultry.

A. General Features of Hymenolepis spp.

- **Eggs:**
    - Characterized by a pyriform apparatus (a hexacanth embryo surrounded by a pear-shaped oncospheral membrane).
- **Species and Hosts:**
    - **Hymenolepis nana:**
        - Hosts: Rodents and humans.
        - Intermediate hosts: In humans, direct life cycle; in rodents, flour beetles and fleas.
    - **Hymenolepis diminuta:**
        - Hosts: Rodents and humans.
        - Intermediate hosts: Fleas and flour beetles.

- **Hymenolepis microstoma:**
    - Hosts: Rodents (typically in the gall bladder, bile duct, or duodenum); intermediate host unknown.
- **Hymenolepis carioca:**
    - **Host:** Poultry (fowl).
    - **Morphology:**
        - Occurs in the small intestine.
        - Scolex armed with elongated spines.
        - Mature proglottids have a unilaterally placed genital pore.
        - Typically, three testes are found in each mature proglottid.
    - **Intermediate Hosts:**
        - Various beetles and Stomoxys spp. (biting flies) serve as intermediate hosts.
- **Hymenolepis lanceolata, H. cantaniana,** and **H. nyrocae:**
    - Reported from ducks, geese, and other birds, with aquatic crustaceans or copepods as intermediate hosts (depending on the species).

Canine Tapeworms

- **Size & Distribution:**
    - Most canine tapeworms are large, often measuring in meters.
    - They occur in carnivores (dogs, cats, foxes, wild canids) and humans.
- **Morphology:**
    - **Gravid proglottids:** Longer than wide.
    - **Scolex & Rostellum:**
        - When present, the rostellum bears two rows of hooks (small and large).
    - **Reproductive System:**
        - A single set of genital organs is present along with numerous testes.
        - The ovary is typically located in the posterior part of each segment, with a median uterus.
- **Eggs:**
    - Eggs (particularly of Taenia spp.) are very characteristic; the capsule is fragile and the embryophore shows a striated appearance.

II. Family Taeniidae

This family comprises the large, metrical tapeworms found in the intestines of carnivores and humans. The most important genera include **Taenia** and **Echinococcus**.

A. Genus Taenia

Key Features:

- Adult worms may reach several meters in length.
- Gravid segments rarely detach spontaneously (e.g., in *T. solium* they tend to remain attached, unlike in *T. saginata*).
- The rostellum, when present, is armed with two rows of hooks.
- A single set of reproductive organs with numerous testes is present.
- Eggs have a delicate capsule that is easily lost and a striated embryophore.

1. Taenia solium (Pork Tapeworm)

- **Hosts:**
  - Definitive: Humans (small intestine)
  - Intermediate: Pigs
- **Morphology:**
  - Length: Approximately 3–5 m.
  - Rostellum with two rows of hooks.
  - Gravid segments: Ovary is trilobed; the uterus has a median stem with 16 lateral branches.
- **Life Cycle:**
  - Eggs are expelled in human feces.
  - When ingested by pigs, the eggs hatch, releasing oncospheres that migrate (via the hepatoportal circulation) into organs such as the liver, muscle, lung, and diaphragm where they develop into cysticerci (Cysticercus cellulosae).
  - Humans acquire taeniasis by eating undercooked pork containing cysticerci.
  - Human cysticercosis may also occur by ingestion of eggs (direct autoinfection or food contamination).
- **Pathogenesis:**
  - Can cause enteritis, neurocysticercosis (when oncospheres migrate to the brain), ocular cysticercosis, and the “measly pork” condition in pigs.

2. Taenia saginata (Beef Tapeworm)

- **Hosts:**
  - Definitive: Humans
  - Intermediate: Cattle
- **Notes:**
  - Life cycle similar to *T. solium*, except the intermediate host is cattle.

- Gravid segments detach more readily than in *T. solium*.

3. Taenia asiatica (Taiwan Taenia)

- **Distribution:**
  - Found in Taiwan, Indonesia, and the Philippines.
- **Characteristics:**
  - Possesses intermediate features between *T. solium* and *T. saginata*.
  - The metacestode, termed cysticercus viscerotropica, is found mainly in the liver.

4. Taenia multiceps

- **Hosts:**
  - Definitive: Dogs
  - Intermediate: Sheep and goats
- **Intermediate Stage:**
  - The infective stage is a coenurus (Coenurus cerebralis), a transparent cyst containing 200–400 scolices.
- **Pathogenesis:**
  - In intermediate hosts, cysts form in the brain or spinal cord, causing neurological signs (e.g., circling or "gid") and skeletal atrophy.

5. Additional Taenia Species in Canines

- **Taenia ovis:**
  - Intermediate stage (Cysticercus ovis) occurs in muscles of sheep.
- **Taenia hydatigena:**
  - Found in dogs and other canids; intermediate stage is Cysticercus tenuicollis, usually located on the liver's surface (leading to hepatitis cysticercosa).
- **Taenia pisiformis:**
  - Definitive host: Dogs (rarely cats)
  - Intermediate hosts: Rabbits, hares, and rodents; the cysticerci develop in the peritoneum.
- **Taenia taeniaeformis (Cat-Rat Tapeworm):**
  - Definitive host: Cats
  - Intermediate stage: Cysticercus fasciolaris in rodents.
- **Taenia krabbei:**
  - Also known as the wolf-caribou tapeworm; intermediate stage (Cysticercus tarandi) is found in reindeer or caribou.
- **Taenia cervi:**

    - Occurs in dogs with intermediate stage (Cysticercus cervi) in deer.
- **Taenia crassiceps:**
    - Occurs in wild carnivores with cysticerci found in rodents.

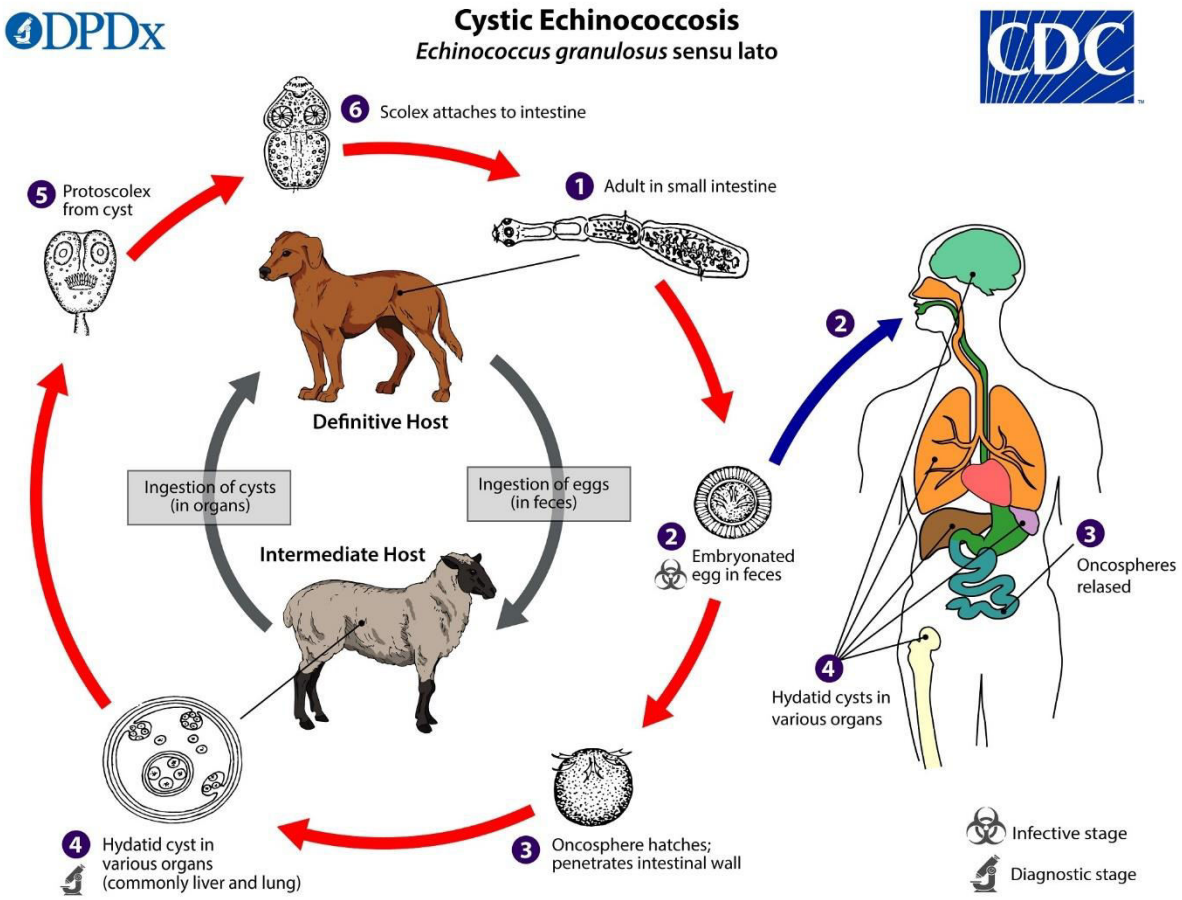
B. Genus Echinococcus

Key Features:

- These are the smallest tapeworms; adults reside in the small intestine of dogs and related canids.
- **Scolex:**
    - Rostellum is armed with two rows of spines.
    - Suckers are unarmed.
- **Segments:**
    - The strobila comprises 2–6 segments (immature, mature, and gravid).
- **Eggs:**
    - Very characteristic; the life cycle involves formation of hydatid cysts (meatcestodes).

1. Echinococcus granulosus

- **Hosts:**
    - Definitive: Dog (and other canids)
    - Intermediate: Sheep, goats, cattle, and other ungulates
- **Life Cycle:**
    - Eggs are passed in the feces.
    - Oncospheres hatch and penetrate the intestinal wall, developing into hydatid cysts in organs (commonly liver and lung).
    - Humans become accidental intermediate hosts upon ingestion.
- **Pathogenesis:**
    - In dogs, may cause enteritis.
    - In intermediate hosts, large hydatid cysts cause pressure atrophy and functional disturbances in vital organs.
- **Diagnosis & Control:**
    - Fecal examination and serological tests (ELISA, IHA, etc.).
    - Treatment in dogs with Praziquantel; in humans, surgical removal or medical therapy (albendazole/mebendazole).



2. Echinococcus multilocularis

- **Hosts:**
  - Definitive: Wild canids (foxes, jackals)
  - Intermediate: Small rodents, squirrels, pigs, monkeys, and humans
- **Distinctive Feature:**
  - Hydatid cysts are multilocular (multiple cavities) and filled with gelatinous material.

3. Other Echinococcus Species

- Briefly noted: E. oligarthus, E. vogeli, and E. shiqucus occur in different geographic areas and host associations.

III. Family Dipylididae

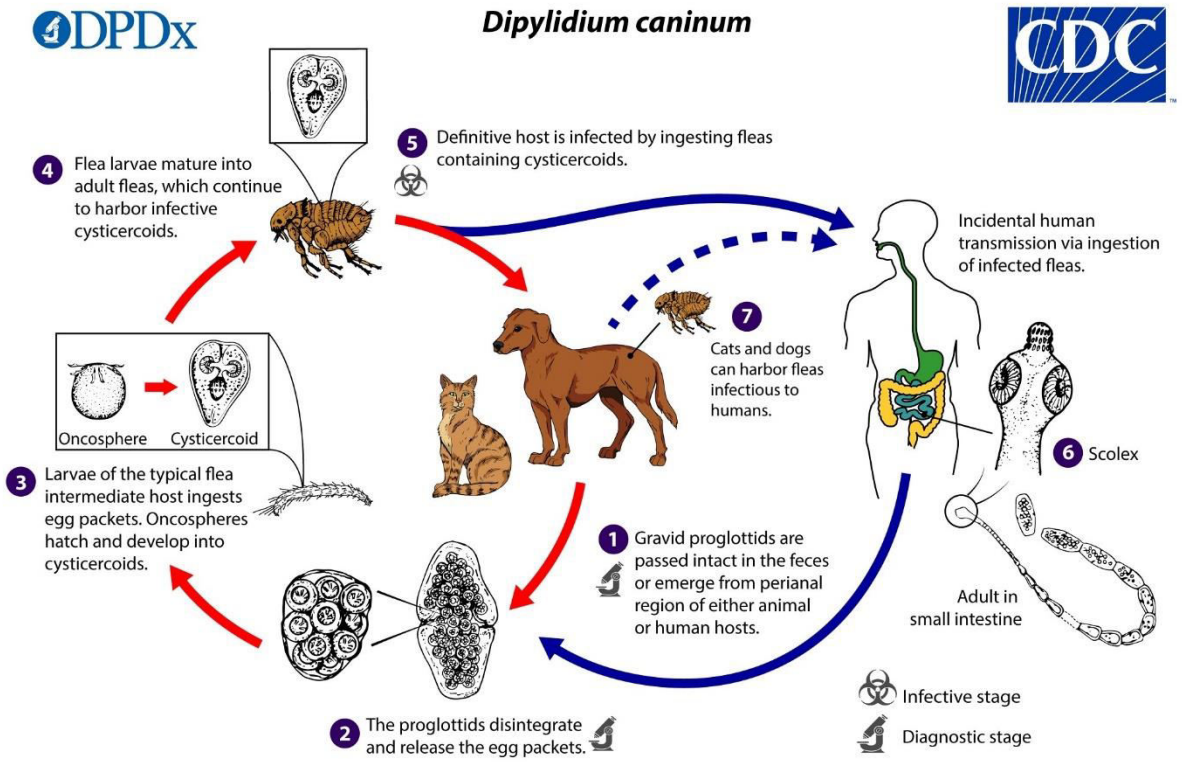
Dipylidium caninum

General Features:

- Commonly known as the double-pored tapeworm of canines.
- **Hosts:**
  - Definitive: Dogs, cats, foxes; rarely humans.

- **Morphology:**
    - Length: Up to 50 cm.
    - The scolex bears a rostellum with 3–4 rows of small, rose-thorn–shaped hooks.
    - Mature segments possess two sets of genital organs with numerous testes.
    - Ovary and vitellaria form a mass that often resembles a bunch of grapes.
    - Gravid proglottids are elongated, oval (resembling cucumber seeds or large rice grains) and show active crawling behavior.
    - Eggs are grouped within egg capsules (each capsule containing 3–30 eggs).

Life Cycle:



- **Egg Release & Intermediate Host:**
    - Gravid segments are shed in feces and may exhibit motility.
    - Eggs must be ingested by arthropod intermediate hosts (dog lice such as *Trichodectes canis* or fleas like *Ctenocephalides* spp. and *Pulex irritans*).
- **Development:**
    - Within the arthropod, cysticercoids develop in about 30 days in lice or may take several months in fleas.
- **Transmission:**
    - Dogs or cats become infected upon ingesting these infected intermediate hosts.

    - Prepatent period is approximately 3 weeks.
- **Pathogenesis:**
    - Although adult worms are generally not harmful, the presence of motile proglottids causes anal irritation ("scooting" behavior).
    - Heavy infections can lead to gastroenteritis.
    - Accidental ingestion by children may also result in gastrointestinal upset.

IV. Summary and Control Measures

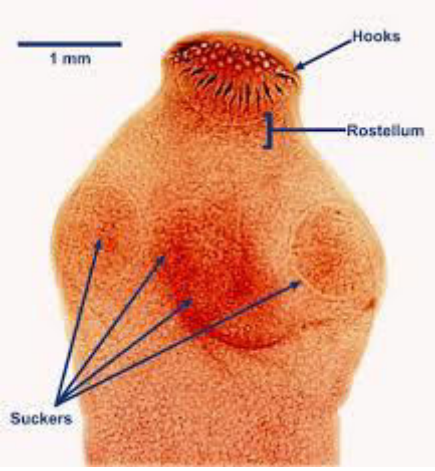
- **Family Taeniidae** (including genera *Taenia* and *Echinococcus*) are generally large tapeworms with complex life cycles involving livestock or wildlife as intermediate hosts. They are of zoonotic importance and can cause severe pathology—ranging from intestinal disturbances in definitive hosts to life-threatening cystic lesions (e.g., neurocysticercosis, hydatidosis) in intermediate hosts and humans.
- **Family Dipylididae** (represented by *Dipylidium caninum*) features a small tapeworm that uses arthropod intermediate hosts (lice and fleas). Though usually less pathogenic, they can cause discomfort and, in heavy infections, gastrointestinal signs.

Control Measures Include:

- Preventing consumption of undercooked meat (for Taenia spp.) and reducing exposure to contaminated intermediate hosts.
- Regular deworming of dogs and cats with agents such as Praziquantel (for Taeniidae and Dipylididae).
- Good sanitation practices, proper disposal of human waste, and controlling flea and lice infestations to break the life cycle of *Dipylidium caninum*.
- For echinococcosis, proper management of livestock and stray dogs plus public health measures (and in some areas, vaccination of pigs with new recombinant vaccines) are key.

Genus Taenia

- **Distribution:** Cosmopolitan.
- **Hosts:**
    - **Definitive hosts:** Humans and various carnivores (dogs, cats, wild canids) harbor adult tapeworms in their small intestine.
    - **Intermediate hosts:** Vary by species (e.g., pigs, cattle, sheep, goats, rabbits, rodents, reindeer/caribou).
- **General Morphology:**

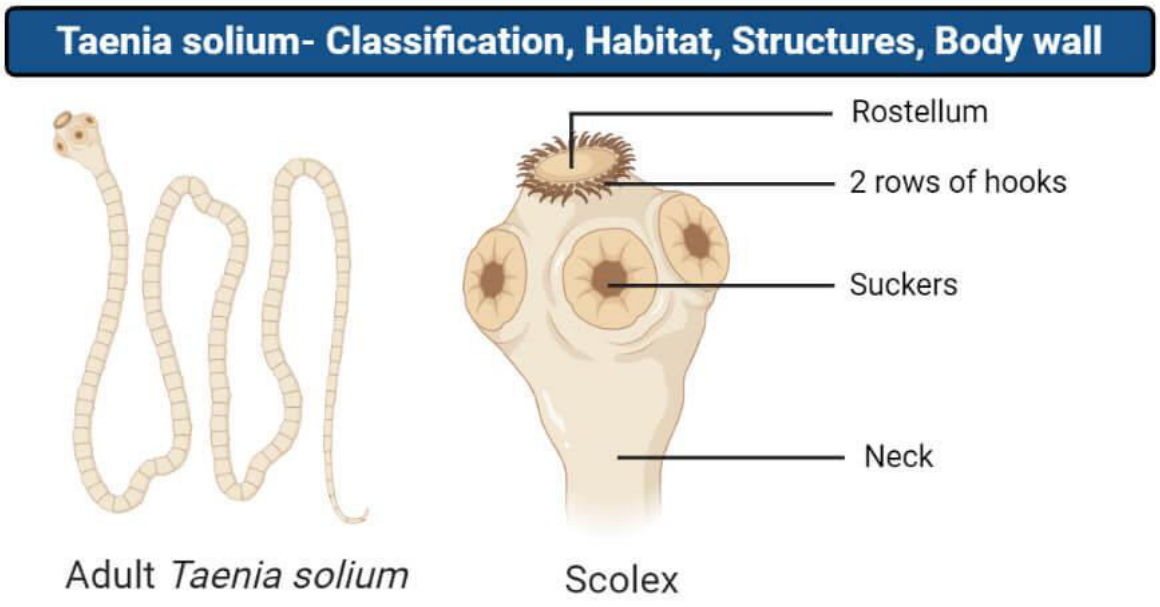


- Adult tapeworms are large (often 3–5 m or longer).
- Gravid proglottids are longer than wide.
- The scolex, when present, often bears a rostellum armed with two rows of hooks (both small and large).
- A single set of reproductive organs is present, with numerous testes and an ovary usually located in the posterior part of each segment; the uterus is median.
- Eggs are characteristic: the delicate capsule is easily lost, and the embryophore is striated.

Species Profiles

1. Taenia solium (Pork Tapeworm)

- **Common Name:** Pork tapeworm.

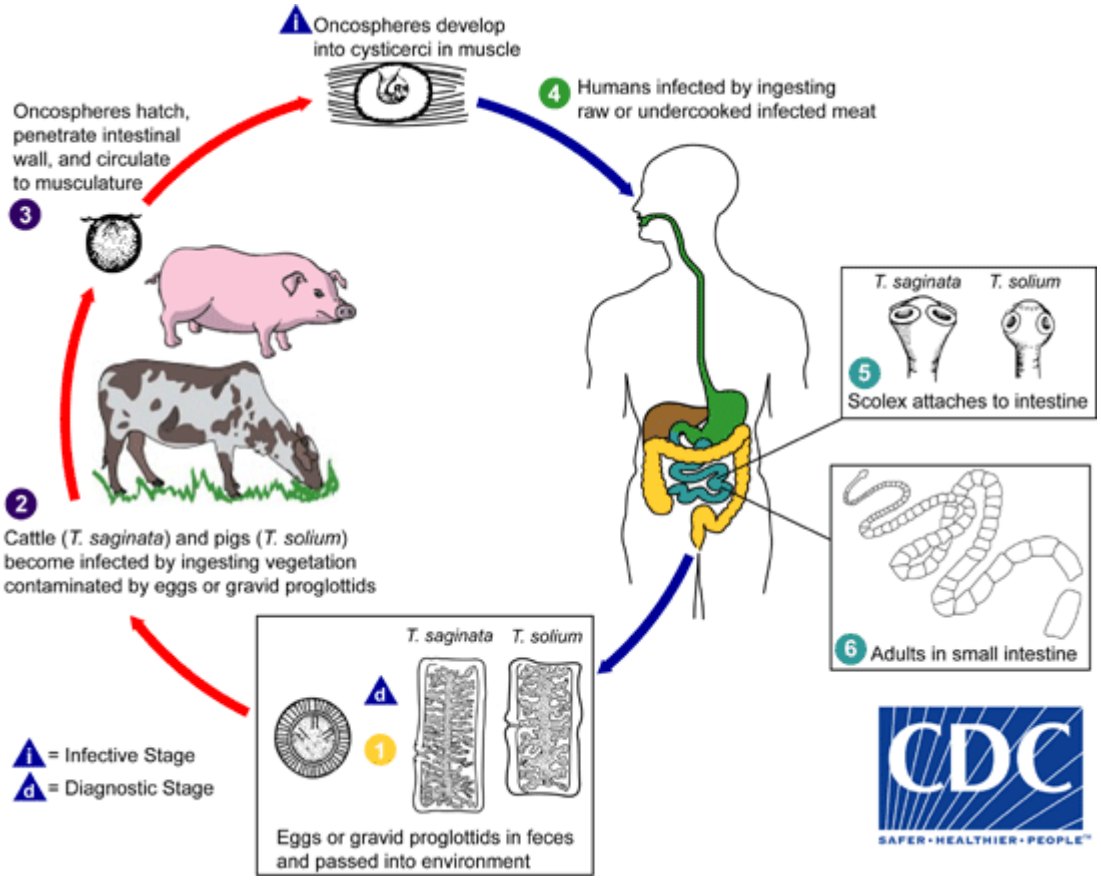


- **Prevalence & Hosts:**

- Definitive host: Humans (small intestine).
- Intermediate host: Pig.

- **Salient Morphology:**
  - Length: 3–5 m.
  - Rostellum present with two rows of hooks.
  - Gravid segments tend to remain attached (not spontaneously detached, unlike in T. saginata).
  - Ovary is trilobed.
  - Uterus: Features a median stem with 16 lateral branches.

- **Life Cycle:**



  - Eggs are expelled in human feces.
  - In pigs, ingested eggs hatch in the intestine; oncospheres migrate (via the hepatoportal system) to the liver and disseminate to muscles, lung, diaphragm, heart, etc.
  - In pig tissues, they develop into cysticerci (Cysticercus cellulosae).
  - Humans acquire infection by consuming undercooked pork containing cysticerci.

    - **Alternate Route:** Ingestion of eggs from contaminated food (raw vegetables, e.g., raw coriander) can result in human cysticercosis; autoinfection may occur via retrosperistaltic movement.

