MEDICAL PARASITOLOGY

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Chapter 15
Medical Parasitology. General understandings

Parasitology is the study of parasites, their hosts, and the relationship between them. *Medical Parasitology* focuses on parasites which cause diseases in humans.

Awareness and understanding about medically important parasites is necessary for proper diagnosis, prevention and treatment of parasitic diseases. The most important element in diagnosing a parasitic infection is the knowledge of the biology, or life cycle, of the parasites. Medical parasitology traditionally has included the study of three major groups of animals:

1. Parasitic protozoa (protists).
2. Parasitic worms (helminthes).
3. Arthropods that directly cause disease or act as transmitters of various pathogens.

Parasitism is a form of association between organisms of different species known as ***symbiosis***. S*ymbiosis* means literally "living together". Symbiosis can be between any plant, animal, or protist that is intimately associated with another organism of a different species. The most common types of symbiosis are *commensalism, mutualism* and *parasitism*.

1. Commensalism involves one-way benefit, but no harm is exerted in either direction. For example, mouth amoeba *Entamoeba gingivalis*, uses human for habitat (mouth cavity) and for food source without harming the host organism.

2. Mutualism is a highly interdependent association, in which both partners benefit from the relationship: two-way (mutual) benefit and no harm. Each member depends upon the other. For example, in humans' large intestine the bacterium *Escherichia coli* produces the complex of vitamin B and suppresses pathogenic fungi, bacteria, while sheltering and getting nutrients in the intestine.

3. Parasitism is an intimate relationship between two organisms in which one (the parasite) lives at the expense of the other (host). This implies that one of the partners benefits, the other is harmed but usually not killed.

Classification of Parasites

Basic types of parasites are classified in regard to:

1. Localisation site:

a) Ectoparasite - lives on surface of the host (for example, ticks, lice, fleas).

b) Endoparasite - lives within the host, in parenchymatous or luminary visceral organs, blood or lymph (e.g., leishmania donovani in visceral organs, malarial plasmodium in blood, round worms in intestines).

2. Parasitic mode of living during the life cycle of the parasite:

a) Obligate, facultative, accidental.

b) Permanent and temporary.

Obligate parasite, one that is physiologically and metabolically dependent on the host. It must compulsorily parasitize another organism (such as all viruses, dysenteric ameoba, malarial plasmodium, most of the helminth parasites).

Facultative parasite, an organism which may be parasitic upon another but is capable of also independent free-living existence. Facultative parasites such as opportunistic ameoba *(Naegleria fowleri* and *Acanthamoeba)*, some parasitic round worms (e.g. *Strongyloides stercoralis*) have completely free living lifecycles in addition to parasitic ones. The parasitic

lifestyle is only taken up opportunistically, and a relationship with a host is established if the opportunity presents itself.

Accidental parasite is an organism parasitizing an animal other than the usual (non-specific) host. For example, the dog or cat *Ascaris* can accidentally affect humans but they do not complete their whole life cycle (reproduction) as they would in the animal species who is the common (specific) host.

Permanent parasite lives its entire life or certain stage of its cycle (sexual or asexual) within or on a host. All the Parasitic protists and helminthes of human are endoparasites.

Temporary parasite contacts its host only for feeding and then leaves. For example, ticks, mites, mosquitoes. All temporary parasites are ectoparasites as well, meanwhile the lice are permanent ectoparasites.

Parasitic Life Cycles. Hosts. Vectors

The host is a specific organism species to where the parasite can penetrate and reproduce to complete the life cycle. Life cycle considers specific stages of parasite developed by specific type of reproduction (sexual/asexual).

Parasitic organisms may have either simple or complicated lifecycles. Some species of parasites (e.g. human Ascaris) develop in just a single host to complete their life cycle, and other species require more than one type of host (alternation of definitive and intermediate hosts) during life cycle. The terms used to describe the hosts harboring different stages in these lifecycles are however the same.

Host organisms

1. Definitive host – where parasite reproduces sexually or the adult stage of parasite (helminth) is present.

2. Intermediate host – required by parasite to complete asexual stage of its life cycle, the larval stage is present in it. For example, the beef is intermediate host for beef tapeworm (larvae develop), and human is definitive host for that helminth (adults develop).