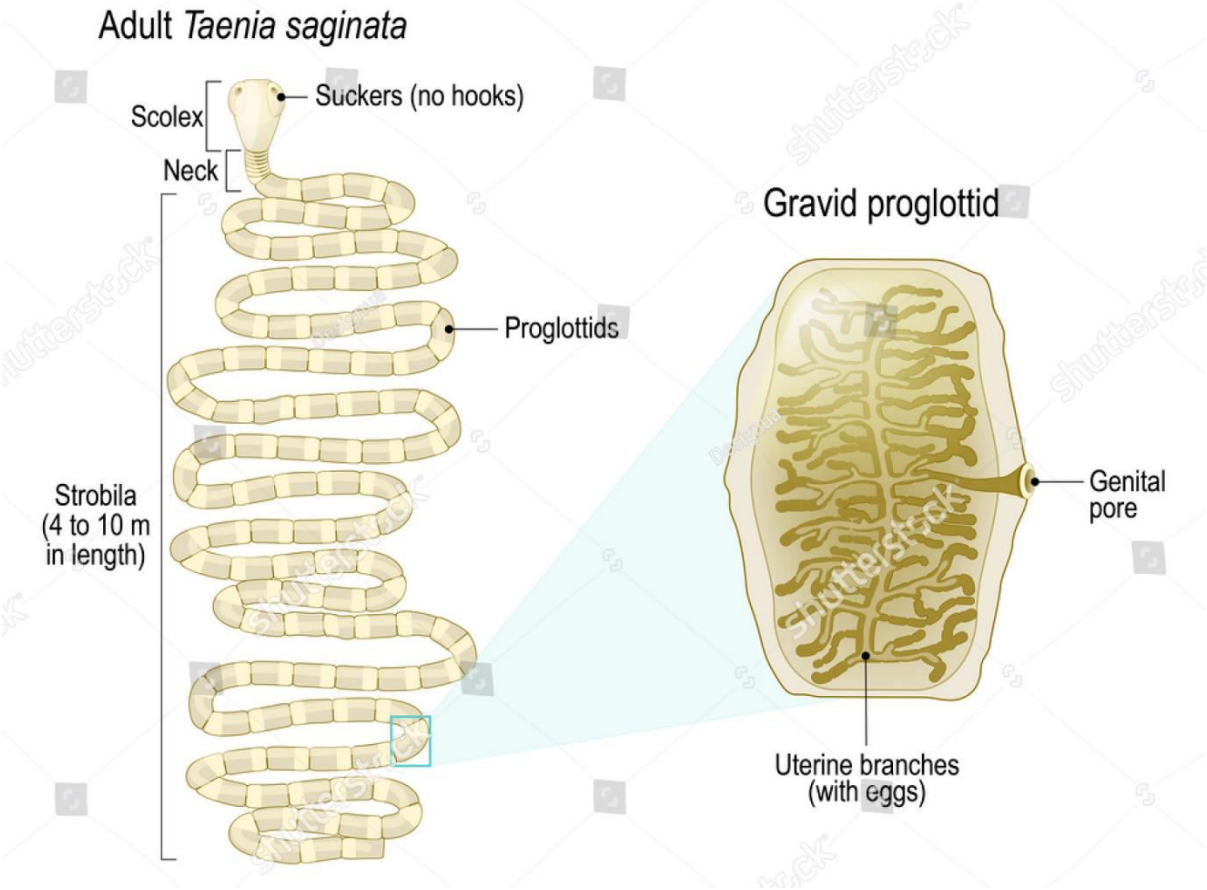
- **Pathogenesis & Clinical Effects:**
    - In humans: Enteritis, nutrient depletion, and most critically, neurocysticercosis (when oncospheres migrate to the brain or eye, causing ocular cysticercosis, conjunctivitis, or rhinitis).
    - In pigs: "Measly pork" due to cyst formation in various organs; severe neurological signs if the brain is involved.
- **Control Measures:**
    - Prevent human consumption of undercooked pork.
    - Prevent pigs from ingesting human fecal matter.
    - Proper sanitation, thorough washing of raw vegetables, adequate cooking (pork should be cooked at 50–60°C or frozen at –20°C for at least ½ hour).

Vaccination: For example**, CYSVAX—the recombinant porcine cysticercosis vaccine.**

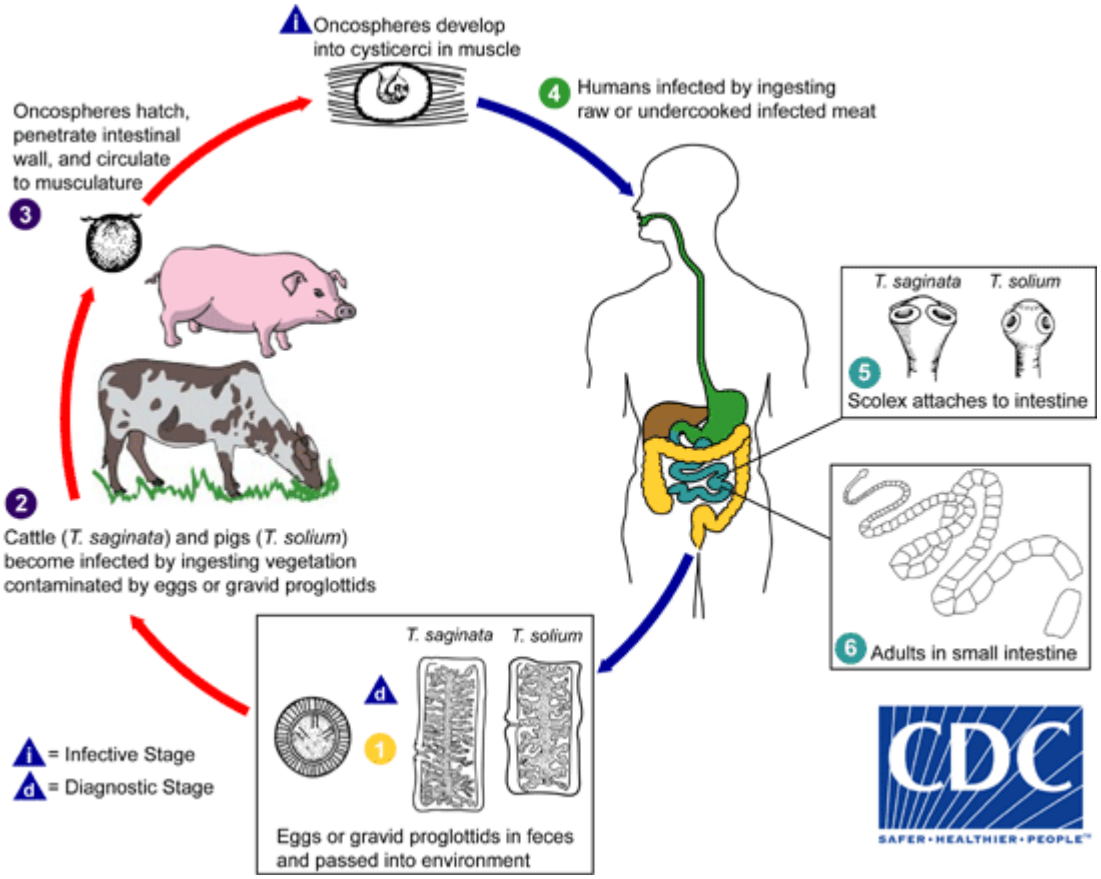
2. Taenia saginata (Beef Tapeworm)

- **Common Name:** Beef tapeworm.
- **Hosts:**
    - Definitive host: Humans (small intestine).
    - Intermediate host: Cattle.

BEEF TAPEWORM



- **Life Cycle & Morphology:**



- Similar to T. solium except that cattle replace pigs as the intermediate host.

- **Control Measures:**
  - Proper cooking/freezing of beef is essential (e.g., freezing at 100°C for 10 days or **180°C for 3 days is recommended).**

3. Taenia asiatica

- **Distribution & Nomenclature:**
  - Found in Taiwan, Indonesia, and the Philippines.
  - Often referred to as Taiwan Taenia; has characters intermediate between T. solium and T. saginata.
- **Intermediate Stage:**
  - The metacestode is termed *Cysticercus viscerotropica* and is found mainly in the liver.

4. Taenia multiceps

- **Hosts:**
  - Definitive host: Dog.
  - Intermediate hosts: Sheep and goats.
- **Morphology & Life Cycle:**

- Prominent armed rostellum.
- The infective stage is *Coenurus cerebralis*, a transparent cyst (typically 200–400 scolices) formed in the brain or other parts of the nervous system (spinal cord, medulla).

- **Pathogenesis:**
  - In intermediate hosts: Can cause enteritis in the dog; neurological signs in sheep/goats include circling movement (gid), atrophy of skeletal bones, and in severe cases, pressure atrophy or perforation of brain structures.
  - Clinical signs vary depending on cyst location (e.g., ventricular, spinal, or cortical involvement).

5. Taenia ovis (Dog-Sheep Tapeworm)

- **Hosts:**
  - Intermediate host: Sheep (cysticercus ovis in muscles, including cardiac muscles).

Definitive host: Dogs and wild carnivores.

6. Taenia hydatigena (Dog-Sheep Tapeworm)

- **Hosts:**
  - Definitive hosts: Dogs, foxes, cats, and other canids/felids.
  - Intermediate hosts: Sheep, goats, cattle, and buffalo.
- **Intermediate Stage:**
  - *Cysticercus tenuicollis* forms after oncospheres migrate via blood to the liver, then emerge to attach to the peritoneum, causing hepatitis cysticercosa.

7. Taenia pisiformis (Dog-Rabbit Tapeworm)

- **Hosts:**
  - Definitive host: Dogs, foxes, wild carnivores (rarely cats).
  - Intermediate hosts: Rabbits, hares, and rodents.
- **Morphology:**
  - Adult tapeworm resembles T. solium, reaching up to 2 m in length.
  - The intermediate stage is *Cysticercus pisiformis*, developing in the peritoneum.

8. Taenia taeniaeformis (Cat-Rat Tapeworm)

- **Hosts:**
  - Definitive host: Cats and other wild carnivores (small intestine).
  - Intermediate host: Rodents.
- **Morphology:**
  - Adult tapeworm has no neck; posterior proglottids are bell-shaped.

- Measures around 60 cm in length.
- The scolex has two rows of hooks.

- **Intermediate Stage:**
  - *Cysticercus fasciolaris* (strobilocercous type) develops in rodents.

9. Taenia krabbei (Wolf-Caribou Tapeworm)

- **Hosts:**
  - Definitive host: Dogs (and wild carnivores).
  - Intermediate host: Reindeer or caribou.
- **Morphology:**
  - Mature segments are much broader than long.

10. Taenia cervi

- **Hosts:**
  - Occurs in dogs; intermediate stage (*Cysticercus cervi*) is found in deer and other ungulates.

11. Taenia crassiceps

- **Hosts:**
  - Occurs in wild carnivores; cysticerci are found in rodents.

V. Pathogenesis & Clinical Signs in Humans and Intermediate Hosts

- **In Humans (Taeniasis & Cysticercosis):**
  - **Taeniasis:**
    - Nutritional deficiency and enteritis due to the adult tapeworm siphoning nutrients.
  - **Cysticercosis:**
    - Occurs when eggs are ingested, leading to oncosphere migration and cyst formation in tissues.
    - **Neurocysticercosis:** When cysticerci form in the central nervous system, causing severe neurological damage.
    - **Ocular cysticercosis:** May result in conjunctivitis or rhinitis if cysticerci form in the eye.
    - Racemose cysticercosis: A grape-like, proliferative form sometimes seen in the CNS.
- **In Intermediate Hosts:**
  - **Pigs:** “Measly pork” results from cysticerci formation in vital organs; severe cases may involve neurological deficits if the brain is affected.

- **Sheep/Goats (T. multiceps):** Neurological disorders such as “gid” (circling) and skeletal atrophy.

VI. Control Measures

- **For Humans:**
  - Avoid consumption of undercooked pork or beef.
  - Proper sanitation and hygiene to prevent fecal contamination of food.
  - Thorough washing of raw vegetables.
- **For Pigs and Cattle:**
  - Prevent pigs from accessing human feces (improve sanitation, proper latrine use).
  - Confine pigs to reduce exposure.
  - Cooking pork/bEEF at recommended temperatures (e.g., cooking to 50–60°C or freezing at –20°C for at least 30 minutes).
- **Vaccine:**
  - The recombinant porcine cysticercosis vaccine (CYSVAX) has been launched to reduce T. solium incidence.
- **For Definitive Hosts (Dogs, Cats):**
  - Regular deworming using appropriate anthelmintics (e.g., Praziquantel) to prevent environmental contamination with eggs.
- **Public Health:**
  - Education on proper meat handling, cooking, and sanitation practices.

Family Diphyllobothriidae

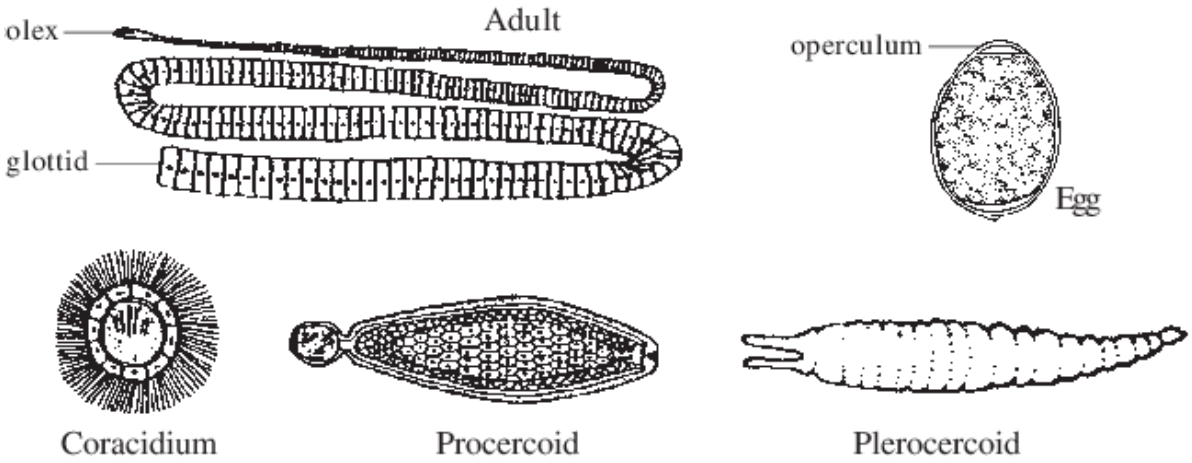
Class: Cotyloda
Order: Diphyllidea
Genera of Importance: *Diphyllobothrium* and *Spirometra*

2.1 Genus Diphyllobothrium

Diphyllobothrium latum (Fish Tapeworm or Broad Tapeworm)

Morphology & Features:

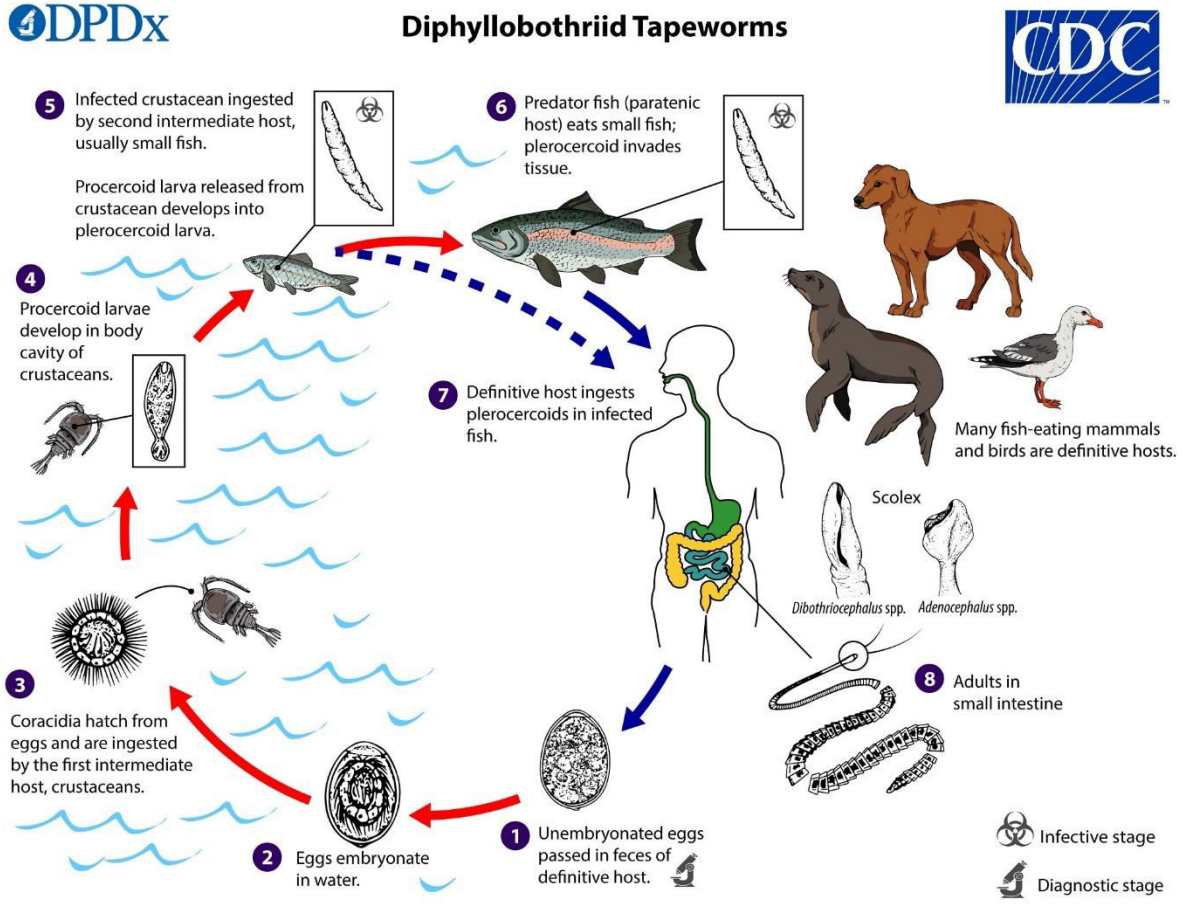
- **Scolex:** Spatula-shaped with a deep median groove called a bothrium (no rostellum).
- **Eggs:** Oval, operculated (some resemblance to trematode eggs).
- **Ovary:** Bilobed; uterus is rosette-shaped.



Hosts:

- **Definitive:** Dogs, cats, foxes, and occasionally pigs or humans.
- **Intermediate:**
    1. **First IH:** Cyclops (a copepod crustacean).
    2. **Second IH:** Freshwater fish.

Life Cycle Stages:



1. **Egg**

2. **Coracidium** (ciliated larva released into water)
3. **Procercoid** (in cyclops)
4. **Plerocercoid** (in fish)
5. **Adult** (in definitive host)

Pathogenesis & Clinical Notes:

- Can cause **vitamin B12 deficiency** in humans, leading to pernicious anemia.
- Gravid segments around the anal region may cause irritation; metabolites may induce nervous disorders (e.g., epileptiform fits).
- **Prevention:** Freezing fish for at least 10 days or thoroughly cooking to kill plerocercoids.

2.2 Genus Spirometra

Important Species

- *Spirometra mansoni*
- *Spirometra mansonoides*
- *Spirometra erinacei*

Hosts:

- Adults typically found in the small intestine of cats (and occasionally dogs or other carnivores).

Life Cycle & Pathogenesis:

- **Larval Stage (Plerocercoid) = "Sparganum"**
    - Infects humans (sparganosis) in subcutaneous tissues or eyes.

Ways Humans Get Infected (Sparganosis):

- **Accidental ingestion** of crustaceans (copepods) containing procercoids; they develop into plerocercoids in human tissues.
- **Ingestion of plerocercoids** in second intermediate hosts (e.g., undercooked frog or snake flesh).
- **Application of raw frog or snake flesh** as poultice on wounds or eyes; plerocercoids can migrate into tissues.

Clinical Importance:

- Adult *Spirometra* rarely cause pathology in cats/dogs.
- Plerocercoids cause **sparganosis** in humans, leading to subcutaneous nodules, potential migration to eyes or CNS.

3. Family Hymenolepididae

Typical Hosts:

- Small intestine of humans, rats, rodents, and birds.
- Some species have **direct** life cycles; others are **indirect**, requiring an intermediate host.

3.1 Hymenolepis nana (Dwarf Tapeworm)

- **Hosts:** Humans (common), rodents.
- **Life Cycle:**
    - **Direct in Humans:**
        1. Eggs ingested.
        2. Oncospheres hatch in the intestinal villi.
        3. Cysticercoids develop within the villi.
        4. Cysticercoids detach, move into the lumen, and mature into adult tapeworms.
    - **Indirect in Rodents:** In beetles or fleas as intermediate hosts (cysticercoid stage).

3.2 Hymenolepis carioca

- **Hosts:** Birds (e.g., poultry).
- **Intermediate Hosts:** Beetles and flies (cysticercoid stage).
- **Infection:** Final host ingests intermediate host harboring cysticercoids.

4. General Treatment of Cestodes

Below is a commonly referenced guide (as per the provided table) for **dogs** and **sheep, goats, cattle**. Note that exact dosages and regimens may vary by country, brand formulations, and veterinary protocols.

Dogs

1. Arecoline hydrobromide
    - Dose: 2–5 mg/kg
2. Arecoline acetarsol
3. Dichlorophen
    - Dose: 0.3–0.6 g/kg
4. Hexachlorophene
5. Bunamidine hydrochloride
    - Dose: 25–50 mg/kg
6. Bithionol
    - Dose: 200 mg/kg
7. Nofenscanate
8. Niclosamide
    - Dose: 100–150 mg/kg
9. Praziquantel
    - Dose: 5 mg/kg

Sheep, Goats, and Cattle

1. Praziquantel
2. Albendazole
    - Dose: 10 mg/kg
3. Fenbendazole
    - Dose: 5 mg/kg
4. Bithionol
5. Niclosamide
    - Dose: 75–150 mg/kg

Note:

- Praziquantel is highly effective for most tapeworms.
- Benzimidazoles (albendazole, fenbendazole) are often used for livestock cestodes.
- Niclosamide is another option for intestinal tapeworms in various species.

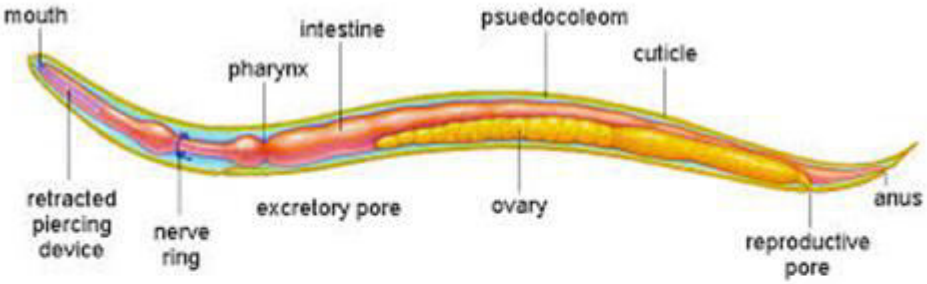
Additional Notes on Therapy

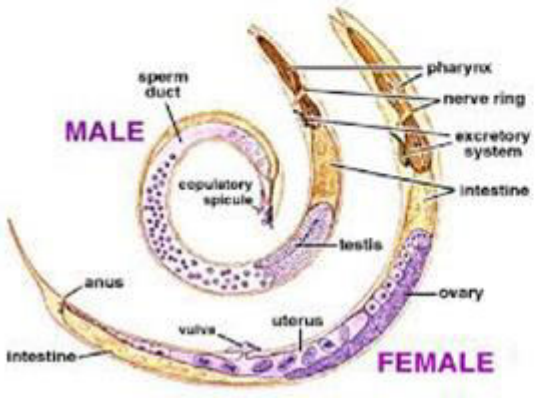
- **Praziquantel** is broadly effective against adult tapeworms in dogs, cats, and livestock.
- **Albendazole** and **Fenbendazole** have proven efficacious in ruminants, often at slightly higher doses for cestodes than for nematodes.
- For **Sparganosis (Spirometra plerocercoids)** in humans, surgical removal of the sparganum may be necessary if accessible.

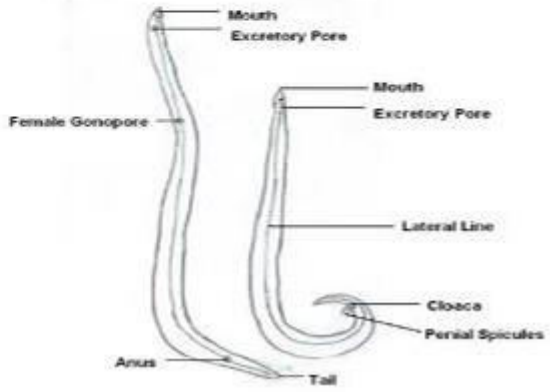
General Characteristics of Nematodes

1. **Phylum:** Nemathelminthes
2. **Class:** Nematoda
3. **Common Names:** Roundworms (due to their circular cross-section).
4. **Habitats:**
    - Free-living (in soil, freshwater, or marine environments)
    - Parasitic (infecting plants, animals, and humans)

A. Morphology







- **Body Form:**
  - Unsegmented, cylindrical worms; sexes are separate (unisexual).
  - Females are usually longer than males.
  - **Cuticle:** Tough, flexible outer covering formed by the hypodermis (subcuticular layer) and an underlying muscle layer.
  - **Body Cavity:** Pseudocoelom; fluid-filled, serving in nutrient transport and structural support.
  - **No Suckers:** Unlike many trematodes or cestodes, nematodes lack suckers.
- **Hypodermis and Muscle Layer:**
  - The hypodermis projects into the body cavity to form two lateral cords (containing excretory canals) and dorsal and ventral cords (containing nerves).

B. Digestive System

- **Structure:**
  - Generally well-developed, starting from the mouth.
  - **Mouth:** May be surrounded by lips; the arrangement and number of lips are taxonomically important.
    - Three lips (one dorsal, two subventral) in ascarids (*Ascaris*, *Toxocara*).
    - Two lips (each trilobed) in spirurids.
    - Lips absent in strongyles (instead, they may have leaf crowns).

- **Pharynx/Oesophagus:** Various types are important for classification:
  - **Bulbus** (posterior bulb) – e.g., *Heterakis gallinarum*.
  - **Double-bulbed** (Oxyuroid type).
  - **Rhabditiform** (anterior pyriform, posterior bulbous) – e.g., *Strongyloides*.
  - **Ventriculus** (anterior muscular part, posterior glandular part) – e.g., spirurid worms.
  - **Filariform** (tubular) – filarial worms.
  - **Trichuroid** (cells arranged in a row) – e.g., *Trichinella*.
- **Intestine and Anus:** The intestine typically ends in a subterminal anus (female) or cloaca (male).

C. Excretory System

- **Osmoregulatory in Function:**
  - Opens via a ventral pore near the anterior end.
  - **Flame Cells:** Absent (in contrast to many flatworms).

D. Nervous System

- Consists of:
  1. **Oesophageal nerve ring**
  2. **Nerve ganglia**
  3. **Nerve fibers** connecting ganglia
  4. **Sense organs** such as phasmids, amphids, cervical papillae, and genital papillae.

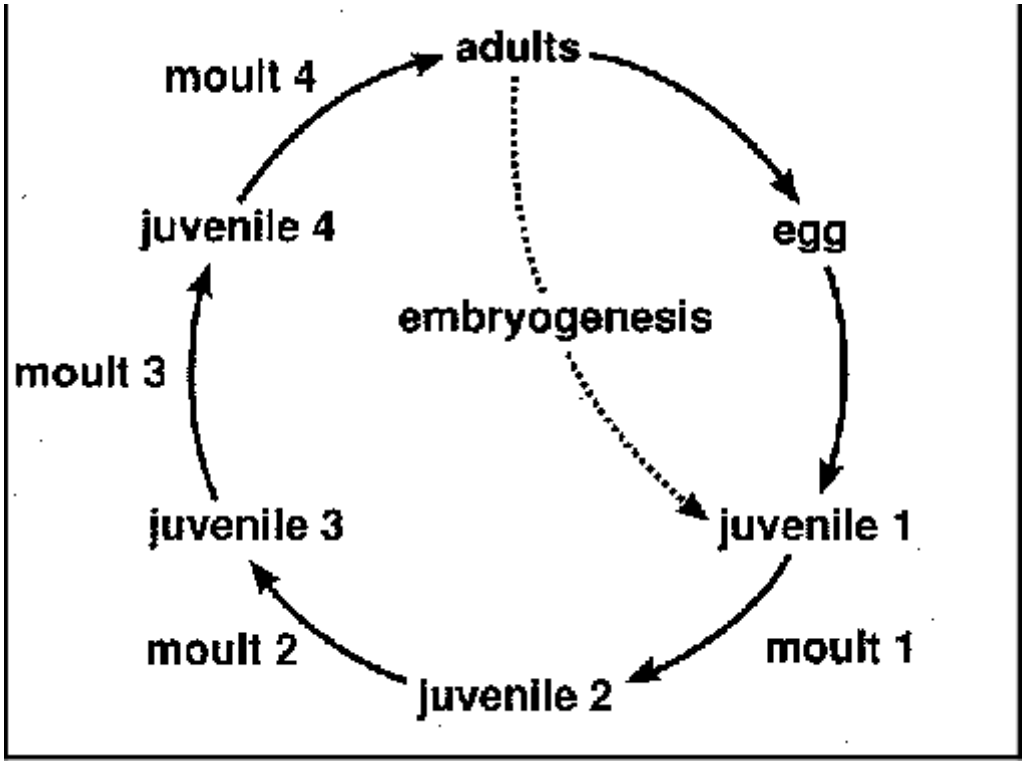
E. Reproductive System

- **Sexes Separate (Dioecious):**
  - **Male Organs:** A single testis, vas deferens, sometimes a seminal vesicle, and a muscular ejaculatory duct opening into the cloaca.
    - Spicules (one or two) help in copulation; may be accompanied by a gubernaculum or telamon (cuticular guides).
    - Some males have a copulatory bursa with bursal rays.
  - **Female Organs:** Usually two ovaries, two uteri, and a single vulva.
    - If the genital opening is posterior, the ovaries run forward (prodelph).
    - If anterior, they run backward (opisthodelph).
    - If mid-body, the uteri may run in opposite directions (amphidelph).
  - **Egg Production:** Highly prolific; a single female can lay thousands of eggs per day.

- **Egg Types:** Oviparous (laying eggs), ovo-viviparous (laying eggs containing fully formed larvae), or viviparous (live larvae).

F. Life Cycle

- **General Scheme:**



- Eggs → 5 larval stages (L1 → L2 → L3 → L4 → L5 [immature adult]) → Mature adult.
- **Molting (Ecdysis):** The cuticle is shed between each larval stage; there are four molts total.
- **Infective Stage:** Often the third-stage larva (L3) in many nematodes. In ascarids, the second-stage larva within the egg is infective.
- **Direct (Monoxenous) vs. Indirect (Heteroxenous) Life Cycles:**
  - Direct: No intermediate host.
  - Indirect: One or more intermediate hosts (insects, molluscs, annelids, etc.).
- **Autoheteroxenous Parasite:** *Trichinella spiralis* (same vertebrate acts first as definitive host, then as intermediate host).

II. Family Ascarididae

Key Genera:

- *Ascaris*, *Toxocara*, *Parascaris*, *Toxascaris*.

Morphological Traits:

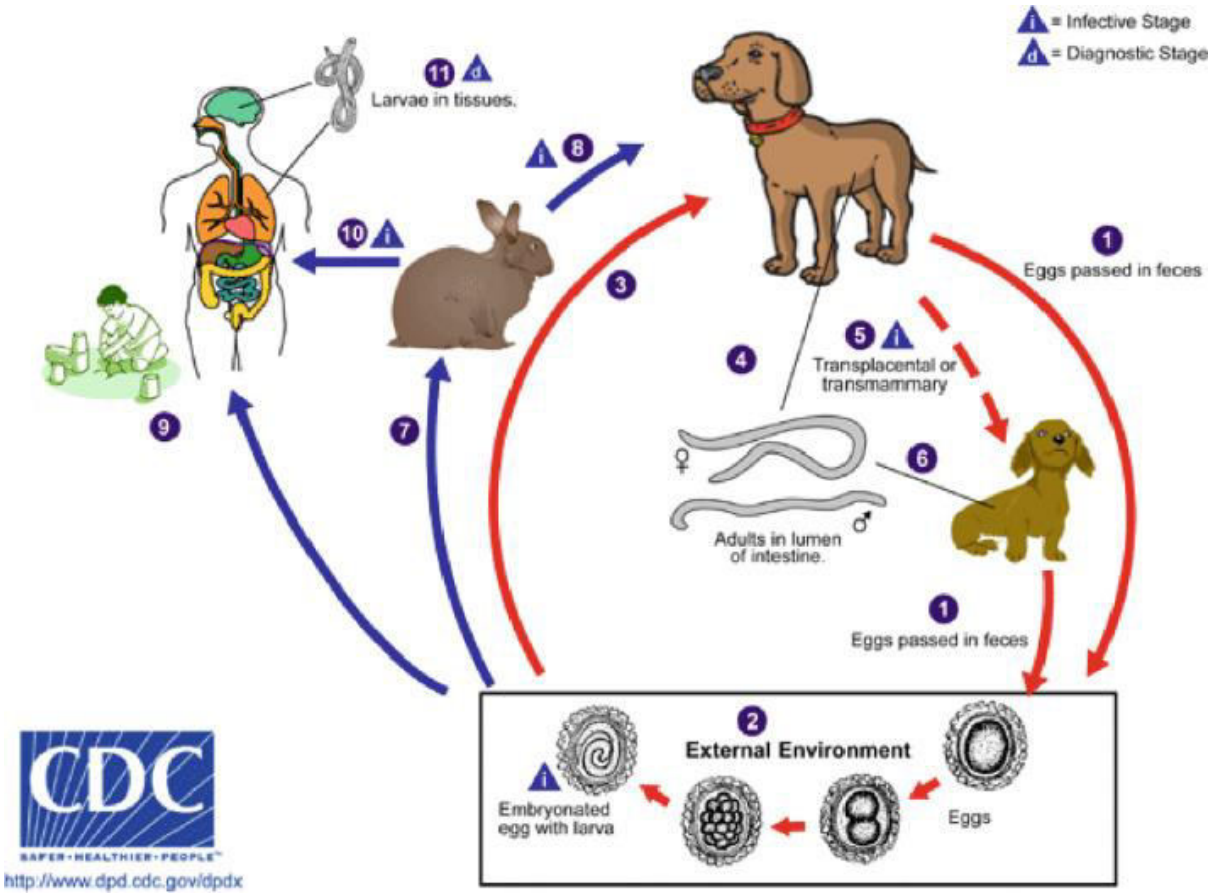
- **Lips:** Three (one dorsal, two subventral), each lip may have two papillae.

- **Interlabia:** Smaller lips may appear between the main lips.
- **No teeth or cutting plates.**
- **No pharynx**; oesophagus typically club-shaped, muscular, without a posterior bulb.
- **Two spicules in males; no copulatory bursa.**
- **Eggs:** Typically round or subglobular with a thick, pitted outer wall.

A. Genus Ascaris

Ascaris suum

- **Common Name:** Large roundworm of pigs.
- **Site:** Small intestine of domestic pigs.
- **Morphology:** Similar to human roundworm *A. lumbricoides*; some consider them synonymous.



- **Life Cycle Stages:**
    1. Egg
    2. Larva 1 in the egg shell
    3. Larva 2 in the egg shell (**infective stage**)
    4. L3 → L4 → Adult
- **Transmission:**

    - Pigs ingest infective eggs (containing L2).
    - Larvae hatch, migrate to the liver via the hepatoportal route, then to the heart and lungs (L3).
    - Tracheal migration: From alveoli → bronchi → trachea → pharynx → swallowed → small intestine → L4 → adult.
- **Pathogenesis:**
    - **Liver:** "Milk spot" lesions (fibrosis and hemorrhage from larval migration).
    - **Lungs:** Pneumonitis ("Ascaris pneumonitis"), hemorrhages, coughing.
    - **Intestine:** Diarrhea, decreased growth rate.
- **Diagnosis:**
    - Clinical signs, fecal exam (brownish yellow ovoid eggs with thick, irregularly mamillated shell).
- **Treatment:** Piperazine is often considered the drug of choice; other broad-spectrum anthelmintics can also be effective.

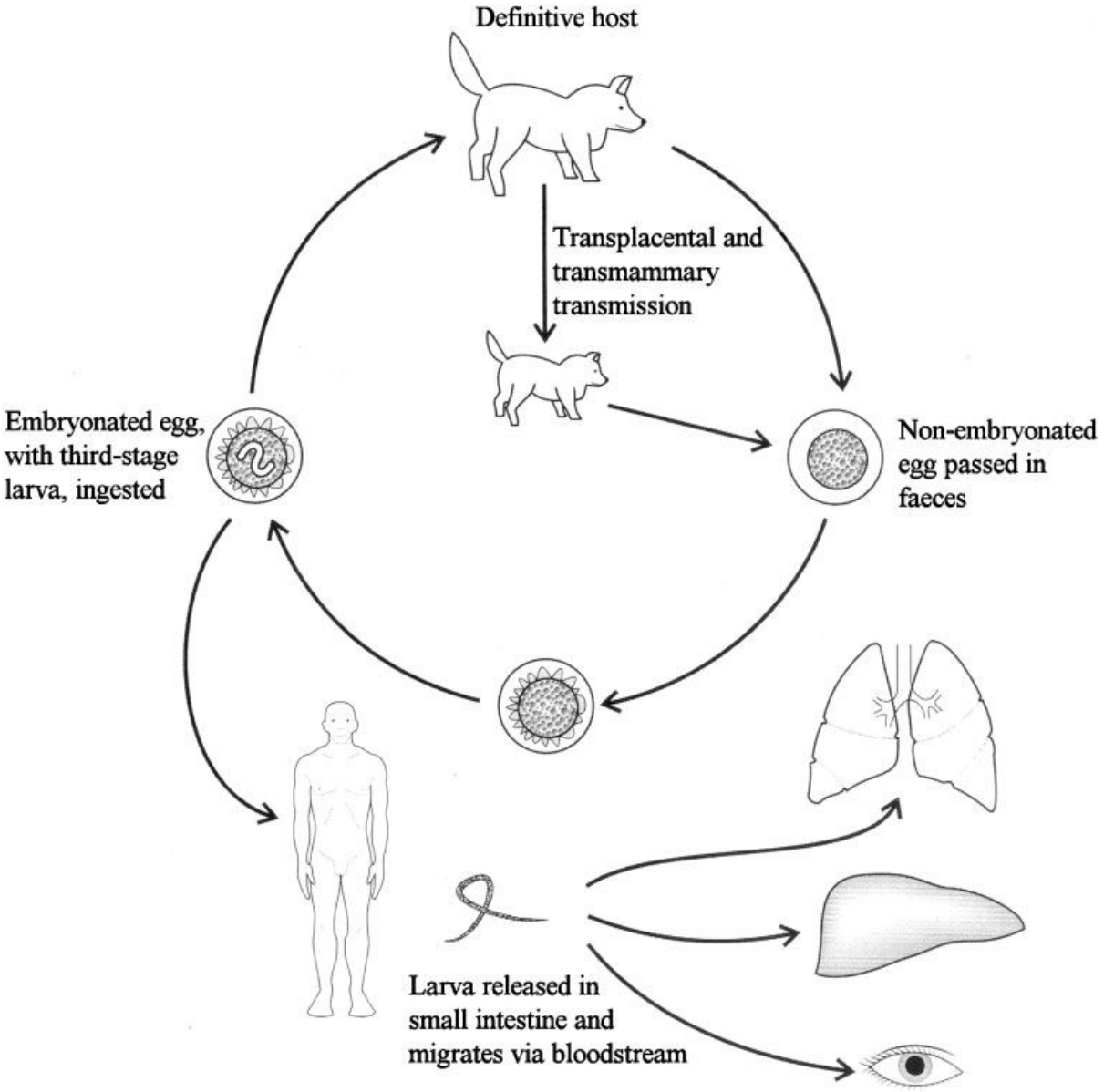
B. Genus Toxocara

Key Species:

1. **Toxocara canis** (dogs)
2. **Toxocara cati** (cats)
3. **Toxocara vitulorum** (cattle/buffalo)

1. Toxocara canis

- **Hosts:** Dogs (final host), typically in the small intestine.
- **Common Name:** Arrow-headed worm (due to prominent cervical alae).
- **Egg:** Subglobular, dark brown, thick shell with a finely pitted surface.
- **Life Cycle:**



- **Direct** (monoxenous).
- Infective stage is the egg containing L2 larvae.
- **Routes of Infection:**
    1. **Oral ingestion** of infective eggs (L2).
        - In pups (<3 months), tracheal migration occurs.
        - In older dogs, larvae follow a somatic route, encysting in tissues.
    2. **Transuterine (prenatal) infection:**
        - Mobilized L2 larvae cross the placenta to infect fetal liver; they molt to L3 before birth.
        - Pups are born with larvae already in their tissues.
    3. **Transmammary (lactogenic) infection:**

        - L3 larvae passed to pups via colostrum; no larval migration in pups by this route.
    4. **Paratenic host** ingestion (rodents harboring dormant L2).
- **Pathogenesis & Clinical Signs:**
    - **Larvae:** Liver and lung damage, pneumonia, alveolar destruction (especially in young pups).
    - **Adults:** Intestinal obstruction, diarrhea, pot-bellied appearance, vomiting, coughing, nervous signs.
    - In severe cases, fatalities can occur during the pulmonary phase.

2. Toxocara cati

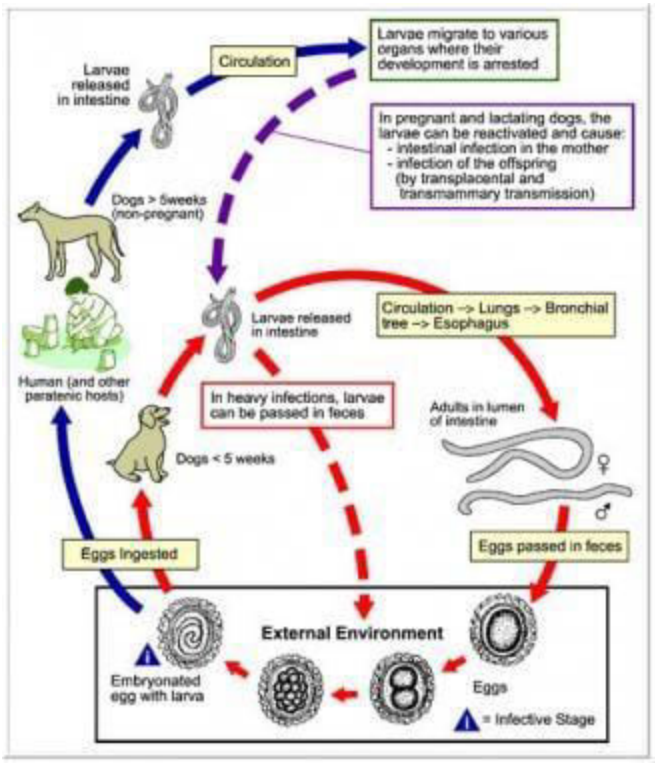
- **Hosts:** Cats (wild and domestic felids).
- **Morphology:** Broad, striated cervical alae; eggs are similar to *T. canis* but colorless.
- **Life Cycle:**
    - **Direct**; Infective egg with L2.
    - **Transmission:**
        1. Oral ingestion of infective eggs.
        2. Transmammary infection.
        3. Paratenic hosts (rodents, birds).
    - **No transplacental infection** in cats (unlike *T. canis* in dogs).

3. Toxocara vitulorum

- **Hosts:** Cattle and buffalo (largest nematode in these species).
- **Site:** Small intestine.
- **Eggs:** Subglobular, colorless, thick, finely pitted shell.
- **Life Cycle:**
    - **Direct**; infective egg with L2.
    - **Transmammary (transcolostral) transmission** is the major route for calves:
        - Dormant L2 larvae in the dam's tissues migrate to the mammary glands late in pregnancy.
        - Calves ingest larvae via colostrum up to 3–4 weeks postpartum.
    - Oral ingestion of infective eggs by adult cattle does not typically lead to a patent infection (larvae encyst instead).
- **Pathogenesis & Clinical Signs:**
    - Heavy infections in young calves (<6 months): Partial or complete intestinal obstruction, diarrhea, steatorrhea, colic, pot-belly, poor coat, emaciation.

- Extremely high egg output from adult worms (millions per day).

III. Visceral Larva Migrans (VLM)



- **Definition:** When infective eggs of ascarids (especially *Toxocara canis* and possibly *T. cati*) are ingested by an abnormal host (e.g., humans), the L2 larvae hatch and migrate extensively through tissues, causing granulomatous reactions.
- **Clinical Manifestations:**
  - **Liver:** Commonly affected; eosinophilia, granulomas.
  - **Ocular Involvement (OLM):** Retinoblastoma-like lesions.
  - Other tissues can also be involved (lungs, brain, heart).
- **Agents Causing VLM:**
  - *Toxocara canis* (most common), *T. cati*, *Toxascaris leonina*, *Capillaria hepatica*, *Gnathostoma spinigerum*, *Lagochilascaris minor*.

Key Takeaways

1. **Nematodes** are roundworms with a distinct pseudocoelom, separate sexes, and a cuticle that molts between larval stages.
2. **Ascarididae** includes large intestinal roundworms (e.g., *Ascaris*, *Toxocara*). They often exhibit hepatic-tracheal migration in the definitive host.
3. **Infective Stage** for most ascarids is the egg containing the second-stage larva (L2).

4. **Transplacental (T. canis)** and **transmammary (T. canis, T. cati, T. vitulorum)** routes are common for passing infection to offspring.
5. **Visceral Larva Migrans** in humans underscores the zoonotic risk of certain ascarids, especially *Toxocara canis*.
6. **Clinical Management** involves anthelmintic treatments (e.g., piperazine, benzimidazoles) and strict hygiene measures to prevent ingestion of infective eggs.

GENUS PARASCARIS

Species: *Parascaris equorum*

- **Largest nematode of equines**
- **Location:** Small intestine of horses, donkeys, and other equines
- **Morphology:**
    - Three well-developed lips
    - Eggs are spherical or sub-spherical, brownish-yellow with thick, pitted shells

II. GENUS TOXASCARIS

General Note on Arrow-Headed Appearance:

- Some *Toxascaris* species (and *Toxocara canis*) have large cervical alae, giving the anterior body a bent dorsal appearance, hence the name "arrow-headed worms."

Toxascaris leonina

- **Hosts:** Dogs, cats, and other wild canids/felids (small intestine)
- **Eggs:** Oval with smooth shells (unlike the pitted shells in *Toxocara*).
- **Life Cycle:**
    - **Direct;** infective stage is the egg containing L2.
    - After ingestion of infective eggs, L2 larvae hatch, invade the intestinal wall for about 2 weeks, then molt to L3 and L4.
    - Larvae re-enter the intestinal lumen, become adult juveniles, and mature.
    - **No extraintestinal migration** (in contrast to *Toxocara canis*).

III. FAMILY ANCylostomatidae (Hookworms)

General Features:

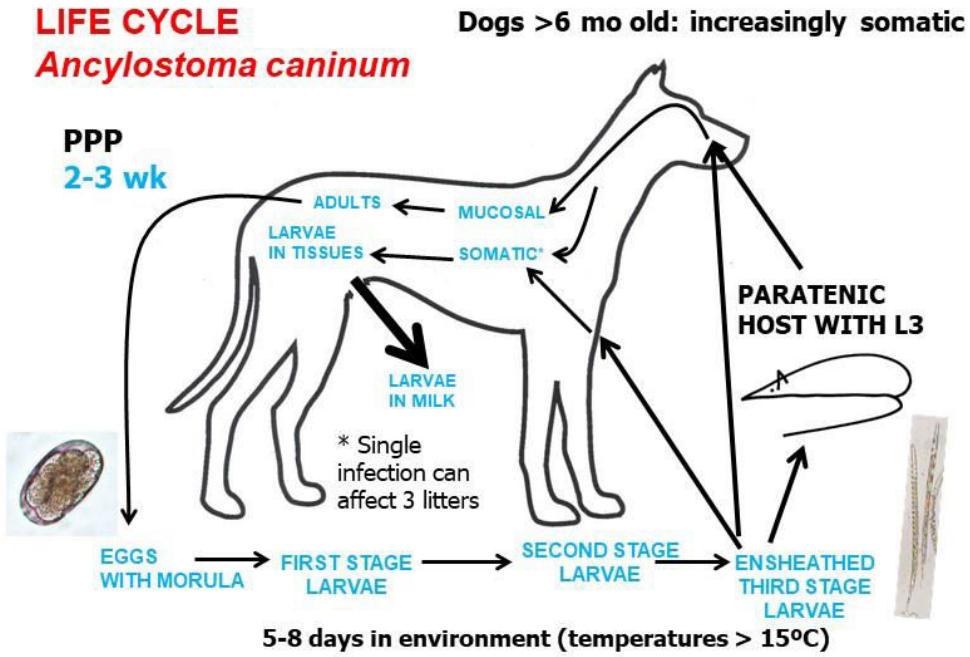
- Characteristic “hook-like” curvature of the anterior end.
- Veracious blood feeders in the small intestine, causing anemia, protein-losing enteropathy, and potentially high morbidity and mortality.

A. Genus Ancylostoma

Ancylostoma caninum

- **Hosts:** Dogs, foxes

- **Location:** Small intestine
- **Common Name:** Canine hookworm
- **Morphology:**
    - Buccal capsule well-developed, with 3 pairs of teeth on the ventral margin.
    - Eggs: Oval, thin-shelled, containing ~8 embryonic cells; sides nearly parallel.
    - Worm color varies depending on ingested blood.
- **Life Cycle:**



    - **Direct**
    - Infective stage: L3 larvae
    - **Routes of Infection:**
        1. Ingestion of L3 (contaminated feed/water)
        2. Skin penetration by L3
        3. Transcolostral (lactogenic)
        4. Transuterine (prenatal)
- **Pathogenesis:**
    - **Larval Phase:**

        - Skin penetration → "ground itch" or ancylostome dermatitis (eczematous lesions).
        - Pulmonary migration → hemorrhage in alveoli, pneumonia.
    - **Adult Worms:**
        - Attach to intestinal mucosa with strong buccal teeth and secrete anticoagulants, causing continuous blood loss (0.1 ml/worm/day).
        - Microcytic hypochromic anemia, diarrhea (often bloody), bottle jaw, progressive weakness.
- **Diagnosis:**
    - Fecal floatation: Characteristic hookworm eggs (oval, thin shell, ~8 embryonic cells).
- **Cutaneous Larva Migrans (Creeping Eruption):**
    - Caused mainly by *A. braziliense* larvae in humans; also *A. caninum* and others.
    - Larvae migrate in the skin, causing tortuous, pruritic, erythematous tracts.