3. Accidental host - An uncommon or rare host to a pathogenic microorganism. For example a round worm of dogs *Toxocara canis* (dog Ascaris) may accidentally infect humans that are non-specific hosts for that parasite.

4. Reservoir host - animals that serve as additional source of infection to humans. This host reserves and accumulates the parasite, and is a source for its spreading. Sometimes the "residence" of parasite can be asymptomatic for the host (asymptomatic carrier), but occasionally fully viable infections may develop in a reservoir host similarly to human. A more accurate term for that host would be an *animal host alternative to human*. That animal should be similarly infected (stage of development of parasite) and affected (symptoms) as the human host. An example of parasite with anthropozoonotic infection is *Schistosoma japonicum*. This parasite, as well as infecting man, can also infect other mammals as definitive hosts, including rodents, cats, dogs, and a wide range of domesticated mammals.

Vectors

Often the parasites cannot be transmitted from one host to another unless there is an organism that actively transports them. Arthropods (insects, ticks) that transfer the parasitic agents from one host to another are called **vectors**. Vectors are *biological* (*specific*) and *mechanical*. The biological vector is a blood sucking insect or tick that is essential in the life

cycle of parasite. It can be a definitive host (e.g. *Anopheles* mosquito for plasmodium) or an intermediate host (like the tse-tse fly for *Trypanosoma brucei*). Mechanical vector is unessential in life cycle of the parasite, and the insect (non-bloodsucking) mechanically transfers it, e.g. flies can transport cysts of amoeba, or eggs of Ascaris, etc.

Routes of Penetration of Parasites

1. Respiratory route. Pathogens often ***release*** from infected host through coughing or sneezing. These agents ***enter*** respiratory tract of new host by being inhaled. For example, pneumonia may be caused by protist pathogens like *Streptococcus* bacteria, influenza virus, corona virus, by mycoplasma.

2. Gastrointestinal or oral route (*per os*). Pathogens often ***eliminate*** from infected host through infected feces and ***enter*** the gastrointestinal tract of new host by being ingested through mouth (*per os*) via contaminated food or water (that is why sometimes referred to as oral-fecal rout). For example, hepatitis A, amoebic and bacterial dysentery, lambliosis, ascaridosis,.

3. Sexual contact (sexually transmitted diseases, **STDs**). Pathogens ***release*** from infected host in fluid from urogenital tract, and ***enter*** the new host through sexual contact. E.g., *Trichomonas vaginalis*. From agents other than protists, HIV and hepatitis B virus (HBV), genital herpes virus, gonorrhea and syphilis bacteria are transmitted sexually.

4. Dermal or percutaneous route (vector-borne and non-transmissive).

a) transmission of a parasite when biting and feeding on blood, for example malarial plasmodium inoculated during mosquito bite from its saliva.
b) exposition of parasitic agents to a host through excretions of the vector. E.g., during blood meal the *reduviid* bugs (vectors of American sleeping sickness or Chagas' disease) defecate on skin following the blood meal. The excreta cause itching, and the agents of *Trypanosoma cruzi* penetrate to blood when scratching.
c) infection by active penetration of the parasite through skin (e.g., cercarial larvae of *Schistosome* blood flukes can penetrate the skin of human when swimming; they release hydrolytic enzymes, which provide lysis of skin).

5. Transplacental route. It is also known as vertical or mother-child transmission. Transplacental transmission is a common way for *Toxoplasma gondii*, which can be transmitted from infected pregnant woman to her fetus through placenta.

6. Transovarial transmission. This refers to hard ticks (Ixodide ticks), the females transmitting parasites to next generation through their infected ova, which may develop all their stages (egg, larva, nymph, adult) parasitizing only on one host organism, and that is why the females transmit the parasite agent to their generations through infected ova. For example, some hard ticks transmit the Russian spring-summer encephalitis virus.

Pathogenic Effects of Parasites on the Host

The pathogenic effects of parasites often depend on multiple factors coming from environment (e.g., stress, nourishment), hosts (immunity) and parasites (tissue-specificity, pathogenicity). Various parasite species do not cause any pathogenic effects after penetration to the host. This host organism does not manifest clinical symptoms and is known as ***asymptomatic carrier*** who is an important source of infection for others. Expression and

severity of the symptoms may depend on various factors related to the host (immunity, age, gender), the parasite (toxicity, habitat, infection dose) and the environment (climate, nourishment, stress).