B. Genus Bunostomum

- **Species:** *Bunostomum trigonocephalum* (sheep/goats), *B. phlebotomum* (cattle/buffalo)
- **Location:** Small intestine (ruminant hookworms)
- **Clinical Features:** Similar to other hookworms (anemia, diarrhea, etc.).

IV. FAMILY DICTYOCAULIDAE (Lungworms)

Genus: *Dictyocaulus*

- **Species:** *D. viviparus* (cattle/buffalo), *D. filaria* (sheep/goats), *D. arnfieldi* (horses/donkeys)
- **Location:** Bronchi and lungs → "Lungworm disease," verminous bronchitis, husk/hoose disease.
- **Morphology:**
    - White, thread-like worms.
    - Small buccal capsule with four lips.
    - Males have a dark brown, boot-shaped spicule; bursal rays look like "fingers."
    - Females are ovoviviparous (lay eggs that hatch quickly into L1).
- **Life Cycle:**
    - **Direct;** L3 is infective.
    - Adults in bronchi lay eggs that hatch into L1, which are coughed up, swallowed, and passed in feces.
    - L1 → L2 → L3 in the environment; L3 move to herbage (often aided by *Pilobolus* fungi).

- After ingestion, L3 penetrate intestinal mucosa → mesenteric lymph nodes (L4) → bloodstream → lungs → bronchioles → final molt.

- **Pathogenesis:**
  - Inflammation of bronchi/bronchioles → exudate, eosinophils, macrophages → alveolar blockage → emphysema, edema, pneumonia.
  - Characteristic cough ("husk" or "hoose").
- **Vaccination:**
  - *D. viviparus:* "Dictol" in Europe using X-irradiated L3.
  - *D. filaria:* "Difil" in India (IVRI) with gamma-irradiated L3. Two doses ~1 month apart; provides ~1 year immunity.

V. FAMILY TRICHOSTRONGYLIDAE

- Common GI parasites in grazing animals (ruminants).
- Small, slender worms with a rudimentary buccal cavity (no teeth) and a well-developed bursa in males.
- **Genera:** *Ostertagia, Cooperia, Nematodirus, Haemonchus, Trichostrongylus.*

A. Genus Ostertagia (Brown Stomach Worm)

- **Species:** *O. ostertagi* (cattle), *O. circumcincta* (sheep/goats, formerly *O. circumcineta*), *O. trifurcata*
- **Location:** Abomasum (occasionally small intestine) of ruminants
- **Morphology:**
  - Brownish color; cephalic inflation (transversely striated).
  - Spicules pigmented brown with specific tips or spurs (depending on species).
- **Pathogenesis:**
  - Larvae invade gastric glands → gastritis, "morocco leather" lesion in abomasum.
  - Causes watery diarrhea, emaciation, anemia.
- **Hypobiosis:**
  - Arrested larval development in adverse conditions; important for seasonal pasture infections.

B. Genus Cooperia

- **Species:** *C. pectinata, C. punctata, C. oncophora, C. curticei*
- **Hosts:** Many ruminants; found in small intestine or abomasum.
- **Morphology:**
  - Anterior cephalic swelling; longitudinal ridges behind it.
  - Spicules have a wing-like expansion in the middle (key identifying feature).

- **Pathology:** Often part of mixed trichostrongylid infections causing enteritis and production losses.

C. Genus Nematodirus

- **Hosts:** Sheep, goats, cattle (small intestine).
- **Spicules:** Long, slender, fused at the tip.
- **Pathology:** Severe diarrhea in young lambs/kids; large, distinctive eggs.

D. Genus Haemonchus (Barber Pole Worm)

- **Species:** *H. contortus* (sheep/goats), *H. placei* (cattle), *H. similis*, *H. bubalis*, *H. longistipes*
- **Location:** Abomasum
- **Morphology:**
    - Small, red/grey worms (blood-filled intestine twisted with white ovaries → "barber pole" appearance).
    - Cervical papillae prominent; bursa well-developed in males with Y-shaped dorsal ray.
    - Spicules slender, barbed anteriorly.
- **Pathogenesis:**
    - Both L4 and adults are blood-suckers.
    - Causes anemia (0.05 ml blood loss/worm/day), hypoproteinemia, bottle jaw (submandibular edema), emaciation, diarrhea.
    - **Self-Cure Phenomenon:** Type-I hypersensitivity reaction to worm antigens leads to increased peristalsis, mucus secretion, and expulsion of worms in presensitized animals.
- **Diagnosis:** Fecal egg counts, larval culture, clinical signs (anemia, edema).
    - **FAMACHA** chart used to assess conjunctival pallor and correlate with anemia.

Key Points to Remember

1. **Parascaris equorum** is the largest equine nematode in the small intestine.
2. **Toxascaris leonina** differs from *Toxocara canis* by lacking extraintestinal larval migration.
3. **Ancylostoma caninum** in dogs can infect via multiple routes, causing severe anemia and "ground itch" in humans.
4. **Dictyocaulus** species (lungworms) cause verminous bronchitis in ruminants and equids; vaccination with irradiated larvae is possible.
5. **Trichostrongylidae** are small GI worms in ruminants, with species like *Haemonchus contortus* (barber pole worm) causing severe blood loss and the "self-cure" phenomenon.
6. **Hypobiosis** (arrested development) is crucial in the epidemiology of many trichostrongylids, influencing seasonal infection patterns.

Genus Trichostrongylus

- **Species Examples:**
  - *T. colibriformis* (Bankrupt worm)
  - *T. axei* (Black scour worm)
  - *T. orientalis*
  - *T. tenuis*
- **Hosts:**
  - Mainly ruminants and camel; rarely in horse, pig, and dog.
- **Location in Host:**
  - Typically in the small intestine, except:
    - *T. axei* – primarily in the abomasum/stomach.
    - *T. tenuis* – found in both small and large intestines.
- **Key Morphology:**
  - The buccal capsule is absent.

2. Family Strongylidae (Strongyles)

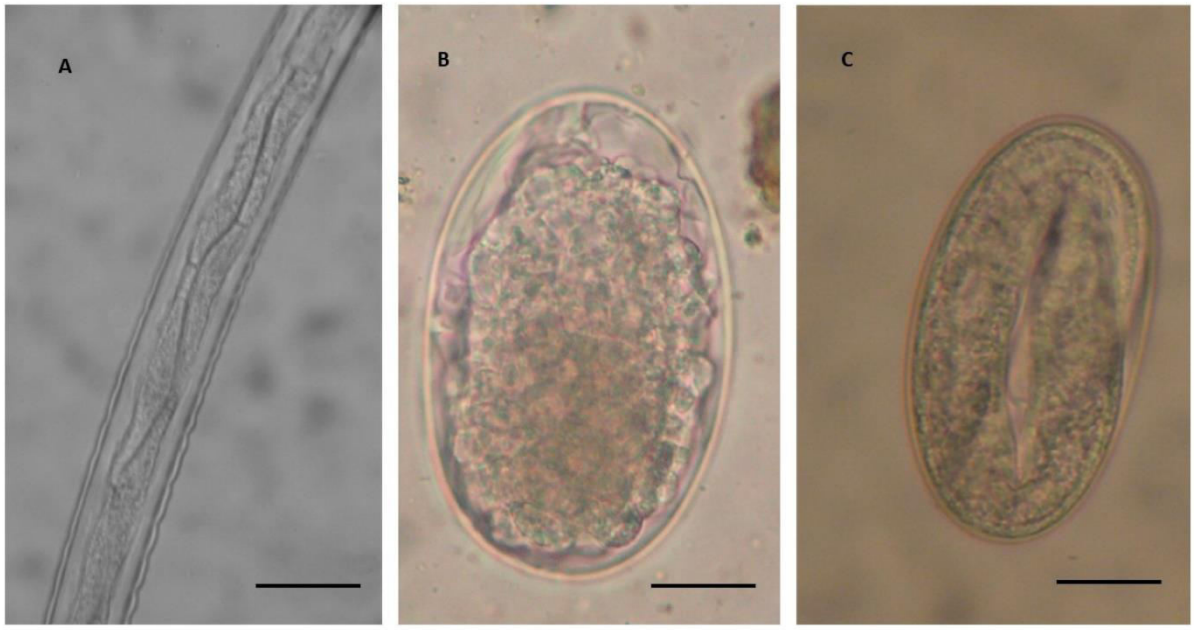
A. Genus Strongylus

Important Species and Common Names:

- *Strongylus edentatus* – "toothless strongyle"
- *Strongylus vulgaris* – "double-toothed strongyle"
- *Strongylus equinus* – "triple-toothed strongyle" (also known as sclerostome or blood worm)

General Morphology:

- **Buccal Capsule:**
  - Bears a corona radiata (or leaf-crowns) arranged as cuticular elements resembling a fence around the mouth opening.
  - Worms with such leaf crowns are sometimes called "palisade worms."



- **Male Reproductive Structure:**
    - Possess a well-developed copulatory bursa (an umbrella-like expansion supported by bursal rays arranged in a defined pattern).

Life Cycles and Specific Details:

1. **Strongylus vulgaris:**
    - **Infection:** Host ingests infective third-stage larvae (L3).
    - **Post-Ingestion:**
        - Exsheathment occurs.
        - Larvae penetrate the intestinal wall and molt into fourth-stage larvae (L4).
        - L4 larvae invade small arteries in the submucosa, migrate via arterial vessels (especially the anterior mesenteric artery) and cause thrombi and aneurysm (verminous aneurysm).
        - Ultimately, the worms reach the caecum/colon where nodules form and rupture into the lumen, allowing sexual maturation.
    - **Pathogenesis:**
        - Endarteritis and formation of thrombi/aneurysms may cause colic due to nerve plexus pressure.

Strongylus equinus:

- **Infection:** Ingestion of L3, followed by exsheathment.
- **Migration:**
    - Larvae penetrate the large intestine wall, form nodules, and molt into L4 within these nodules.

        - Subsequently, they leave the nodules, enter the peritoneal cavity, migrate to the liver (11 days), then to the pancreas before returning to the peritoneal cavity.
    - **Pathogenesis:**
        - Larvae can produce hemorrhagic tracts in the liver and pancreas leading to colic, anorexia, and general malaise.

Strongylus edentatus:

- **Post-Ingestion:**
    - After exsheathment, larvae penetrate the intestinal wall.
    - They then migrate to the liver via the hepatoportal circulation and molt to become L4.
    - In the liver, the larvae migrate for several days before reaching the right abdominal flank (via the hepatic ligament) where hemorrhagic nodules form.
    - Later, they migrate to the caecum/colon forming further hemorrhagic nodules.
- **Pathogenesis:**
    - Hemorrhagic nodules in the liver and intestines, potential peritonitis and toxemia.

General Pathogenesis of Strongyles:

- **Adults:**
    - Attach to the intestinal mucosa and suck blood, leading to normochromic, normocytic anemia.
- **Larvae:**
    - Particularly in *S. vulgaris*, migration causes arterial inflammation and vascular damage.
- **Clinical Signs:**
    - Colic, diarrhea, weight loss, and signs of anemia.

3. Family Strongyloididae

Key Genera:

- *Strongyloides* species (e.g., *S. papillosus, S. cati, S. westeri, S. ransomi, S. stercoralis*)

General Features:

- **Common Name:** Intestinal threadworms.
- **Habitat:** Small intestine of various hosts (sheep, goats, cattle, cats, pigs, and humans).
- **Life Cycle Characteristics:**
    - The nematodes exhibit two types of life cycles:

1. **Homogonic Life Cycle (Direct):**
    - Eggs are expelled and hatch in the environment.
    - Larvae develop to the infective stage (typically L3) and infect the definitive host via skin penetration or orally.
    - Larvae enter circulation, reach the lung, ascend the respiratory tract, and are swallowed to reach the intestine.
2. **Heterogonic Life Cycle (Indirect):**
    - Eggs hatch into free-living males and females that mate and produce eggs, which then develop into infective larvae.

- **Oesophagus:**
    - Rhabditiform in the free-living generation and filariform in the parasitic stage.

- **Pathogenesis:**
    - **Cutaneous:**
        - Larval penetration can cause skin lesions.
        - Conditions such as cutaneous larva migrans and larva currens may occur.
    - **Systemic:**
        - In humans (*S. stercoralis*), can lead to strongyloidiasis, causing gastrointestinal symptoms and, in immunocompromised individuals, potentially disseminated infection.

- **Additional Diseases:**
    - In animals, *Strongyloides papillosus* is associated with intestinal disease; in pigs, *S. westeri* and *S. ransomi* are significant.

4. Genus Oesophagostomum

General Features:

- **Habitat:**
    - Bursate nematodes inhabiting the large intestine of ruminants and pigs.
- **Economic Impact:**
    - Cause "nodular worm" or "knotty gut" (pimply gut) disease, affecting productivity and potentially causing mortality.
- **Morphology:**
    - Prominent cervical alae in the head region.
    - A mouth collar and a ventral cervical groove are present.
    - An inflated cuticular area anterior to the cervical groove (cephalic vesicle).
- **Life Cycle:**

    - Infection occurs via ingestion of infective L3 larvae.
    - Larvae penetrate the intestinal wall and form nodules (cysts) where they remain for several days, then molt to L4.
    - L4 larvae eventually exit the nodules to mature in the lumen.
- **Pathogenesis:**
    - Nodules are formed as an antigen–antibody reaction with eosinophilic and fibroblastic infiltration.
    - The "pimply" or "knotty" gut is characterized by button-like nodules filled with purulent exudate.
- **Clinical Signs:**
    - Persistent diarrhea with mucus and blood, especially in lambs.
    - Chronic cases may present with severe emaciation, cachexia, and death.

5. Genus Chabertia

- **Habitat:**
    - Found in the colon of domestic and other ruminants.
- **Notable Species:**
    - *Chabertia ovina* – reported in sheep (e.g., in the Kumaon hills, India).
- **Pathogenesis:**
    - Infection causes emaciation, anemia, and diarrhea with mucus and blood.
    - Associated with reduced productivity and poor body condition.

Summary of Key Points

- **Trichostrongylus spp.** are common in various hosts with location differences (small vs. large intestine) and are notable for the absence of a buccal capsule.
- **Strongylidae (Strongyles)** are large, bursate nematodes of equids with complex life cycles and significant vascular migration (especially *S. vulgaris*), leading to serious intestinal and vascular lesions.
- **Strongyloididae** exhibit dual (homogonic and heterogonic) life cycles, with infective larvae capable of causing cutaneous and systemic disease.
- **Oesophagostomum spp.** cause nodular lesions in the gut of ruminants, leading to "pimply gut" disease, which may severely impact animal productivity.
- **Chabertia spp.** infect the colon and cause gastrointestinal distress in ruminants.

Family Heterakidae

Genus: Heterakis

Species: Heterakis gallinarum

- **Hosts & Location:**

- Occurs in the caeca of fowl, turkeys, gallinaceous birds, ducks, and other birds.

- **Common Name:**
  - Caecal worm of poultry.
- **Life Cycle:**
  - Similar to *Ascaridia galli*:
    - **Infective Stage:** Egg containing second-stage larva (L2).
    - **Transmission Routes:**
      1. Ingestion of infective eggs (with food or water).
      2. Earthworms may serve as transport hosts (birds ingest earthworms harboring L2).
- **Pathogenesis & Importance:**
  - Usually non-pathogenic by themselves but play a critical role in transmitting the protozoan *Histomonas meleagridis*, which causes entero-hepatitis (blackhead disease) in turkeys.
  - May produce nodular typhlitis leading to anemia, emaciation, and diarrhea.

2. Ascaridia galli (Poultry Ascarid Worm)

- **Hosts & Location:**
  - Final hosts: Domestic and wild birds; inhabits the small intestine.
- **Key Features:**
  - Largest nematode of poultry.
- **Life Cycle:**
  - **Direct life cycle:**
    - **Infective Stage:** Egg containing L2 larvae.
    - **Transmission:**
      1. Ingestion of infective eggs with food or water.
      2. Earthworms may act as transport hosts.
- **Pathogenesis:**
  - Young birds (<12 weeks) are most susceptible.
  - Larval migration produces catarrhal or hemorrhagic enteritis; heavy infections can cause intestinal obstruction and death.
  - Dietary deficiencies predispose to more severe infections.

3. Family Syngaminidae

Genus: Syngamus

Species: Syngamus trachea

- **Hosts & Location:**
  - Occurs in the trachea of fowl.
- **Common Names:**
  - Gape worm, forked worm, Y-shaped worm.
- **Morphology:**
  - Buccal capsule is cup-shaped, containing 6–10 teeth; no leaf crown.
  - Males are much smaller than females; male and female remain permanently attached, forming a characteristic Y-shape.
- **Pathogenesis:**
  - Causes tracheitis with heavy mucus accumulation leading to tracheal obstruction.
  - Clinical sign: "gaping" movement (birds open their mouth widely to clear airway).

4. Family Subuluridae

Genus: Subulura

Species: Subulura brumpti

- **Hosts & Location:**
  - Commonly referred to as the "pin worm" of fowl; inhabits the intestine.
- **Note:**
  - Generally of low pathogenicity.

5. Family Stephanuridae

Genus: Stephanurus

- **Hosts & Location:**
  - In pigs (*Stephanurus dentatus*) and in man (*Stephanurus laryngeus*), known as the kidney worm.
  - Occurs in the kidney (perirenal fat, renal pelvis, ureter).
- **Morphology:**
  - Buccal capsule is cup-shaped with six cusped teeth at its base.
- **Life Cycle:**
  - **Direct life cycle** with infective stage being the third-stage larva (L3).
  - **Transmission Routes:**
    - Ingestion of free L3 (with food/water).
    - Ingestion of earthworms (transport hosts harboring L3).
    - Can also occur percutaneously or prenatally.

    - Larvae undergo further molting (third ecdysis in stomach or muscles) and eventually migrate via liver → peritoneum → ureter → kidney.

- **Pathogenesis:**
    - Causes nodules and edema on the skin (if penetration occurs), liver abscesses, and cyst formation in the kidney.
    - Migrating larvae may induce portal fibrosis and coagulative necrosis in liver tissues, with local purulent reactions in the kidney.

6. Family Dioctophymidae

Genus: Dioctophyma

Species: Dioctophyma renale

- **Common Name:**
    - Giant kidney worm of dog.
- **Key Features:**
    - Largest nematode of domestic animals (female up to 103 cm long); blood-red in color.
    - Males measure 35–45 cm; have a single spicule and a cup-shaped bursa without bursal rays.
    - Eggs: Barrel-shaped, single-celled, with pitted shells (except at poles).
- **Life Cycle:**
    - **Indirect life cycle:**
        - **Intermediate Host:** Oligochaete annelid (e.g., *Lumbriculus variegatus*).
        - **Infective Stage:** Third-stage larva (L3).
- **Pathogenesis:**
    - Worms destroy renal parenchyma (often right kidney more frequently affected).
    - Formation of a sac-like structure in the kidney capsule.
    - Clinical signs: Dysuria, hematuria (especially at the end of micturition), and renal colic.

7. Family Filaroididae

Genus: Filaroides

Species: Filaroides osleri

- **Hosts & Location:**
    - Occurs in the bronchi and trachea of dogs.
- **Note:**

- These filaroid nematodes are important causes of respiratory disease in canines.

8. Family Metastrongylidae

Genus: Metastrongylus

Species: Metastrongylus elongatus

- **Hosts & Location:**
  - Lung worm of pigs; inhabits bronchi and bronchioles.
- **Life Cycle:**
  - **Infective Stage:** L3 larvae.
  - **Intermediate Host:** Earthworms.

9. Family Protostrongylidae

Genus: Prontostrongylus

Species: Prontostrongylus nifescens

- **Hosts & Location:**
  - Known as the red lung worm; found in the bronchioles of goats, sheep, and related animals.

Genus: Mullerius

Species: Mullerius capillaris

- **Common Names:**
  - Hair lung worm or nodular lung worm.
- **Hosts & Life Cycle:**
  - Final hosts: Goats, sheep, wild ruminants.
  - **Intermediate Hosts:**
    - Snails (e.g., *Helix, Helicella, Theba, Zebrina*) and slugs (e.g., *Limax, Agriolimax*).
  - Life cycle is indirect.

10. Family Oxyuridae

Genus: Oxyuris

Species: Oxyuris equi

- **Hosts & Location:**
  - Found in the large intestine of equines.
- **Common Name:**
  - Pin worm or seat worm of horse.

- **Life Cycle:**
    - **Infective Stage:** L2 larvae.
- **Pathogenesis:**
    - Causes mild enteritis, anal pruritus, and a “rat-tailed” appearance of the worm.
    - Can lead to discomfort and irritation.

11. Family Theiaziidae

Members of this family inhabit the conjunctival sac, lacrimal duct, and digestive tract of mammals and birds. Key genera include:

Genus: Thelazia (Eye Worms)

- **Species Examples:**
    - *Thelazia rhodesii* (cattle, sheep, goats),
    - *T. lacrymalis* (horse),
    - *T. gulosa* (cattle),
    - *T. callipaeda* (dog),
    - *T. skrajabini* (cattle).
- **Life Cycle:**
    - **Indirect:**
        - L1 larvae are excreted in lacrimal secretions.
        - Ingested by flies (e.g., *Musca convexifrons, M. larvipara*) which serve as intermediate hosts.
        - Infected flies deposit infective L3 larvae into the eyes during feeding.
- **Pathogenesis:**
    - Cause lacrimation, conjunctivitis, corneal ulceration, keratitis, muco-purulent discharge, and potentially blindness.
- **Treatment:**
    - Levamisole and tretamisole are drugs of choice.

12. Genus: Spirocerca

Species: Spirocerca lupi

- **Hosts & Location:**
    - Found in dogs; typically inhabits the wall of the oesophagus, stomach, and aorta.
- **Intermediate Host:**
    - Coprophagous beetles.
- **Morphology:**

    - Worms are spirally coiled with a funnel-shaped pharynx and a trilobed lip.
    - Male tail features lateral alae with four pairs of papillae.
    - Eggs are embryonated, elongated, and have thick shells.
- **Life Cycle:**
    - Eggs are passed in feces.
    - They do not hatch until ingested by coprophagous beetles (or, sometimes, transport hosts such as birds or reptiles).
    - Infective L3 larvae develop in the beetle.
    - Final host (dog) becomes infected by ingesting the infected beetle or a transport host.
    - Larvae are released, penetrate the stomach wall, and migrate via arterial routes (gastric, gastroepiploic, coeliac) to the thoracic aorta and oesophagus.
- **Pathogenesis:**
    - Causes formation of nodules in the oesophagus and aorta.
    - Associated lesions include oesophagitis, thrombosis, aneurysms, and potentially malignant transformation (e.g., osteosarcoma, fibrosarcoma).
    - Other complications: hypertrophic pulmonary osteoarthropathy, deformative ossifying spondylitis.
- **Treatment:**
    - Diethyl carbamazine at 20 mg/kg body weight is used.

Filarial and Cardiopulmonary Nematodes

A. Genus Dirofilaria

- **Species:** *Dirofilaria immitis* (Heartworm)
- **Hosts:**
    - Definitive: Dogs, foxes, and related canids
- **Intermediate Hosts:**
    - Mosquitoes (e.g., *Anopheles, Culex, Aedes*)
- **Morphology:**
    - Adult worms inhabit the heart and pulmonary arteries.
    - Posterior end of the male shows several (4–5 pairs) ovoid papillae, along with two pairs of finger-shaped papillae and minute conical papillae.
- **Pathology:**
    - Pulmonary hypertension, congestive heart failure, hemoglobinuria, and jaundice.
    - Both larvae and adults lodge between the right atrium and ventricle, leading to right ventricular hypertrophy and passive congestion.

- **Clinical Signs:**
    - Shallow coughing, weakness, and signs of heart failure.
- **Diagnosis:**
    - Knott's test: Blood mixed with formalin, centrifuged, and sediment stained (e.g., with methylene blue).

B. Genus Parafilaria

- **Species:**
    - *Parafilaria multipapillosa*: Found on the skin of equines, forming hemorrhagic nodules.
    - *Parafilaria bovicola*: Found on the skin of cattle; nodules may show seasonal "summer bleeding."
- **Note:**
    - Although the worms themselves are not highly pathogenic, their nodular lesions may persist.

II. Peritoneal and Cerebrospinal Nematodes (Setaridae & Stephanuridae)

A. Family Setaridae

Genus Setaria

- **Species Examples:**
    - *Setaria digitata, S. labito-papillosa, S. cervi, S. equina*
- **Hosts & Location:**
    - Inhabit the peritoneal cavity of cattle, deer, and equines.
- **Pathology:**
    - In equines, migrating larvae can cause cerebrospinal nematodosis (encephalitis, meningitis).

Genus Stephanofilaria

- **Species Examples:**
    - *Stephanofilaria assamensis* – associated with "hump sore" in pigs.
    - *S. dedoesi, S. kaeli, S. stilesi, S. zaheeri* – cause various skin sores (leg, abdominal, ear) in cattle.

B. Other Related Genera

Genus Dipetalonema

- **Species Examples:**
    - *Dipetalonema perstam*, *D. reconditum, D. evansi, D. grassi*
- **Hosts & Locations:**

- Found in the peritoneal cavity (in man), kidney (dogs), spermatic artery (camels), or subcutaneous tissues (dogs).

III. Renal and Respiratory Nematodes

A. Family Dioctophymidae

Genus Dioctophyma

- **Species:** *Dioctophyma renale* (Giant Kidney Worm)
- **Hosts:**
  - Definitive: Dogs (occasionally other domestic animals)
- **Morphology:**
  - Largest nematode (female up to 103 cm), blood-red in color.
  - Males are shorter (35–45 cm) with a single spicule and a cup-shaped bursa (without bursal rays).
  - Eggs are barrel-shaped with pitted shells (except at the poles).
- **Life Cycle:**
  - **Indirect:** Intermediate host is an oligochaete annelid (e.g., *Lumbriculus variegatus*); infective stage is L3.
- **Pathology:**
  - Destruction of renal parenchyma, frequently affecting the right kidney.
  - Leads to dysuria, hematuria, and renal colic.

B. Family Filaroididae

Genus Filaroides

- **Species:** *Filaroides osleri*
- **Hosts & Location:**
  - Found in the bronchi and trachea of dogs.
- **Clinical Relevance:**
  - Can cause respiratory distress in infected animals.

C. Family Metastrongylidae

Genus Metastrongylus

- **Species:** *Metastrongylus elongatus*
- **Hosts & Location:**
  - Lung worm of pigs; inhabits bronchi and bronchioles.
- **Life Cycle:**
  - Infective L3 stage; intermediate host is an earthworm.

D. Family Protostrongylidae

Genus Prontostrongylus

- **Species:** *Prontostrongylus nifescens* (Red lung worm)
- **Hosts & Location:**
    - Found in the bronchioles of goats, sheep, and other ruminants.

Genus Mullerius

- **Species:** *Mullerius capillaris* (Hair lung or Nodular lung worm)
- **Hosts & Life Cycle:**
    - Final hosts: Goats, sheep, wild ruminants.
    - Intermediate hosts: Snails and slugs (e.g., *Helix, Theba, Zebrina; Limax, Agriolimax*).

IV. Gastrointestinal and Ocular Nematodes

A. Family Oxyuridae

Genus Oxyuris

- **Species:** *Oxyuris equi*
- **Hosts & Location:**
    - Occurs in the large intestine of equines.
- **Common Name:**
    - Pin worm or seat worm of horses.
- **Life Cycle:**
    - Infective stage: L2.
- **Pathology:**
    - Causes mild enteritis, anal pruritus, and a “rat-tailed” appearance of the worm.

B. Family Theiaziidae

This family includes several genera that infest ocular and upper digestive tract sites.

Genus Thelazia

- **Species Examples:**
    - *Thelazia rhodesii* (cattle, sheep, goats), *T. lacrymalis* (horse), *T. gulosa* (cattle), *T. callipaeda* (dog), *T. skrajabini* (cattle)
- **Life Cycle:**
    - **Indirect:** L1 larvae are secreted via lacrimal fluid, ingested by flies (e.g., *Musca convexifrons, M. larvipara*), develop to L3 in 2–4 weeks, and are transmitted during fly feeding.
- **Pathology:**

    - Causes lacrimation, conjunctivitis, corneal ulceration, keratitis, muco-purulent discharge, and in severe cases, blindness.

- **Treatment:**
    - Levamisole and tretamisole are commonly used.

Genus Spirocerca

- **Species:** *Spirocerca lupi*
- **Hosts & Location:**
    - Occurs in dogs, primarily within the wall of the esophagus, stomach, and aorta.
- **Intermediate Host:**
    - Coprophagous beetles (and sometimes secondary transport hosts such as birds or reptiles).
- **Morphology:**
    - Worms are spirally coiled; have a funnel-shaped pharynx with a trilobed lip; males have lateral alae with four pairs of papillae.
    - Eggs are elongated and thick-shelled.
- **Life Cycle:**
    - Eggs are shed in feces, develop in the intermediate host, and infect dogs when the beetle (or transport host) is ingested.
    - Larvae migrate to the arterial system via the stomach wall.
- **Pathogenesis:**
    - Causes nodular lesions in the esophagus and aorta.
    - Lesions may include thrombosis, aneurysm, and malignant transformation (e.g., osteosarcoma, fibrosarcoma).
    - Can lead to complications such as hypertrophic pulmonary osteoarthropathy.
- **Treatment:**
    - Diethyl carbamazine (20 mg/kg body weight) is used.

V. Subcutaneous and Lymphatic Nematodes

A. Family Dracunculidae

Species: *Dracunculus medinensis* (Guinea Worm)

- **Hosts:**
    - Humans (and occasionally dogs).
- **Intermediate Host:**
    - Aquatic arthropods (Cyclops; e.g., *Mesocyclops leukarti*).
- **Morphology & Life Cycle:**

    - The female is very long (3–4 meters); males are much shorter.
    - A specific cuticular structure called a “helmet” is a salient feature.
    - Life stages: L1–L4 develop in the Cyclops; infective stage is L3.
- **Pathogenesis:**
    - Infected individuals develop subcutaneous swellings that rupture to form painful ulcers.
    - Causes localized inflammation and secondary infection.

B. Family Trichuridae

- **Common Name:**
    - Whipworms.
- **Hosts & Location:**
    - Affect a variety of species (cattle, dogs, humans, etc.); reside in the large intestine.
- **Morphology:**
    - Long, whip-like anterior (thin) and thicker posterior body.
    - Females are oviparous; males have a curled hind end with a spicule in a sheath.
    - Eggs are brown, barrel or lemon-shaped with transparent plugs at either pole.
- **Transmission:**
    - Ingestion of eggs containing L1 larvae with feed, water, or soil.
- **Pathogenesis:**
    - Can cause colitis, diarrhea, and weight loss in heavy infections.

C. Family Trichinellidae

- **Species:** *Trichinella spiralis* (Pork worm)
- **Hosts & Location:**
    - Found in pigs, humans, rodents, and wild animals.
    - Adult worms reside in the small intestine; larvae encyst in striated muscles.
- **Key Features:**
    - Males are 1.4–1.6 mm long; females 3–4 mm long.
    - Females are larviparous; no free-living stage – an auto-heteroxenous life cycle.
- **Pathogenesis:**
    - Human trichinellosis (acquired by eating undercooked pork) leads to muscle pain, fever, and, in severe cases, systemic complications.
- **Diagnosis:**
    - Trichinoscopy, serology.

- **Treatment:**
    - Benzimidazoles.

VI. Capillaria (Trichuriform Nematodes)

- **General Features:**
    - Capillaria species are small nematodes with a single spicule in males; females are oviparous.
- **Egg Morphology:**
    - Eggs are colorless, more barrel-shaped with nearly parallel sides; bipolar plugs are present but not as projecting as in Trichuris.
- **Species & Hosts/Locations:**
    - *Capillaria caudinflata:* Found in the duodenum and ileum of fowl and pigeons.
    - *Capillaria annulata:* Occurs in the crop and esophagus.
        - Intermediate host: Earthworm.
    - *Capillaria hepatica:* Found in the liver of rats, mice; occasionally in dogs, cats, and humans.
    - *Capillaria aerophila:* Found in the trachea and bronchi of dogs, foxes, and coyotes.
        - Life cycle may be direct or indirect (with earthworms as intermediate hosts for some species).
    - *Capillaria philippinensis:* Fish may act as intermediate hosts.

Summary

These notes cover a broad range of nematode families important in veterinary and human medicine:

- **Filarial and cardiopulmonary nematodes** (e.g., *Dirofilaria immitis*, *Spirocerca lupi*) cause serious heart and vascular lesions.
- **Peritoneal and skin-associated nematodes** (Setaridae, Stephanuridae) affect cattle, equines, and pigs.
- **Renal and respiratory parasites** (e.g., *Dioctophyma renale*, lungworms in Metastrongylidae/Protostrongylidae) cause significant organ damage.
- **Gastrointestinal and ocular nematodes** (e.g., *Oxyuris equi*, *Thelazia* spp.) are common in domestic animals.
- **Subcutaneous/lymphatic and whipworm-type nematodes** (e.g., *Dracunculus medinensis*, *Trichuris*, *Trichinella spiralis*) have important zoonotic implications.
- **Capillaria species** infect various organs depending on the species and are notable for their distinctive egg morphology.

Protozoology

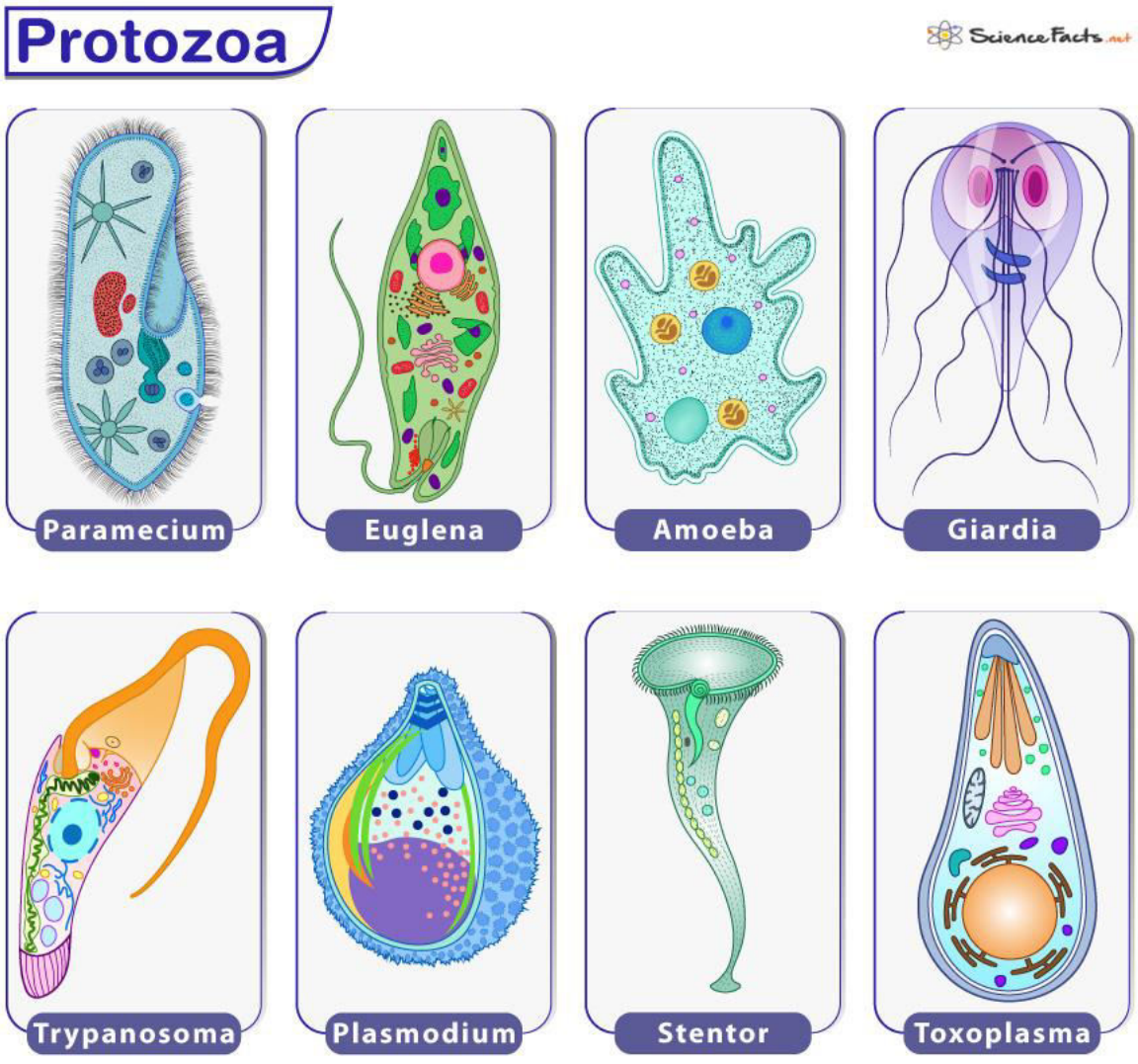
1. Definition and Origin

- **Protozoology** is the study of protozoa.

- The term “protozoa” is derived from the Greek words:
    - **“Proto”** meaning “first”
    - **“Zoa”** meaning “animals”
- Protozoa are considered the first animal life forms on Earth.
- Discovered and first observed by Antoni van Leeuwenhoek, known as the Father of Protozoology.

2. Basic Characteristics of Protozoa

- **Unicellular, microscopic, and eukaryotic** organisms.



- **Distinct nucleus:** Enclosed by a nuclear membrane (in contrast to bacteria, which lack a nucleus).
- **Cellular Organization:**
    - **Cytoplasm:** Divided into two regions:

        - **Ectoplasm:** The clear, outer, hyaline region involved in locomotion and sensory functions.
        - **Endoplasm:** The inner granular part containing food vacuoles and organelles (mitochondria, Golgi apparatus, endoplasmic reticulum).
    - **Nucleus:** Usually one per cell; in some groups, there may be two types:
        - **Vesicular (macronucleus):** Regulates cytoplasmic functions.
        - **Compact (micronucleus):** Involved in reproductive functions.

Some protozoa (e.g., *Balantidium coli*) have dissimilar nuclei, whereas others (e.g., Giardia spp.) may have two similar nuclei.

3. Nutrition

- **Holophytic Nutrition:**
    - Plant-like (photosynthetic) nutrition using chlorophyll in specialized organelles (e.g., *Euglena*, *Volvox*).
- **Holozoic Nutrition:**
    - Ingestion of food materials by phagocytosis or pinocytosis through a cytostome; food is digested in food vacuoles (e.g., *Entamoeba*, *Balantidium coli*).
- **Saprozoic Nutrition:**
    - Absorption of dissolved nutrients through the cell membrane (e.g., *Eimeria, Babesia, Theileria, Trypanosoma* spp.).

4. Locomotion Mechanisms

- **Pseudopodia (False Feet):**
    - Temporary projections of ectoplasm used for movement and phagocytosis (e.g., *Entamoeba* spp.).
- **Flagella:**
    - Long, whip-like structures arising from a blepharoplast.
    - They may be free or attached to the cell (forming an undulating membrane), as seen in *Trypanosoma* and *Giardia*.
- **Cilia:**
    - Short, hair-like structures covering the cell surface that beat rhythmically to aid movement (e.g., *Balantidium coli*).
- **Gliding:**
    - Some protozoa (especially members of the Apicomplexa like *Toxoplasma*, *Eimeria*, and *Cryptosporidium*) move by gliding along surfaces without specialized organelles.

5. Excretion and Osmoregulation

- **Excretion:**

- Waste products are eliminated either directly by diffusion through the plasma membrane or via contractile vacuoles that also help regulate osmotic balance.

6. Reproduction in Protozoa

A. Asexual Reproduction

- **Binary Fission:**
  - The nucleus divides first followed by the division of the cytoplasm.
- **Schizogony (Multiple Fission):**
  - The nucleus divides repeatedly to form a multinucleated schizont that later divides to produce merozoites.
- **Budding:**
  - One or more daughter cells bud off from the parent cell.
- **Endodyogeny:**
  - Internal budding where two daughter cells are formed within the parent cell (e.g., in *Toxoplasma gondii*).
- **Endopolygeny:**
  - Multiple daughter cells are produced internally from a multinucleate cell (e.g., in *Toxoplasma* and *Sarcocystis*).

B. Sexual Reproduction

- **Conjugation:**
  - Exchange of nuclear material between two cells (common in ciliates).
- **Syngamy:**
  - Fusion of two gametes to form a zygote.
  - **Isogamy:** Fusion of gametes of equal size.
  - **Anisogamy:** Fusion of unequal gametes (microgamete and macrogamete).
- **Sporogony:**
  - Asexual multiplication of the zygote within a cyst (oocyst) leading to the production of sporozoites.

7. Modes of Transmission of Protozoan Parasites

- **Direct Transmission:**
  - Ingestion of oocysts or cysts from contaminated food/water (e.g., *Giardia, Entamoeba, Balantidium coli*).
  - Transmission via infected meat (e.g., *Trypanosoma, Sarcocystis*).
  - Sexual (venereal) transmission (e.g., *Tritrichomonas, Trypanosoma equiperdum*).
  - Congenital transmission (e.g., *Toxoplasma gondii*).

- Through crop milk (e.g., *Trichomonas gallinae*).

- **Indirect Transmission:**
  - **Via Vectors:**
    - Mechanical transmission (e.g., intermittent feeding of flies with *Trypanosoma*).
    - Biological transmission (e.g., *Leishmania* by sand flies, *Plasmodium* by mosquitoes, *Theileria* by ticks, *Babesia* by ticks).
  - **Through Eggs of Other Parasites:**
    - For instance, *Histomonas meleagridis* can be transmitted via the eggs of *Heterakis gallinarum*.
  - **By Ingestion of Infected Intermediate Hosts:**
    - As in many protozoa that require an invertebrate host for part of their life cycle.

Classification of Key Protozoan Parasites

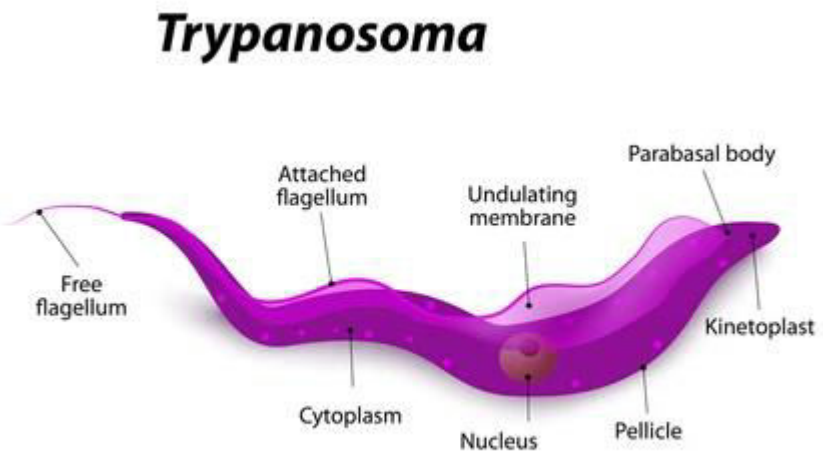
Phylum: Sarcomastigophora

- **Subphylum: Mastigophora**
- **Class: Zoomastigophorea**
- **Key Order:** Kinetoplastida
  - **Family: Trypanosomatidae**

A. Genus Trypanosoma

General Features:

- **Haemoflagellates:**

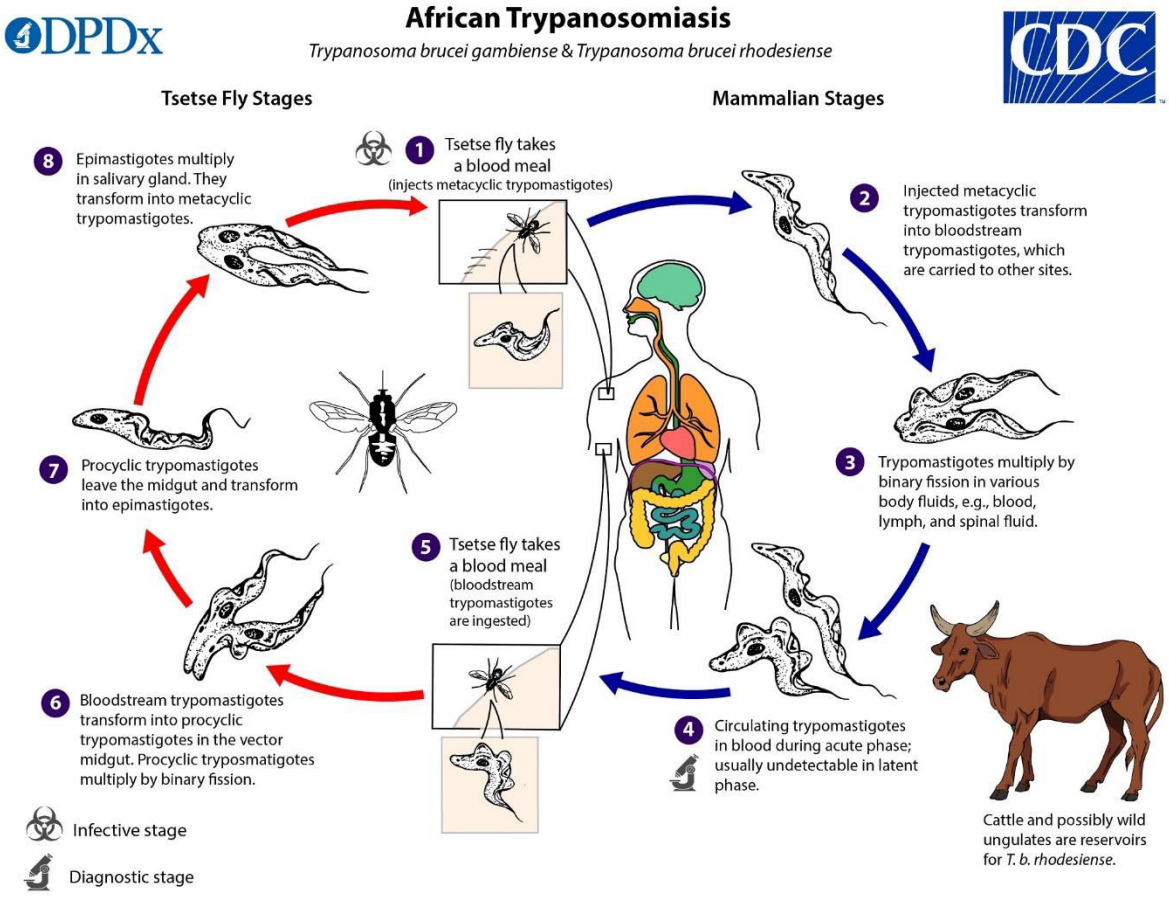


  - Typically elongated, leaf-like cells with a single flagellum that runs along an undulating membrane.

- Possess a centrally located vesicular nucleus and a distinct DNA-containing kinetoplast located just posterior to the basal body.

- **Developmental Stages:**
  - **Trypomastigote:** The typical bloodstream form with a fully developed undulating membrane and free flagellum.
  - **Epimastigote:** Found in the vector, with a short free flagellum and the kinetoplast anterior to the nucleus.
  - **Promastigote:** A stage with only a short free flagellum (seen in some vectors or culture).
  - **Amastigote:** A non-flagellated, rounded form (as seen in *Leishmania*).

Transmission:



- **Cyclical Transmission:**
  - Occurs when trypanosomes multiply in a blood-sucking insect vector.
  - Two main patterns:
    - **Salivarian Transmission:** (e.g., *T. brucei, T. congolense, T. vivax*) where infective metacyclic trypomastigotes are transmitted via saliva.

        - **Stercorarian Transmission:** (e.g., *T. cruzi*) where metacyclic forms are passed in feces.

- **Mechanical Transmission:**
    - Occurs when vectors (e.g., Tabanus or Stomoxys) transmit parasites without supporting development.
- **Venereal Transmission:**
    - Example: *Trypanosoma equiperdum* (transmitted during sexual intercourse).

Species Examples:

- *Trypanosoma evansi* – causes Surra (especially severe in camels, horses, and dogs).
- *Trypanosoma equiperdum* – causes dourine in equids.
- *Trypanosoma theileri* – generally non-pathogenic in cattle.
- *Trypanosoma gambiense, T. rhodesiense* – cause sleeping sickness in Africa.
- *Trypanosoma cruzi* – causes Chagas disease in South America.

Pathogenesis (e.g., T. evansi):

- Causes progressive anemia, hypoglycemia, and undulating fever due to antigenic variation of the Variant Surface Glycoprotein (VSG) coat.
- Clinical signs vary by host: in horses (hindlimb weakness, edema), in camels (chronic emaciation, hump disappearance), in dogs (fever, neurological signs), and in cattle/buffalo (subclinical to acute forms).

B. Genus Leishmania

General Features:

- **Obligatory Intracellular Parasites:**
    - Reside within macrophages of vertebrate hosts.
- **Two Main Developmental Forms:**

1. **Amastigote:**
        - Found in the vertebrate host.
        - Oval or round, lacks flagellum, kinetoplast oriented at right angles to the nucleus.
2. **Promastigote:**
        - Found in the sandfly vector.
        - Spindle-shaped with a free anterior flagellum.

- **Transmission:**
    - By the bite of sandflies (genus *Phlebotomus* in the Old World; *Lutzomyia* in the New World).