Here are the most common pathogenic mechanisms that are exerted by most parasites:

1. Mechanical effect. For example, the hydatid cyst of *Echinococcus granulosus* mechanically **presses** the parenchymal tissues where it localizes (liver, lungs, brain). Ascaris can **block** the bile duct, large helminthes like *Diphyllobothrium latum*, can block the intestinal lumen leading to intestinal obstruction (***ileus***).

2. Toxic effect. Parasites can release or excrete toxic chemicals that can have deleterious effects on host. E.g., malarial plasmodium ruptures erythrocytes, and the merozoites along with destructed particles of RBCs release into blood circulation and affects the CNS causing high temperature, headache, insomnia, malaise suppression of the appetite (anorexia). The toxins of many parasites can cause nausea and vomiting.

3. Nutritional deprivation. The parasites that especially are larger in sizes (helminthes), deprive the host from nutrients when feeding through whole their surface. They cause undernourishment, sometimes physical exhaustion. The helminthes utilize also essential vitamins, and hypovitaminosis develops (e.g., *Diphyllobothrium latum* uses the vit. B_{12} from intestines).

4. Anemia. The mechanisms of its development can vary. For example, *Entamoeba histolytica* causes **haemorrhagic anaemia** (rupture of intestinal wall vessels and bleeding), *Leishmania donovani* **suppresses blood formation** (hemopoiesis), *Diphyllobothrium latum* develops vit. B_{12} deficiency anemia, which is also related to impaired hemopoiesis (vit. B_{12} is a hemopoietic factor), malarial *Plasmodium* ruptures RBCs and causes **hemolytic anemia**.

5. Allergic reactions. Many parasites can cause allergic reactions through their metabolites, which are strong allergens. The allergic effects are particularly expressed in parasitic diseases where the agent passes a migration during its development in human organism. Among them are *Ascaris lumbricoides*, lung fluke (*Paragonimus westermani*), blood flukes (*Schistosomes*), *Echinococcus granulosus*. The allergic reactions clinically manifest as allergic skin rash. The blood examination reveals eosinophilia (high count of certain type of leukocytes – eosinophils), Eosinophils contain granules of histamine that release into blood upon allergic reaction.

6. Immune depression. Suppression of immune responses of the host that can decrease the resistance also to other pathogenic agents. For example, *Leishmania donovani* penetrates macrophage cells and suppresses cellular immunity, in addition it affects also bone marrow and causes leukopenia (decreased synthesis of leukocytes, which are immune-competent cells).

Adaptations of Parasites to Parasitism

Parasitic adaptations are responses to features in the parasite's environment, and this environment is the body of another organism, the host. This seems to be a difficult environment to invade but those organisms that have done so have often been very successful both in terms of numbers of individuals and numbers of species. Blood and tissues seem to be harder to invade than the gut, as is shown by the smaller number of blood and tissue parasites. This is probably in part related to the difficulties of getting eggs to the outside from sites within the host. Parasite adaptations help in staying within the host (***morphological adaptations***) and spreading between hosts (***life cycle adaptations***).

Morphological Adaptations

1. Size: many parasites are large compared with their free-living relatives. This could be related to increased egg production.

2. Shape: most parasites are dorso-ventrally flattened and this is related to the need to cling on to the host. Fleas are laterally flattened and rely on escape through the hairs.

3. Loss of locomotory organs in multicellular parasites, particularly in endoparasites.

4. Reduction of other organs: for example CNS and sense organs in many endoparasites are very primitive, degradation of gut and absorption of nutrients through the whole body surface (tapeworms). Helminthes tend either to loose their gut and absorb nutrients through their teguments, or else retain their gut and have a thick resistant cuticle (like round worms, e.g. *Ascaris*).

5. Organs of attachment. There are two types of attachment organs, the development of either hooks or suckers. Suckers occur in such widely divergent groups as fluke worms (trematodes), tapeworms (cestodes), parasitic crustaceans. Specific attachment modifications are the *bothria* – sucking grooves in *Diphyllobothrium latum*.