Species of Importance and Associated Diseases:

- *Leishmania donovani* – causes visceral leishmaniasis (Kala-azar).
- *Leishmania tropica* – causes cutaneous leishmaniasis (Oriental sore).
- *Leishmania major* – causes cutaneous leishmaniasis.
- *Leishmania braziliensis* – associated with mucocutaneous leishmaniasis.
- *Leishmania mexicana* – causes localized cutaneous disease.
- *Leishmania chagasi* – now considered synonymous with *L. infantum* causing visceral leishmaniasis in the New World.

Genus Leishmania

Overview

- **Leishmania** is an obligate intracellular protozoan parasite.
- It has two developmental stages:
    - **Promastigote:** Spindle-shaped, flagellated form found in the sand fly vector.
    - **Amastigote:** Non-flagellated, oval/round form found inside the macrophages of vertebrate hosts.
- **Transmission:**
    - When an infected sand fly feeds, a plug of promastigotes is dislodged and injected into the host.
    - Infection may also occur if an infected sand fly is crushed on the skin.
    - Once inside the host, promastigotes are phagocytosed by macrophages, transform into amastigotes, and multiply by binary fission.

Leishmania donovani – Visceral Leishmaniasis (Kala-azar / Dumdum Fever)

- **Historical Note:**
    - First reported in 1903 by William Leishman and Charles Donovan in India; initially observed in spleen smears/biopsies from patients.
- **Disease:**
    - Causes Visceral Leishmaniasis, also known as Kala-azar or Dumdum fever.
- **Pathogenesis:**
    - Amastigotes multiply within macrophages in the spleen, liver, bone marrow, lung, kidney, lymph nodes, and skin.
    - This leads to destruction of macrophages, blockage of the reticuloendothelial system, and subsequent anemia.
    - Advanced infection may cause ulceration of the digestive tract with marked enlargement of the liver and spleen.
- **Clinical Symptoms (Humans):**
    - Irregular intermittent fever.

    - Diarrhea and dysentery.
    - Abdominal distension due to splenomegaly and hepatomegaly.
    - Anemia and emaciation.
    - Darkening of the facial skin (hence the term “Kala-azar” meaning “black fever”).
- **In Dogs:**
    - Initially develop “spectacles” (loss of hair around the eyes), then generalized alopecia, ulcers, and eczema.
- **Post Kala-azar Dermal Leishmaniasis (PKDL):**
    - Occurs 2–10 years after recovery from visceral leishmaniasis.
    - Presents as small, lentil-sized whitish nodules, especially on the face and neck.
- **Diagnosis:**
    - Clinical examination and history.
    - Post-mortem findings: enlarged spleen, liver, lymph nodes, anemia, emaciation.
    - Blood smear examination to detect amastigote forms.
    - Culture of blood in NNN (Novy, MacNeal, Nicolle) media.
    - Biopsy of spleen, bone marrow, or lymph nodes.
    - Serological tests (CFT, IHA, IFA, ELISA).
    - Montenegro (skin) test.
- **Treatment:**
    - Pentavalent antimony compounds (e.g., sodium stibogluconate, administered intramuscularly on alternate days).
    - Pentamidine isothionate.
    - Amphotericin B.
    - Miltefosine.
    - Paromomycin.
- **Control:**
    - Treat infected hosts.
    - Control sand fly vectors by insecticides, eliminating breeding sites, and clearing decaying vegetation.
- **Vaccine:**
    - Leishmune vaccine (developed for dogs against L. donovani).

Leishmania tropica – Cutaneous Leishmaniasis (Oriental Sore)

- **Hosts:**

    - Final host: Humans.
    - Reservoir hosts: Dogs and rodents.
- **Vector:**
    - Sand flies such as *Phlebotomus papatasi* or *P. sergenti*.
- **Location of Infection:**
    - Primarily infects macrophages and reticuloendothelial cells in the skin.
- **Disease:**
    - Causes Cutaneous Leishmaniasis, also known as Oriental sore, Delhi boil, or Old World Cutaneous Leishmaniasis.
- **Pathogenesis & Clinical Features:**
    - Initially, a reddish papule develops at the bite site.
    - The lesion progresses to form an ulcer.
    - Multiple small lesions may coalesce into a larger ulcer.
    - The disease is generally non-fatal and may heal within 2–12 months, leaving scars.
    - Healed lesions on the face, nose, ear, or eye may lead to disfigurement.
- **Diagnosis:**
    - Microscopic detection of amastigote forms in smears from the edge of the ulcer.
    - Cultivation of biopsy material on NNN medium.
    - Biopsy of local lymph nodes.
    - Serological tests.
- **Treatment:**
    - Lithium antimony thiomalate.
    - Berberine sulphate.
- **Control:**
    - Vector control similar to visceral leishmaniasis (reducing sand fly breeding and exposure).

Genus Leishmania

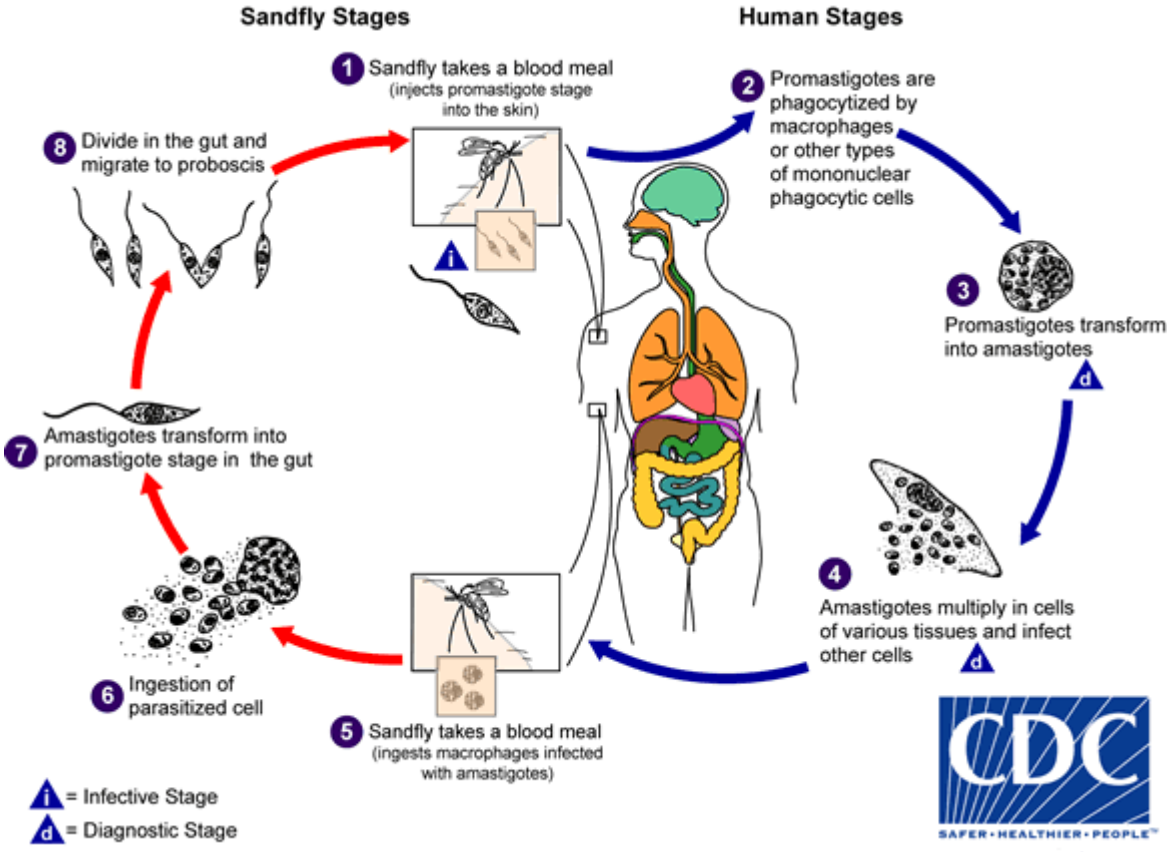
1. Overview

- **Leishmania** is an obligate intracellular protozoan parasite.
- It has two developmental stages:
    - **Promastigote:** Flagellated, spindle-shaped form found in the sand fly vector.
    - **Amastigote:** Non-flagellated, oval/round form found within the macrophages of the vertebrate host.

2. Transmission

- **During Sand Fly Feeding:**
    - Infected sand flies may dislodge a plug of promastigotes that is injected into the host during blood feeding.
- **Alternate Route:**
    - Infection may also occur if infected sand flies are crushed on the skin.
- **Within the Host:**
    - Promastigotes are phagocytosed by macrophages where they transform into amastigotes and multiply by binary fission.

2. Leishmania donovani – Visceral Leishmaniasis (Kala-azar)



Historical Background

- First reported in 1903 by William Leishman (in a soldier's spleen smear from Dum Dum, Kolkata) and Charles Donovan (in a spleen biopsy from an Indian patient).
- Named *Leishmania donovani*; the disease is also called Dumdum Fever.

Disease and Pathogenesis

- **Disease:**
    - Visceral leishmaniasis (also known as Kala-azar, Dumdum fever).
    - Also caused by *L. infantum* in some regions.

- **Pathogenesis:**
    - Amastigotes multiply within macrophages in the spleen, liver, bone marrow, lung, kidney, lymph nodes, and skin.
    - Destruction of macrophages leads to blockage of the reticuloendothelial system.
    - Advanced disease features include ulceration of the digestive tract and significant hepatosplenomegaly.
- **Clinical Symptoms (Humans):**
    - Irregular, intermittent fever.
    - Diarrhea and dysentery.
    - Abdominal distension (due to splenomegaly and hepatomegaly).
    - Anemia, emaciation.
    - Darkening of the facial skin ("Kala-azar" meaning "black fever").
- **In Dogs:**
    - Initial "spectacles" (loss of hair around the eyes), followed by generalized alopecia, ulcers, and eczema.
- **Post Kala-azar Dermal Leishmaniasis (PKDL):**
    - Develops 2–10 years after recovery from visceral disease.
    - Characterized by lentil-sized whitish nodules on the face and neck.

Diagnosis

- **Clinical & Post-mortem:**
    - Examination of symptoms, enlarged spleen, liver, lymph nodes, anemia, and emaciation.
- **Laboratory Methods:**
    - Blood smear examination to detect amastigote forms.
    - Culture in NNN (Novy, MacNeal, and Nicolle) medium to yield promastigotes.
    - Biopsy of spleen, bone marrow, or lymph nodes.
    - Serological tests: Complement fixation test (CFT), indirect hemagglutination assay (IHA), indirect fluorescent antibody (IFA), and ELISA.
    - Montenegro (skin) test – sensitive and specific.

Treatment

- **Drugs:**
    - Pentavalent antimony compounds (e.g., sodium stibogluconate): 2–5 ml intramuscularly on alternate days for 10 injections.
    - Pentamidine isothionate: 4 mg/kg body weight intramuscularly.

    - Amphotericin B: 5–10 mg/kg body weight intravenously.
    - Miltefosine.
    - Paromomycin.
- **Control Measures:**
    - Treatment of infected hosts.
    - Vector control using insecticides, elimination of breeding sites, and clearing decaying vegetation.
- **Vaccine:**
    - Leishmune vaccine (a fructose-mannose-ligand antigen complex) developed for dogs against *L. donovani*.

4. Leishmania tropica – Cutaneous Leishmaniasis

Hosts, Reservoirs, and Transmission

- **Final Host:**
    - Humans.
- **Reservoir Hosts:**
    - Dogs and rodents.
- **Vector:**
    - Sand flies (e.g., *Phlebotomus papatasi* or *P. sergenti*).
- **Site of Infection:**
    - Macrophages/reticuloendothelial cells in the skin.

Disease and Clinical Features

- **Disease:**
    - Cutaneous leishmaniasis (also called Oriental sore, Delhi boil, or Old World Cutaneous Leishmaniasis).
    - Also caused by *L. major* in some areas.
- **Pathogenesis:**
    - Initial reddish papules develop at the site of the sand fly bite.
    - Lesions progress to form ulcers; multiple ulcers may coalesce into a larger lesion.
    - The disease is typically non-fatal and may heal within 2–12 months, but healing results in scar formation (often disfiguring, particularly on the face, nose, ear, and eye).

Diagnosis

- **Microscopic Examination:**
    - Detection of amastigote forms in smears prepared from lesion edges.

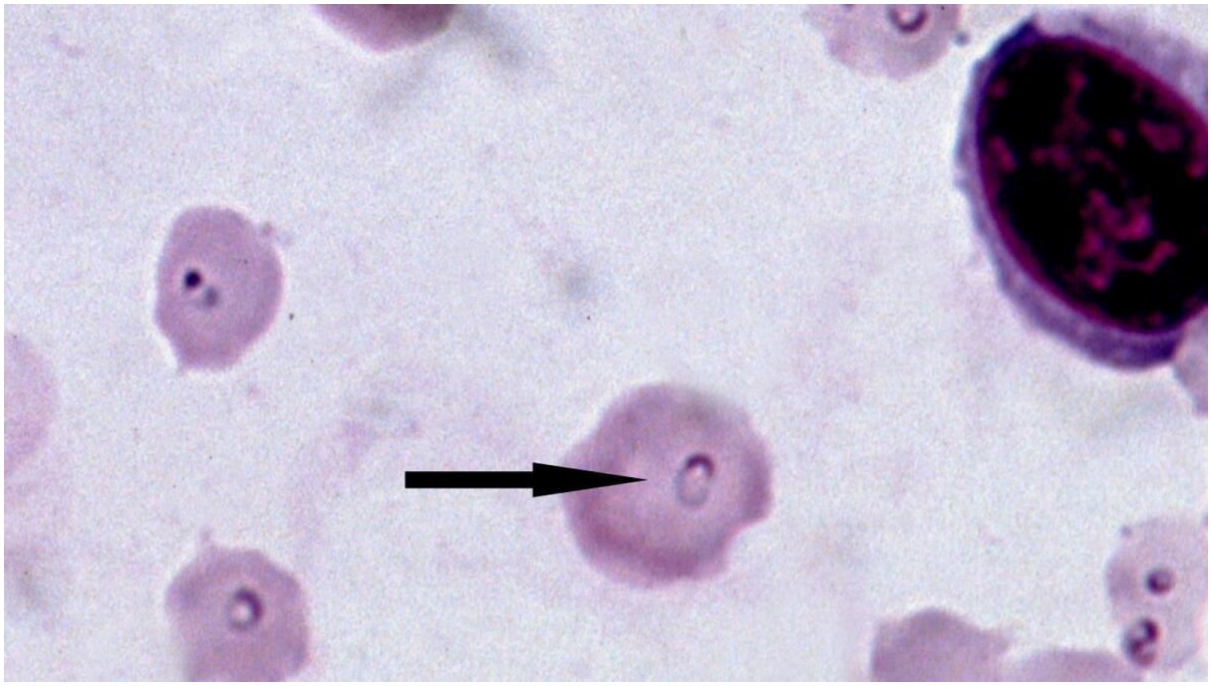
- **Culture:**
    - Promastigotes can be demonstrated by culturing biopsy or post-mortem material on NNN medium.
- **Additional Tests:**
    - Biopsy of local lymph nodes.
    - Various serological tests may be employed.

Treatment

- **Drugs:**
    - Lithium antimony thiomalate.
    - Berberine sulphate.

Genus Theileria

Overview:



- The genus is named in honor of Arnold Theiler, who differentiated East Coast fever from redwater.
- *Theileria* is a tick-transmitted haemoprotozoan parasite of ruminants and captive ungulates.
- Two key developmental stages are observed:
    - **Piroplasm Stage:** Occurs in red blood cells (RBCs). For example, in *T. annulata* the piroplasms are generally annular (ring-shaped), whereas in *T. parva* they are rod-shaped (although round, comma, or oval forms can also occur).
    - **Schizont Stage:** Occurs within the cytoplasm of lymphocytes in infected lymph nodes and spleen.

- **Macroschizonts:** 2–16 µm in size (average ~8 µm) with about 8 nuclei; they stain blue (Koch's blue bodies).
- **Microschizonts:** Similar in size but contain 30–120 nuclei.

Key Species, Hosts, Vectors, and Diseases

Species	Definitive Host	Vector	Disease
T. annulata	Cattle, buffalo	*Hyalomma anatolicum anatolicum* or *H. excavatum* (3-host ticks)	Bovine tropical/ Egyptian/ Mediterranean theileriosis
T. parva	Cattle, buffalo	*Rhipicephalus appendiculatus*	East Coast Fever (January fever)
T. lawrenci	Cattle, buffalo	*Rhipicephalus appendiculatus*	Corridor disease
***T. lestoquardi* (T. hirci)**	Sheep, goat	*Rhipicephalus*, *Haemaphysalis*, *Dermacentor* species	Malignant theileriosis
T. ovis	Sheep, goat	–	Benign theileriosis
T. mutans	Cattle	–	Benign bovine theileriosis
T. equi* (Babesia equi)	Equines	*Rhipicephalus* & *Dermacentor*	Equine piroplasmosis

*Note: *T. equi* was formerly classified as a Babesia but is now recognized as Theileria equi.

Transmission

- **Transtadial Transmission:**
  - Ticks acquire the parasite during feeding as larvae or nymphs on infected hosts.
  - The parasite then develops within the tick, and the subsequent nymph or adult stage transmits infective sporozoites to a new host during feeding.
- **Infective Stage:**
  - Sporozoites are inoculated into the final host during blood feeding by the tick.

Life Cycle

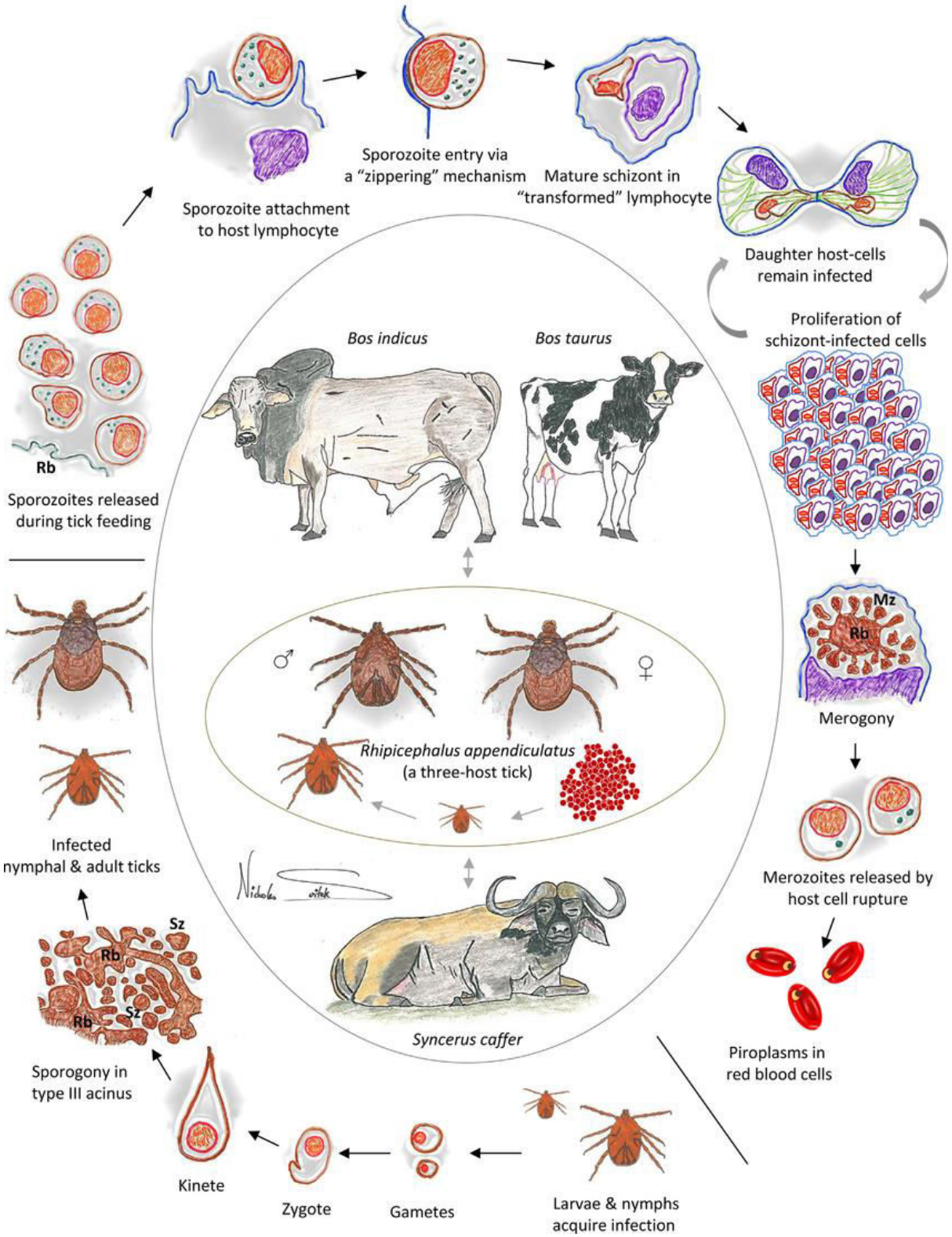
In the Vertebrate Host (Asexual Cycle):

1. **Sporozoite Stage:**
   - Infected ticks inject sporozoites into the host during feeding.
2. **Schizogony:**
   - Sporozoites invade lymphocytes in peripheral lymph nodes.
   - They multiply asexually by schizogony in the cytoplasm, forming **macroschizonts** (Koch's blue bodies).

- Macroschizonts may further develop into **microschizonts**.

3. **Piroplasm Stage:**
    - When lymphocytes rupture, microschizonts are released.
    - These invade RBCs and develop into the piroplasm stage.

In the Tick (Sexual Cycle):



1. **Ingestion:**
    - When a tick feeds on an infected host, it ingests RBCs containing piroplasms.
2. **Gametocyte Formation:**
    - Piroplasms transform into gamonts within the tick's gut.

3. **Gamete Fusion:**
    - Gamonts differentiate into macrogametocytes and microgametocytes, which fuse to form a zygote.
4. **Ookinete and Sporozoite Formation:**
    - The motile zygote (ookinete) develops and invades the tick's salivary glands, transforming into infective sporozoites.

Pathogenesis

- **Schizont Stage:**
    - Macroschizonts multiply within lymphocytes, leading to increased lymphoblasts, lymphocytosis, and later leucopenia.
- **Piroplasm Stage:**
    - Parasites in RBCs cause erythrophagocytosis by macrophages, resulting in anemia.
- **Clinical Manifestations:**
    - High fever.
    - Enlargement of superficial lymph nodes (especially prescapular).
    - Loss of appetite, cessation of rumination, decreased milk production.
    - Lacrimation, nasal discharge, and corneal opacity.
    - Hemorrhagic diarrhea and respiratory distress due to pulmonary edema.
- **Post-mortem Findings:**
    - Punched-out necrotic ulcers in the abomasum.
    - Generalized lymphadenopathy, hepatomegaly, and splenomegaly.

Diagnosis

- **Blood Smear Examination:**
    - Peripheral blood smears (Giemsa or Leishman stained) may reveal ring-shaped piroplasms (e.g., *T. annulata*) within RBCs.
- **Lymph Node Biopsy:**
    - Aspirate from lymph nodes can show macroschizonts (Koch's blue bodies) within lymphocytes.
- **Clinical History and Post-Mortem Findings:**
    - Enlargement of spleen, liver, and lymph nodes, combined with anemia and emaciation.

Treatment

- **Buparvaquone (Butalex):**
    - 2.5 mg/kg body weight, intramuscularly, is the drug of choice.

- **Combination Therapy:**
    - Oxytetracycline (active against schizonts) combined with Diminazene aceturate (active against piroplasms).
- **Other Drugs:**
    - Parvaquone, Halofuginone, Menoctone.
    - Chloroquine sulphate at 5 mg/kg body weight (orally) may also be used.

Control Measures

- **Chemotherapy:**
    - Treatment of infected animals with antitheilerial drugs.
- **Chemoimmunoprophylaxis:**
    - Inoculation of infective sporozoites or viable schizont material (e.g., ground-up tick suspensions) into young susceptible calves combined with prophylactic drugs (e.g., Oxytetracycline) to reduce virulence and stimulate immunity.
- **Vaccination:**
    - *Rakshavac* is a schizont culture vaccine used in India:
        - Dose: 3 ml, administered subcutaneously to calves aged two months or older.
        - Revaccination is recommended every three years.

Special Note: Theileria equi

- Formerly known as *Babesia equi*, it is reclassified as *Theileria equi* based on evolutionary, morphological, biochemical, and genetic evidence.
- In *T. equi*, sporozoites invade lymphocytes to form schizonts, releasing merozoites that infect RBCs.
- Infected RBCs may develop into tetrads (resembling a "Maltese cross") during division.

Family Eimeriidae (Coccidia)

1. Background and History

- **Discovery:**
    - *Eimeria* was first observed by Antoni van Leeuwenhoek in 1674.
    - Dobell officially named the genus in 1922.
- **General Concept:**
    - Coccidian parasites are intracellular, apicomplexan protozoa primarily infecting the intestinal epithelial cells of vertebrates.
    - They reproduce both asexually and sexually within the host.
- **Host Specificity:**
    - They are highly host- and organ-specific.