6. Prolific reproductive organs. In many parasites there is a tremendous elaboration of the reproductive system, associated with increased gamete production leading to high fertility. Parasites usually produce more eggs and sperm than their free-living relatives. Other adaptations, which increase egg production, are hermaphroditism (every individual produces eggs) and parthenogenesis at different stages.

Life Cycle Adaptations

1. **Development with alternation of hosts:** infection of definitive and intermediate hosts in many parasites. This has the following advantages:
   a) it increases range of the parasite in space and time. That is, infection of more than one host can increase the geographical range of a parasite, particularly if one host is terrestrial and the other aquatic. By infecting more than one host species the parasite can survive periods when one host is temporarily scarce.
   b) an intermediate host can direct the parasite towards its definitive host since the intermediate host is frequently part of the final host's food chain or else closely related ecologically.
2. **Behavioral changes in hosts.** These include:
   a) Behavioral responses of the host mediated by the parasite. For example, the roundworm *Enterobius vermicularis* (pin worm) causes intense itching of perianal skin when crawling out from anus for oviposition, and the eggs pass under finger nails when scratching and are again a source for re-infection.
   b) Changing the behaviour of the infected intermediate host to increase the chances of them being eaten by the definitive host (e.g., the infected ants that are the second intermediate host of *Dicrocoeleum lanceatum*, change their behaviour, by running up, and attaching themselves, by their jaws, to the tops of blades of grass, where they can be accidentally ingested as their herbivorous definitive hosts graze.
3. **Synchronization (*syn=together, chronos=time*) of life cycles.** There are many ways in which the life cycle of a parasite becomes integrated (occurs simultaneously) with that of its host. They fall into two broad mechanisms:

a. The oviposition of blood flukes (*Schistosomes*) occurs usually at hot daytime, when there is higher probability for swimming of humans in hot waters, so the eggs can be liberated from definitive host at this time and pass to the intermediate host, fresh water snail.
b. Life cycle of some vectors matches with the periodicity of microfilaria (larvae of filarial roundworms), when they can be found in peripheral blood and be available for the insect vector when biting the host (for example, the black fly usually bites at daytime, when the microfilaria of *Loa loa* are found in the blood).

Host Response to Parasite

When two organisms live in close association, each responds to the activities of the other. This is especially true for host-parasite relationship. The responses of vertebrate host to the parasite express in two ways: non-specific and specific. First, there are non-specific responses: when these reactions are not dependent on specific recognition of the "non-self" organism (molecule). It is the first line of defense in most vertebrates. The second type of response is a specific recognition of foreign or "non-self" molecules.

Non-specific responses. The non-specific responses involve **phagocytosis, inflammation** and **abnormal tissue growth (*hyperplasia* and *neoplasia*).**

A primary defense against small foreign invaders (like bacteria or parasitic protists) is the ***phagocytosis***, the process of ingesting foreign particles. Monocytes, macrophages and phagocytes in the liver and spleen (reticuloendothelial cells) are involved in phagocytosis. The phagocytosis is considered as a c*ell-mediated immune response.* If the pathogen is rather large, it is not phagocytosis, and an ***inflammation*** takes place. Inflammation is characterized by redness, heat, swelling and pain. Another non-specific response to parasites is abnormal growth of tissue or ***hyperplasia***, in which the parasite stimulates the host to produce an increased number of cells. For example, when the liver fluke *Fasciola hepatica,* reaches a bile duct, it induces the enlargement of the epithelium of the bile ducts. Sometimes a connective tissue is formed around the parasites to limit its further spreading (e.g., in echinococcosis the hydatid cyst larva of echinococcus is surrounded by connective tissue capsule within the affected organs).

Neoplasia (cancer) is also an abnormal growth response leading to formation of atypical tissue. There are a number of parasites that cause malignant malformations of different organs. For example, the urinary schistosomosis develops high risk for urinary bladder cancer.

Specific response. The surfaces of parasites have characteristic proteins and polysaccharides, which are recognized by host as "non-self". In other instances parasites secrete specific antigens, which trigger a specific immune response through formation of antibodies or immunoglobulins that provide *humoral immune response*.

Countermeasures by Parasites to Host Immune Response

Vertebrates react to the presence of foreign material in their tissues by the production of a humoral and cell-mediated response, so any parasite must have some mechanism for avoiding or mitigating the host's immune response.