2. Basic Biology and Structure

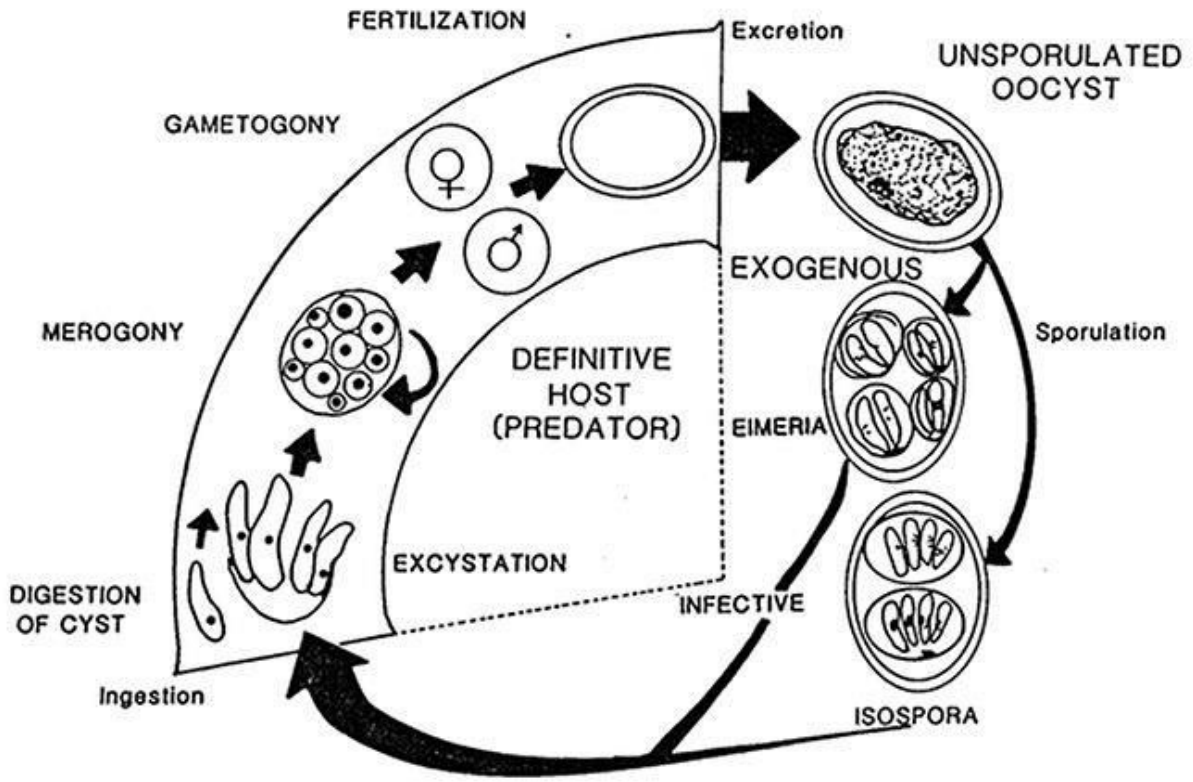
A. Cellular Structure

- **Intracellular Parasites:**
    - Mainly reside within epithelial cells of the intestine.
- **Reproduction:**
    - Undergo both asexual (schizogony) and sexual reproduction (gametogony and syngamy).

B. Oocyst Morphology

- **Unsporulated Oocysts:**
    - Shape: Can be spherical, sub-spherical, ellipsoidal, or oval.
    - Structure: Typically bilayered and transparent.
    - **Micropyle:** A small pore (often at the narrower end) may be present and is frequently covered by a polar (micropylar) cap.
    - Contains a central nucleated mass called the sporont.
- **Sporulated Oocysts:**
    - Formed by sporulation (occurs outside the host in the environment).
    - Each sporulated oocyst contains four sporocysts; each sporocyst usually houses two banana-shaped sporozoites.
    - Additional structures may include a stieda body and sporocyst residuum.
    - **Sporulation Conditions:**
        - Optimal at 29–30°C with sufficient oxygen and moisture.
        - Sporulation typically occurs within 1–3 days.
    - Sporulated oocysts are the infective stage for the host.

4. Life Cycle of Eimeria



A. Environmental Phase

- **Excretion:**
  - Unsporulated oocysts are passed out with the feces of the infected host.
- **Sporulation:**
  - Occurs outside the host, transforming the unsporulated oocysts into infective sporulated oocysts.

B. Intrahost Phase

1. **Excystation:**
   - Ingestion of sporulated oocysts by the host.
   - In the presence of CO_2, bile, and trypsin in the gut, the oocyst wall ruptures, releasing sporozoites.
2. **Schizogony (Asexual Reproduction):**
   - Sporozoites invade intestinal epithelial cells and transform into trophozoites.
   - Trophozoites multiply by multiple fission (schizogony) forming schizonts that contain numerous elongated merozoites.
   - Schizonts rupture, releasing merozoites that infect neighboring cells.
3. **Gametogony (Sexual Reproduction):**
   - Merozoites differentiate into male (microgametocytes) and female (macrogametocytes) gametocytes.

- Microgametes (flagellated) are released from ruptured host cells and fertilize macrogametes, forming a zygote.

4. **Oocyst Formation:**
    - The zygote transforms into an unsporulated oocyst within the host.
    - These unsporulated oocysts are excreted in the feces, restarting the cycle.

4. Eimeria Species in Different Hosts

A. Poultry

- **Eimeria tenella:**
    - **Site:** Caecum
    - **Disease:** Caecal coccidiosis (characteristic "caecal core" with dark, caseous mass)
- **Eimeria necatrix:**
    - **Site:** Small intestine
    - **Disease:** Intestinal coccidiosis with severe hemorrhagic lesions
- **Eimeria brunetti:**
    - **Site:** Rectum
    - **Disease:** Rectal coccidiosis
- **Eimeria acervulina, E. maxima, E. mitis, E. parecox:**
    - **Site:** Various parts of the small intestine

Disease: Generally cause intestinal coccidiosis (ranging from malabsorptive to **hemorrhagic types)**

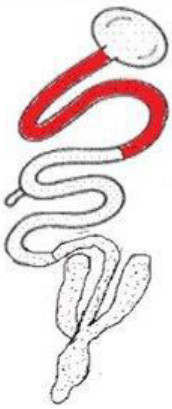
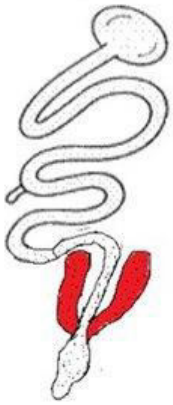
B. Bovines

- **Eimeria zuernii:**
    - **Remarks:** Most common and pathogenic; causes winter coccidiosis.
- **Eimeria bovis:**
    - Also common; typically less severe than E. zuernii.
- **Other Species:**
    - E. alabamensis, E. bukidnonensis, E. canadensis (vary in size and pathogenicity)

C. Sheep and Goats

- **Eimeria ovina:**
    - Most common and pathogenic in sheep.
- **Eimeria intricata:**
    - Largest Eimeria species in sheep.

- **Eimeria granulosa:**
    - Produces egg- or urn-shaped oocysts.
- **Additional Species in Goats:**
    - E. arloingi, E. caprina, E. hirci, E. Ninakohlyakimovae

Species	*E. Acervulina*	*E. maxima*	*E. Brunetti*	*E. necatrix*	*E. tenella*
Portion of the intestine where lesions are mostly seen					
Symptoms	Anemia, light enteritis, loss of appetite	Diarrhoea, droppings may be flacked with blood	Enteritis, occasionally bloody	Bloody enteritis, drops in feed intake	Bloody droppings, reduce in feed intake
Pathogenicity	High morbidity, low mortality		Dysentery, high morbidity, high mortality		

D. Other Hosts

- **Eimeria stiedae:**
    - Found in the liver of rabbits, causing hepatic coccidiosis.
- **Coccidia in Dogs and Cats:**
    - *Isospora canis, Isospora ohioensis* in dogs; *Isospora felis* in cats.
- **Toxoplasma gondii:**
    - Though not classified in Eimeriidae, T. gondii is a coccidian parasite transmitted by ingestion of sporulated oocysts, causing toxoplasmosis.

5. Clinical Features and Diagnosis

A. Clinical Signs (Poultry)

- **Caecal Coccidiosis (E. tenella):**
    - Droppings may be bloody.
    - Reduced feed intake, dehydration, and high mortality in young birds.
- **Intestinal Coccidiosis (Other species):**
    - Watery or bloody diarrhea, poor growth, and weight loss.

- **General:**
    - Young animals are most susceptible; adults often act as carriers.

B. Diagnosis

- **Microscopic Examination:**
    - Fecal examination for unsporulated or sporulated oocysts.
    - Post-mortem examination is often more reliable due to the severity of lesions before oocyst shedding.
- **Laboratory Methods:**
    - Sporulation of unsporulated oocysts in 2.5% potassium dichromate solution (provides oxygen and inhibits bacterial overgrowth).
    - Identification based on oocyst morphology (shape, size, presence of micropyle, number of sporozoites, stieda body).

6. Control and Treatment

A. Environmental Management

- **Hygiene:**
    - Good sanitation and management practices to reduce environmental oocyst load.
- **Stress Reduction:**
    - Overcrowding and poor hygiene predispose to outbreaks.

B. Chemotherapy

- **Anticoccidial Drugs:**
    - **Sulphonamides:** e.g., Sulphadimidine at 120–250 ppm.
    - **Amprolium:** 62.5–125 ppm; blocks thiamine uptake, effective against early trophozoites and schizonts.
    - **Diclazuril:** 1–5 ppm.
    - **Toltazuril:** Around 25 ppm.
    - **Ionophores:**
        - Monensin (100–125 ppm), Lasalocid (100–125 ppm), Salinomycin (50–70 ppm).
    - **Other Agents:**
        - Semduramicin, halofuginone, nicarbazin (inhibit schizont development).

C. Management Strategies

- **Shuttle Programs:**
    - Rotating anticoccidial drugs within a flock to delay or prevent resistance.
- **Vaccination:**

- Live vaccines:
    - Unattenuated vaccines (e.g., Coccivac, Immunocox, Nobilis) and attenuated vaccines (e.g., Livacox, Paracox) are used to stimulate immunity.
- Vaccination typically targets early exposure to build natural immunity in the flock.

Entomology – Study of Insects and Related Arthropods

1. Classification Overview

A. Phylum Arthropoda

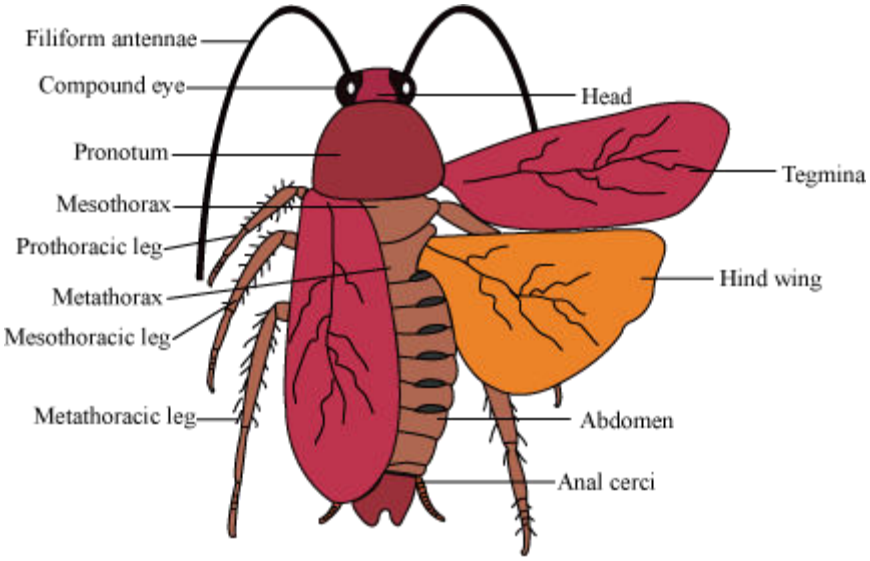
- **Key Features:**
    - **Jointed Appendages:**
        - "Arthro" means joint, "podos" means foot.
    - **Exoskeleton:**
        - Hard, chitinous covering.
    - **Segmented Body:**
        - Body is divided into repetitive segments.
- **Major Classes and Groups:**
    - **Insecta (Insects)**
    - **Arachnida** (Spiders, Ticks, Mites)

- **Myriapoda** (Centipedes, Millipedes)
- **Crustacea** (Crabs, Lobsters, Shrimp)
- Other groups include Alyriapoda, Pentastomida, etc.

B. Insecta – Key Classification

- **Subclasses and Divisions:**
  - **Pterygota (Winged Insects):**
    - Further divided based on wing development:
    - **Endopterygota (Holometabolous):**
      - Wings develop internally.
      - Orders include:
        - *Siphonaptera* (fleas)
        - *Diptera* (flies)
        - *Hymenoptera* (bees, ants, wasps)
        - *Coleoptera* (beetles), etc.
    - **Exopterygota (Hemimetabolous):**
      - Wings develop externally.
      - Orders include:
        - *Mallophaga* (biting lice)
        - *Siphunculata* (sucking lice)
        - *Orthoptera* (grasshoppers, cockroaches)
        - *Hemiptera* (bugs)
        - *Odonata* (dragonflies), etc.
  - **Apterygota (Wingless Insects):**
    - Insects that lack wings entirely.

3. External Morphology and the Exoskeleton



A. Exoskeleton

- **Composition:**
  - Mainly composed of chitin.
- **Function:**
  - Provides a protective, rigid, and segmented covering.
- **Sclerites (Chitinous Plates):**
  - **Dorsal Plate:** Tergum.
  - **Ventral Plate:** Sternum.
  - **Lateral Plate:** Pleuron.
- **Segmentation:**
  - The body is divided into metameric segments (head, thorax, abdomen).

B. Molting (Ecdysis)

- **Definition:**
  - The periodic shedding of the old exoskeleton and formation of a new one.
- **Terminology:**
  - Each shedding event is called “molting” or “ecdysis.”

3. Internal Organs

A. Circulatory System

- **Type:**
  - Open circulatory system.
- **Haemocoel:**
  - A body cavity filled with hemolymph (insect “blood”) that bathes the organs.

- **Heart:**
    - An enlarged dorsal blood vessel enclosed in a pericardial sac.
    - Contains openings called **ostia** through which hemolymph enters.

B. Respiratory System

- **In Insects:**
    - **Tracheal System:**
        - A network of fine, branching tubes (tracheae) that deliver air directly to tissues.
        - Air enters through external openings called spiracles (stigmata).
- **In Other Arthropods:**
    - Aquatic forms (e.g., crustaceans) may use gills.
    - Some arachnids have lung-books or gill-books.

C. Digestive System

- **Divided into Three Regions:**
    - **Foregut (Stomodaeum):**
        - May include a sucking pharynx, crop (proventriculus), and gizzard.
    - **Midgut (Mesenteron):**
        - Main site of digestion and absorption.
    - **Hindgut (Proctodaeum):**
        - Passage for undigested food; typically lined with chitin.

D. Excretory System

- **In Insects:**
    - **Malpighian Tubules:**
        - Tubules that collect metabolic wastes from the haemocoel and empty them into the proctodaeum.
- **In Arachnids:**
    - In addition to Malpighian tubules, arachnids possess coxal glands that open at the bases of their legs.

E. Nervous System

- **Central Components:**
    - **Brain (Cerebral Ganglia):**
        - Located in the head.
    - **Ventral Nerve Cord:**

        - A double nerve cord running along the ventral side with segmental ganglia in each body segment.

- **Sensory Organs:**
    - Compound eyes, simple eyes (ocelli), and various sensory setae.

F. Reproductive System

- **Characteristics:**
    - Sexes are separate (unisexual).
    - In insects, the reproductive organs are well developed and vary by order.

4. Head, Thorax, and Appendages

A. Head

- **Structure:**
    - An ovoid or globular capsule composed of several sclerites.
    - **Eyes:**
        - Usually compound eyes positioned laterally.
        - May be holoptic (touching at the midline) or dichoptic (widely separated).

B. Thorax

- **Segmentation:**
    - Divided into three segments: prothorax, mesothorax, and metathorax.
- **Appendages:**
    - Each thoracic segment typically bears a pair of jointed legs.
    - In most insects, the mesothorax and metathorax also bear wings.

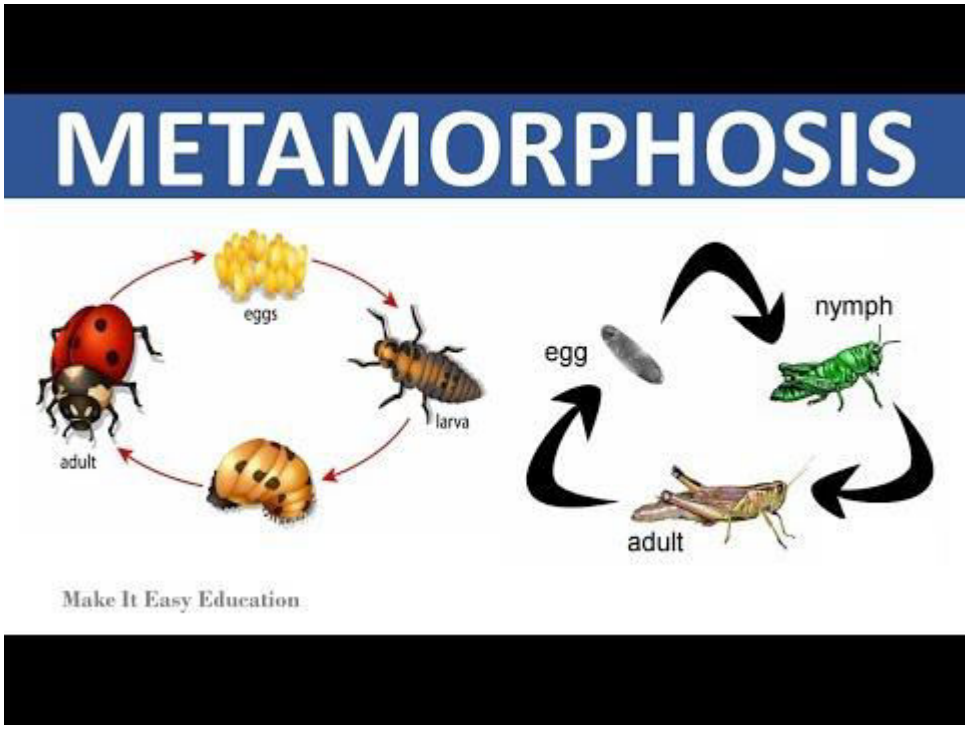
Leg Structure

1. **Coxa:**
    - The basal segment that attaches the leg to the body.
2. **Trochanter:**
    - A small, connecting segment.
3. **Femur:**
    - The largest segment of the leg.
4. **Tibia:**
    - A slender, often spined segment.
5. **Tarsus:**
    - The terminal segment, typically subdivided and ending in a pretarsus (claws).

C. Wings

- **Types and Characteristics:**
  - **Forewings:**
    - May be thickened (e.g., elytra in beetles) or narrow (e.g., tegmina in orthopterans).
  - **Hindwings:**
    - Typically membranous and used for flight.
- **Special Structures:**
  - In Diptera, the hindwings are reduced to halteres, which act as balancers during flight.

6. Metamorphosis



A. Complete Metamorphosis (Holometabolism)

- **Life Stages:**
  - Egg → Larva → Pupa → Imago (Adult).
- **Examples:**
  - Butterflies, bees, ants, flies, beetles.
- **Pupal Forms:**
  - **Obtect Pupae:**
    - Appendages are held tightly against the body (e.g., Lepidoptera).
  - **Exarate Pupae:**

        - Appendages are free and extended (e.g., Hymenoptera).
    - **Coarctate Pupae:**
        - Develop within the larval cuticle.

B. Incomplete Metamorphosis (Hemimetabolism)

- **Life Stages:**
    - Egg → Nymph → Imago.
- **Features:**
    - Nymphs resemble adults but lack fully developed wings and reproductive structures.
- **Examples:**
    - Grasshoppers, cockroaches, true bugs.

Order Siphonaptera – Fleas

General Overview:

- Members of Siphonaptera are commonly called fleas.
- They are blood-sucking ectoparasites which cause direct damage (via biting) and indirect losses (restlessness, decreased production).

Economic and Veterinary Importance:

- Flea infestation causes discomfort and stress in animals.
- Specific species like the stick-tight flea (*Echidnophaga gallinacea*) are very important in poultry, causing significant constraints.

Morphological Characteristics:

- **Body Shape:**
    - Laterally compressed body (in contrast to lice, which are dorsoventrally compressed).
- **Antennae:**
    - Typically three-segmented.
- **Eyes:**
    - May be present or absent; when present, they are simple (compound eyes are never found).
- **Legs:**
    - Three pairs of legs are present.
    - The third pair of legs is notably well developed.
- **Body Segmentation:**
    - The body is divided into three regions: head, thorax, and abdomen.
    - The abdomen is segmented into 10 segments.

        - The 9th segment bears a distinctive structure called the **sensilium** or **pygidium**.
        - Just anterior to this, setae are present and are known as antisensilial or antipygidial bristles.

- **Male Genitalia:**
    - The male flea possesses a chitinous and coiled penis (aedeagus).
- **Anal Structures:**
    - The final abdominal segment bears two hooked processes called **anal struts** used for substrate attachment or locomotion.
- **Feeding:**
    - Both sexes are blood-suckers; only adult fleas are parasitic.

Additional Morphological Details:

- Fleas are wingless.
- Prominent spines, known as combs or ctenidia, are present:
    - **Genal combs:** Located on the head.
    - **Pronotal combs:** Located on the posterior border of the first thoracic segment.

Ctenidium Distribution in Selected Species:

Flea Species	Host	Key Ctenidial Features
Ctenocephalides canis	Dog	Both genal (horizontal) and pronotal combs present.
Ctenocephalides felis	Cat	Both genal (horizontal) and pronotal combs present.
Spilopsyllus cuniculi	Rabbit	Both genal and pronotal combs present; genal comb is oblique.
Ceratophyllus gallinae	Poultry	Only pronotal comb is present.
Echidnophaga gallinacea	Poultry	Ctenidia are absent; forehead is angled anteriorly.
Pulex irritans	Human (also pig, dog, cat)	Ctenidia absent; frons (forehead) is rounded.
Tunga penetrans	Man & Pig	Only pronotal comb present.
Xenopsylla cheopis	Rat	(Key vector of plague; no additional specific notes given.)

Pathological Significance & Disease Transmission:

- **Direct Effects:**
    - Flea bites cause irritation, restlessness, and loss of body condition.

    - Initial bites cause erythema with pinpoint elevations, progressing to papules and pustules (flea bite dermatitis).
    - Flea-bite allergy is a hypersensitivity reaction to flea saliva.
        - Flea saliva contains an incomplete antigen (hapten) that binds host collagen to form a complete allergen.
        - The allergy involves both immediate and delayed hypersensitivity reactions.
- **Vector Role:**
    - *Ctenocephalides canis*, *C. felis*, and *Pulex irritans* serve as intermediate hosts for:
        - *Dipylidium caninum* (dog tapeworm)
        - *Dipetalonema reconditum* (dog filarial worm)
    - *Xenopsylla cheopis* is a vector of *Yersinia pestis* (plague) and *Rickettsia typhi* (murine/endemic typhus).
    - *Spilopsyllus cuniculi* (rabbit flea) transmits myxomatosis.

Treatment and Control:

- **Insecticides:**
    - Spray infested animals with insecticides such as deltamethrin, malathion, or lindane.
- **Systemic Treatments:**
    - Ivermectin (1 ml per 50 kg body weight, subcutaneously) can be used.
- **Physical Control:**
    - Flea collars impregnated with insecticides like methoprene are commonly used in dogs and cats.

Order Diptera – True Flies

General Overview:

- Members of Diptera are known as “true flies.”
- Their bodies are commonly divided into three main parts: head, thorax, and abdomen.
- They exhibit complete metamorphosis.

Morphological Characteristics:

- **Body Segmentation:**
  - Head, thorax (divided into prothorax, mesothorax, and metathorax), and abdomen.
  - The prothorax and metathorax are fused with the mesothorax.
- **Wings:**
  - A pair of thin, membranous wings is present on the mesothorax.
  - The hind pair of wings are modified into halteres (balancers).
- **Antennae:**
  - A single pair of antennae is present on the head.
- **Metamorphosis:**
  - Complete metamorphosis (holometabolism) is found in Diptera.

- **Larvae:**
  - Apodous (lack legs) and without a distinct head.
- **Pupa:**
  - Typically coarctate (pupal case remains attached) or obtect (appendages held tightly against the body).

Subdivision of Diptera:

Suborders:

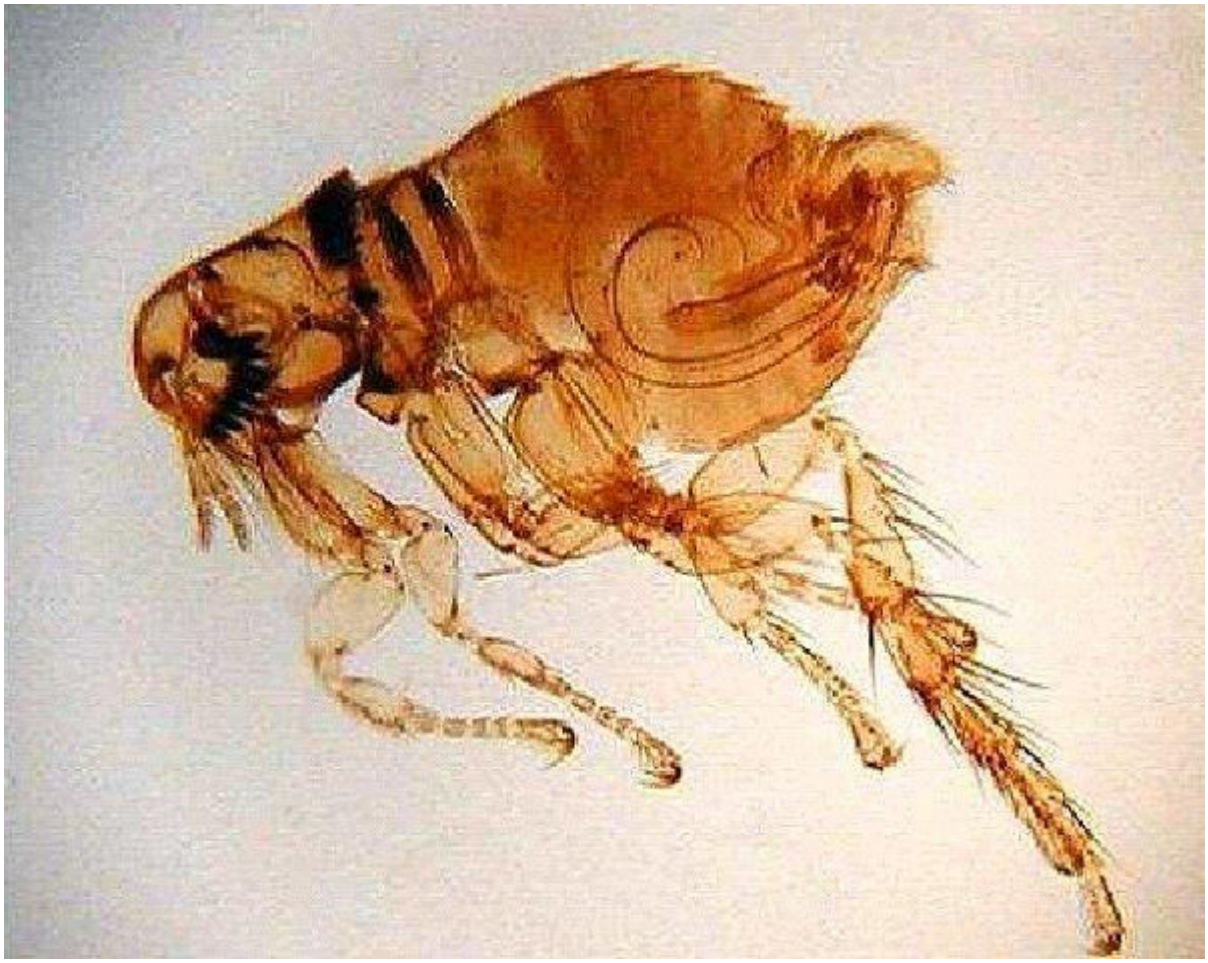
- **Brachycera:**
  - Generally robust, short antennae.
- **Nematocera:**
  - Generally slender, long antennae.
- **Cyclorrhapha:**
  - A group within Brachycera characterized by the way the pupa emerges.

Example: Family Tabanidae (Horse Flies)

- **Genera:**
  - *Tabanus*, *Haematopota*, *Chrysops*, *Pangonia*
- **Common Name:**
  - Horse fly (e.g., *Tabanus rubidus*, *Tabanus striatus*)
- **Morphology:**
  - Dark-colored and robust.
  - Large eyes: Holoptic (in males; touching) or dicoptic (in females; separated).
  - **Proboscis:**
    - Shorter than the head; adapted for blood-sucking and lapping.

    - **Antennae:**
        - Three-segmented.
- **Life Cycle:**
    - **Blood Meal:**
        - Female flies require blood meals for egg development.
    - **Eggs:**
        - Cigar-shaped eggs are laid and hatch into larvae.
    - **Larval Stage:**
        - Larvae possess “Graber’s organ” at the terminal end.
        - Larvae are predators, usually greyish white, found close to the ground.
        - They burrow 1–2 inches into the soil and form a pupal cell.
    - **Pupal Stage:**
        - The pupa is of the obtect type.
    - **Adult Emergence:**
        - The adult fly emerges from the pupa.
- **Pathological Significance:**
    - Bites cause painful, irritating lesions; affected animals become restless.
    - They play a role in transmitting various viral, bacterial, and protozoan diseases such as:
        - Equine infectious anemia
        - Bovine leukemia
        - Hog cholera
        - Anthrax
        - Anaplasmosis
        - Nagana (trypanosomiasis)
        - “Ma-de-cadras” (context-specific)
        - Trypanosomiasis

Order Siphonaptera – Fleas



General Overview

- **Common Name:** Fleas
- **Economic/Health Significance:**
    - Direct damage from flea bites.
    - Causes restlessness and loss of production in hosts.
    - *Echidnophaga gallinacea* (stick-tight flea) is especially problematic in the poultry industry.

Morphological Characteristics

- **Body Shape:**
    - Laterally compressed (flattened side-to-side) — in contrast to lice, which are dorsoventrally compressed.
- **Antennae:**
    - Typically three segmented.
- **Eyes:**
    - May be present or absent; when present, they are simple (compound eyes are never found).

- **Legs:**
    - Three pairs of legs present; the third pair is notably well developed.
- **Body Regions:**
    - Divided into head, thorax, and abdomen.
    - **Abdomen:** Consists of 10 segments.
        - The 9th segment bears a specialized structure called the **sensilium** or **pygidium**.
        - Anterior to the 9th segment are setae called **antisensilial** or **antipygidial bristles**.
- **Male Genitalia:**
    - Males possess a chitinous, coiled penis (aedeagus).
- **Terminal Structures:**
    - The last abdominal segment has two hooked processes known as **anal struts** (used for substrate attachment or locomotion).
- **Feeding:**
    - Both sexes are blood suckers, but only adult fleas are parasitic.

Additional Morphological Details

- **Surface Ornamentation:**
    - Prominent combs (ctenidia) are present:
        - **Genal combs:** Located on the head.
        - **Pronotal combs:** Located on the posterior border of the first thoracic segment.
- **Species-Specific Notes on Ctenidia:**
    - **Ctenocephalides canis (Dog Flea):**
        - Host: Dog.
        - Both genal (horizontal) and pronotal combs are present.
    - **Ctenocephalides felis (Cat Flea):**
        - Host: Cat.
        - Both genal (horizontal) and pronotal combs are present.
    - **Spilopsyllus cuniculi (Rabbit Flea):**
        - Host: Rabbit.
        - Both genal and pronotal combs are present; genal comb is oblique.
    - **Ceratophyllus gallinae (Chicken Flea):**

        - Host: Poultry.
        - Only the pronotal comb is present.
    - **Echidnophaga gallinacea (Stick-tight Flea):**
        - Host: Poultry.
        - No ctenidia; the forehead is angled anteriorly.
    - **Pulex irritans (Human Flea):**
        - Hosts: Humans, also found on pig, dog, cat, and rat.
        - Ctenidia are absent; the frons (forehead) is rounded.
    - **Tunga penetrans (Chigoe, Sand Flea):**
        - Hosts: Humans and pigs.
        - Only the pronotal comb is present.
    - **Xenopsylla cheopis (Black Rat Flea/Oriental Flea):**
        - Host: Rat.

Pathological Significance & Disease Transmission

- **Direct Effects:**
    - Bites cause irritation and discomfort; animals may become restless.
    - First-time bites cause erythema with pinpoint elevations, progressing to papules and pustules (flea bite dermatitis).
    - Flea-bite allergy: Flea saliva contains an incomplete antigen (hapten) that binds host collagen to form a complete allergen, triggering immediate and delayed hypersensitivity reactions.
- **Vector Role:**
    - *C. canis, C. felis,* and *Pulex irritans* can serve as intermediate hosts for:
        - *Dipylidium caninum* (dog tapeworm)
        - *Dipetalonema reconditum* (dog filarial worm)
    - *Xenopsylla cheopis* is a vector of *Yersinia pestis* (plague) and *Rickettsia typhi* (murine/endemic typhus).
    - *Spilopsyllus cuniculi* on rabbits transmits myxomatosis.

Treatment & Control

- **Topical and Systemic Insecticides:**
    - Spray animals with deltamethrin, malathion, or lindane.
- **Systemic Therapy:**
    - Ivermectin (1 ml per 50 kg body weight, administered subcutaneously).

- **Physical Control:**
    - Flea collars impregnated with insecticides (e.g., methoprene) are effective in controlling fleas on dogs and cats.

III. Family Ceratopogonidae – Biting Midges

General Overview

- **Common Names:**
    - Biting midges, no-see-ums, and punkies.
    - "Punkies" derives from the word *punkwa* ("ash-like") due to the burning sensation of their bite.
    - "No-see-ums" reflects their extremely small size; they often go unnoticed.
- **Significance:**
    - Important vectors for transmission of filarial worms and other pathogens.

Genera & Species

- **Key Genera:**
    - *Culicoides* and *Austroconops*.
- **Example Species:**
    - *Culicoides puncticolis*.

Morphological Characteristics

- **Size:**
    - Very small (0–2.5 cm in length as stated; note: typically they are measured in millimeters).
- **Thorax:**
    - Characteristically humped with a distinct humeral pit.
- **Wings:**
    - Display a dark and light color combination.
- **Body:**
    - Thoracic and abdominal segments are similar in size.
    - Body is generally hairless.
- **Abdomen:**
    - Divided into 10 segments; the 9th segment bears a dorsal plate (sensilium/pygidium) with surrounding antisensilial (antipygidial) bristles.
- **Pupa:**
    - Brown-colored with respiratory horns.

Life Cycle

- **Eggs:**
  - Characteristically banana-shaped.
- **Larva:**
  - Typical nematoceran larva with:
    - A sclerotized head.
    - 11 body segments.
    - No appendages.
    - Movement by oscillatory (swimming) motions.
  - Larvae feed on nematodes and other small predators.
  - Four molting events (ecdyses) occur during the larval stage.
- **Pupal Stage:**
  - Pupa is of the obtect type and possesses prothoracic horns.
- **Adult (Imago):**
  - Emerges from the pupa.

Disease and Vector Role

- **Pathogen Transmission:**
  - Vectors for *Dipetalonema perstans*, *Onchocerca gibsoni*, and *Haemoproteus meleagridis*.
- **Allergic Reactions:**
  - Culicoides robertsi can cause allergic dermatitis in horses ("sweet itch," "sweat itch," or "Queensland itch").

IV. Family Simuliidae – Black Flies

General Overview

- **Common Names:**
  - Black flies, turkey gnats, buffalo gnats.
- **Vector Role:**
  - Vectors for diseases such as Leucocytozoonosis, Eastern Equine Encephalitis (EEE), Vesicular Stomatitis, and Onchocerca.

Species Examples

- *Simulium indicum*, *Simulium ornatum*.

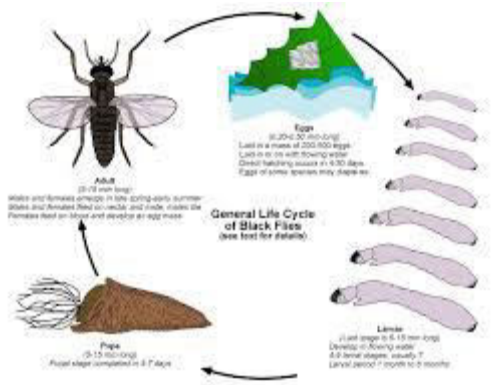
Morphological Characteristics

- **Body:**

    - Small, dark, robust, and stout-bodied.
    - Size larger than Ceratopogonidae.
- **Eyes:**
    - In females: Dichoptic (well separated).
- **Antennae:**
    - Segments are very characteristic, appearing globular and are 11-segmented.
- **Wings:**
    - Short but broad.
    - No scales or hairs (although a few bristles may be present).
- **Body Hairs:**
    - Characteristic golden and silver hairs are present.
- **Larvae:**
    - Possess prolegs.
- **Pupae:**
    - Boot-shaped or slipper-shaped.
    - Possess paired gills.

Life Cycle

1. **Egg Laying:**
    - Female flies lay eggs on objects in or near running water.
2. **Larval Stage:**
    - Larvae hatch and are hour-glass shaped.
    - Identifying features include an eye spot, anal gills, and a posterior sucker.
    - Presence of prolegs is key; these are surrounded by a circlet of hooks.
    - An anterior hairy brush-like structure is also present.
3. **Pupal Stage:**
    - Larvae spin a cocoon; the pupa is divided into two parts: cephalothorax and abdomen.



V. Family Psychodidae – Sand Flies and Owl Midges

General Overview

- **Common Names:**
  - Sand flies, owl midges.
- **Vector Role:**
  - Vectors of important protozoan parasites such as *Leishmania*.

Genera & Species

- **Genus:** *Phlebotomus*
- **Species Examples:**
  - *Phlebotomus papatasi, P. argentipes, P. sergenti, P. major, P. logipalpalis, P. orientalis*

Morphological Characteristics

- **Size and Appearance:**
  - Small-sized, brownish flies with an elongated, shiny, and narrow body.
- **Antennae and Legs:**
  - Noticeably long; antennae are 16-segmented.
- **Wings:**
  - Lanceolate (spear-shaped) wings that remain erected on the body.
- **Surface Covering:**
  - Both body and wings are covered with numerous hairs.
  - The flies are strongly humped.
- **Mouthparts:**
  - Contain several knife-like setae.
- **Egg Laying and Reproduction:**

- Females lay eggs in moist crevices or cracks.
- They may be **autogenous** (no blood meal required for the first gonotrophic cycle) or **anautogenous** (blood meal required for subsequent cycles).

- **Life Cycle:**
  - **Egg Stage:**
    - Eggs are laid in moist habitats.
  - **Larval Stage:**
    - Larvae are grayish-white with a dark head; elongated and without legs (apodous).
    - Undergo four larval instars.
  - **Pupal Stage:**
    - Pupa is of the exarate type (appendages free).

VI. Summary

- **Order Siphonaptera (Fleas):**
  - Wingless, laterally compressed ectoparasites with three pairs of legs, distinctive combs, and specialized abdominal structures; important for causing irritation and serving as vectors for various pathogens.
- **Order Diptera (True Flies):**
  - Body divided into head, thorax, and abdomen; possess a pair of membranous wings (with halteres in Diptera) and undergo complete metamorphosis.
  - **Family Tabanidae (Horse Flies):**
    - Robust flies with blood-sucking mouthparts, large eyes, and a larval stage characterized by Graber's organ.
  - **Family Ceratopogonidae (Biting Midges):**
    - Tiny flies (no-see-ums/punkies) with laterally compressed bodies, characteristic humeral pits, and distinctive wing patterns; vectors for filarial parasites and cause allergic dermatitis.
  - **Family Simuliidae (Black Flies):**
    - Stout, dark flies with dichoptic eyes, globular antenna segments, and distinctive larval and pupal features; important vectors of several diseases.
  - **Family Psychodidae (Sand Flies/Owl Midges):**
    - Small, elongated, hairy flies with long antennae and lanceolate wings; important vectors for *Leishmania* spp.

Arthropoda and Insecta

- **Phylum Arthropoda:**

- Key features: Jointed appendages ("arthro" = joint; "podos" = foot), hard chitinous exoskeleton, segmented (metameric) body.
- Major groups include Insecta, Arachnida, Myriapoda, Crustacea, and others (e.g., Pentastomida).

- **Class Insecta:**
  - **Subclasses:**
    - **Pterygota (Winged Insects):**
      - *Endopterygota (Holometabolous):* Wings develop internally; orders include Siphonaptera (fleas), Diptera (flies), Hymenoptera (bees, ants, wasps), Coleoptera (beetles), etc.
      - *Exopterygota (Hemimetabolous):* Wings develop externally; orders include Mallophaga (biting lice), Siphunculata (sucking lice), Orthoptera (grasshoppers, cockroaches), Hemiptera (bugs), Odonata (dragonflies), etc.
    - **Apterygota:** Wingless insects.

II. Order Siphonaptera – Fleas

General Characteristics

- Fleas are wingless, laterally compressed insects that are blood-sucking ectoparasites.
- They cause irritation and restlessness in hosts, leading to indirect production losses.
- **Economic Importance:**
  - *Echidnophaga gallinacea* (stick-tight flea) severely affects the poultry industry.

Morphology

- **Body Structure:**
  - Laterally compressed (flattened from side-to-side); contrast with dorsoventrally compressed lice.
  - Divided into three regions: head, thorax, and abdomen.
- **Antennae:**
  - Typically three segmented.
- **Eyes:**
  - Simple; may be present or absent (compound eyes are never found).
- **Legs:**
  - Three pairs; the third pair is especially well developed.
- **Abdomen:**
  - Consists of 10 segments.
  - The 9th segment bears the **sensilium/pygidium**.

- Setae anterior to the 9th segment are called **antisensilial/antipygidial bristles**.

- **Male Genitalia:**
  - Chitinous, coiled penis (aedeagus).
- **Terminal Structures:**
  - The last segment has two hooked processes (anal struts) for attachment or locomotion.
- **Feeding:**
  - Both sexes are blood suckers; only adults are parasitic.
- **Surface Ornamentation – Combs (Ctenidia):**
  - **Genal combs:** On the head.
  - **Pronotal combs:** On the posterior border of the first thoracic segment.

Species Examples & Key Features

Species	Host	Ctenidial Characteristics
Ctenocephalides canis	Dog	Both genal (horizontal) and pronotal combs present.
Ctenocephalides felis	Cat	Both genal (horizontal) and pronotal combs present.
Spilopsyllus cuniculi	Rabbit	Both combs present; genal comb is oblique.
Ceratophyllus gallinae	Poultry	Only pronotal comb present.
Echidnophaga gallinacea	Poultry	No ctenidia; forehead is angled anteriorly.
Pulex irritans	Human (also pig, dog, cat, rat)	Ctenidia absent; frons rounded.
Tunga penetrans	Man & Pig	Only pronotal comb present.
Xenopsylla cheopis	Rat	(Key vector of plague; additional details not provided.)

Pathological Significance & Disease Transmission

- **Direct Effects:**
  - Bites cause immediate irritation, erythema, papules, and potentially flea bite dermatitis.
  - Flea saliva contains a hapten that binds with host collagen, forming complete allergens and causing both immediate and delayed hypersensitivity.
- **Vector Role:**
  - *C. canis, C. felis,* and *Pulex irritans* can transmit:
    - *Dipylidium caninum* (dog tapeworm)

        - *Dipetalonema reconditum* (dog filarial worm)
    - *Xenopsylla cheopis* transmits *Yersinia pestis* (plague) and *Rickettsia typhi* (typhus).
    - *Spilopsyllus cuniculi* on rabbits can transmit myxomatosis.

Control Methods

- **Chemical Control:**
    - Insecticides such as deltamethrin, malathion, and lindane applied by spraying on animals and in their housing.
- **Systemic Control:**
    - Ivermectin (1 ml/50 kg body weight, subcutaneously).
- **Physical Control:**
    - Flea collars impregnated with insecticides (e.g., methoprene).

III. Order Diptera – True Flies

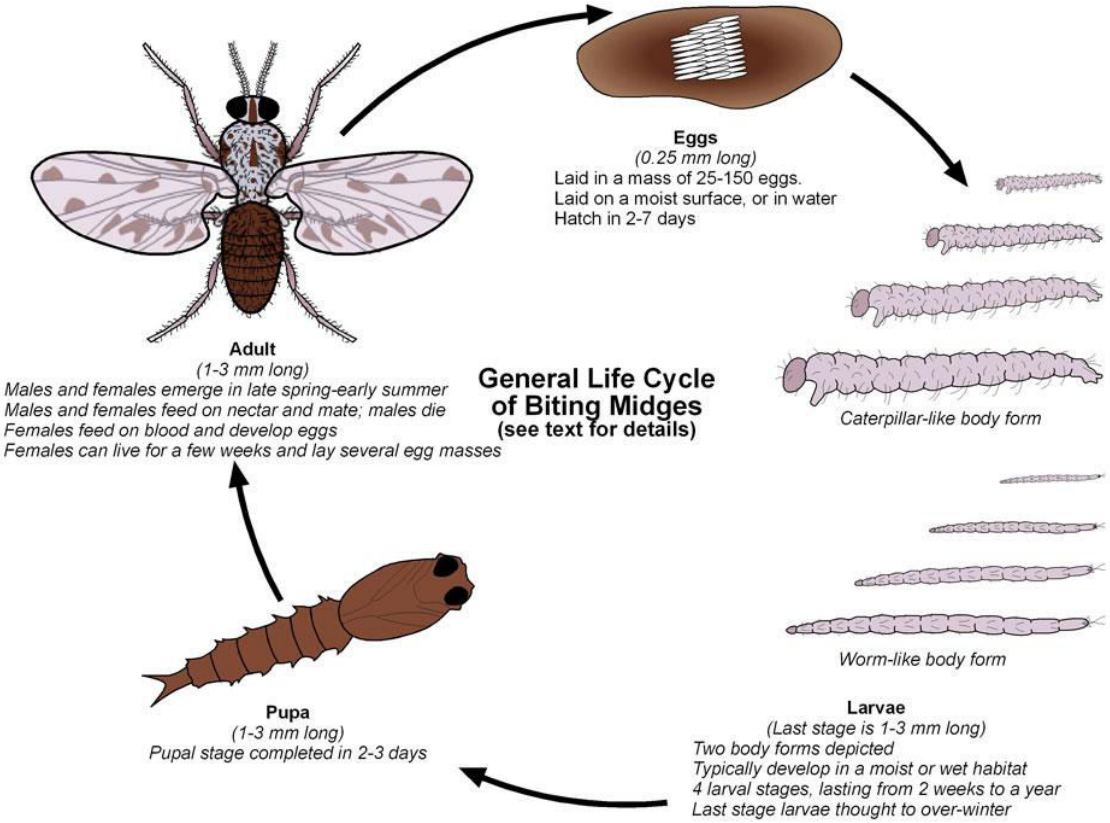
General Characteristics

- **Body Structure:**
    - Divided into head, thorax, and abdomen.
    - Thorax is subdivided into prothorax, mesothorax, and metathorax; the latter two typically bear wings.
- **Wings:**
    - A single pair of membranous wings arises from the mesothorax.
    - Hind wings are modified into halteres (balancers).
- **Antennae:**
    - One pair is present.
- **Metamorphosis:**
    - Undergo complete metamorphosis (holometabolism): egg → larva → pupa → adult.
    - Larvae are apodous (no legs) with poorly developed heads; pupae are coarctate or obtect.

Suborders of Diptera

- **Brachycera:**
    - Generally robust flies with short antennae.
- **Nematocera:**
    - Generally slender flies with long, multi-segmented antennae.
- **Cyclorrhapha:**
    - A subgroup within Brachycera with specific pupal emergence characteristics.

IV. Family Ceratopogonidae – Biting Midges (No-see-ums, Punkies)



General Overview

- **Common Names:**
  - Biting midges, no-see-ums, punkies.
  - "Punkies" is derived from *punkwa* (ash-like) due to the burning sensation of their bite.
  - "No-see-ums" refers to their extremely small size.
- **Significance:**
  - Vectors for important filarial worms.

Key Genera and Characteristics

- **Genera:** *Culicoides* and *Austroconops*.
- **Example Species:** *Culicoides puncticulis*.

Morphological Features

- **Size:**
  - Very small (approximately 0–2.5 cm; typically measured in millimeters).

- **Thorax:**
    - Characteristically humped with a distinct humeral pit.
- **Wings:**
    - Show a distinct pattern of dark and light areas.
- **Body:**
    - Thoracic and abdominal segments are of similar size; adult body is hairless.
- **Pupa:**
    - Brown in color, bearing respiratory horns.

Life Cycle

- **Eggs:**
    - Banana-shaped.
- **Larva:**
    - Typical nematoceran type with a sclerotized head, 11 body segments, no appendages, and moves by oscillatory (swimming) movements.
    - Larvae feed on nematodes and other small predators.
    - Undergo four molts (ecdyses) before pupation.
- **Pupa:**
    - Obtect type, with prothoracic horns.
- **Adult:**
    - Emerges from the pupa.

Vector and Allergic Roles

- Vectors for pathogens such as *Dipetalonema perstans*, *Onchocerca gibsoni*, and *Haemoproteus meleagridis*.
- Can cause allergic dermatitis in horses (known as “sweet itch,” “sweat itch,” or “Queensland itch”).