The strategies against host immune response may differ in Protozoa and helminthes, however some of them may overlap.

Protozoan immune evasion mechanisms

1. Intracellular location. By replicating inside a host cell some protist parasites avoid the immune response, since the parasite inside is not recognized by T-lymphocytes. For example, plasmodium lives in RBCs, *Leishmania* parasites and *Trypanosoma cruzi* live inside the cells of reticuloendothelial system (e.g., macrophages, monocytes).

2. Antigenic variation. Trypanosomes have surface antigens that trigger antibody production in the host. These parasites may periodically vary their surface antigens, and while the host produces antibodies to the current antigens, the trypanosomes already switch to express a new antigen. The parasites expressing the new antigens (variant surface glycoproteins – VSG) will escape antibody detection and replicate to continue the infection. This cycling continues throughout the infection, and the parasite can thus survive for months or years.

3. Different antigens produced by different morphological stages of parasite. For example, malarial *Plasmodiuim* has trophozoite, schizont, merozoite, gametocyte, all of which express individual antigens.

4. Immunosuppression - manipulation of the immune response e.g. *Leishmania* produce anti-oxidase enzymes, which suppress infected macrophage lysosomes.

Helminth immune evasion mechanisms in the vertebrate host.

1. Large size and anatomical seclusion. The immune system finds it difficult to eliminate the larger parasites, usually helminthes. The primary response is inflammation to initiate expulsion but often worms are ignored. E.g., *Ascaris* living in the lumen of small intestine provokes little or no immune response.

2. Antigenic masking (coating with host proteins). *Schistosomes* take up host blood proteins (e.g., blood group antigens), therefore, the worms are seen as "self". Tegument (external non-cellular layer) of cestode and trematode worms, is able to adsorb host components, e.g. RBC antigens, thus giving the worm the immunological appearance of host tissue.

3. Molecular mimicry. The parasite is able to mimic a host protein structure. For example, *Schistosomes* have an E-selectin molecule that may help in adhesion or invasion to vein vessels.

4. Immunosuppression. Sometimes high burdens of roundworms may be carried with no prominent sign of infection. It is considered that parasite-secreted products include anti-inflammatory agents which act to suppress the immune-competent leukocytes.

5. Production of parasite enzymes. Proteolytic enzymes released by helminthes can degrade human's digestive enzymes. Such proteolytic activity is common for *Schistosoma* and *Fasciola.*

Classification of Parasitic Diseases

Parasitic diseases are named after the parasite agent causing it plus a suffix "-*osis*" or "-*asis*". Basically parasitic diseases are classified in regard to:

*1. **Epidemiology*** (epidemiology literally means "as it falls upon the people"). Epidemiology is the study of factors affecting transmission and distribution of disease within populations. It considers the ecology of disease, i.e., all aspects of the pathogen, host(s), environment, social conditions that contribute to or influence the maintenance of a disease among given population.

a) Endemic - A disease pathogen is present in an area and is naturally expected to be there.

b) Non-endemic – diseases that are found worldwide.

c) Epidemic - Disease that affects a large number of humans and spreads rapidly in a certain zone. The presence of a disease is at levels higher from normally expected one.

d) Pandemic - An epidemic that spreads worldwide.

2. Origin of the parasitic agent. Infectious diseases are caused by transmittable parasitic agents including bacteria, viruses, fungi, protozoa and helminthes. They are classified into 2 groups, based on whether parasite does reproduce in the host or no:

a) infection

b) infestation.

Infection usually implies reproduction of the agent resulting in a growing number of pathogens (usually viruses, bacteria, fungi, protozoa).

Infestation is characterized by a constant number of pathogens (usually helminthes). They may reproduce but not increase in number. The severity of disease often depends on infection dose.

3. Host organisms infected by the parasite:

Anthroponosis (*Anthropos=human, nosos=disease; Greek*) – diseases that is common only for humans (e.g., amoebic dysentery, malaria).

Zoonosis – disease that is common only for animals (e.g., bird malaria).

Anthropozoonosis or zooanthroponosis – diseases common for both humans and animals (e.g., trypanosomosis, balantidiasis).

4. Mode of transmission:

a) *non-transmissive* diseases are spread without a contact with a vector organism, e.g. amoebic dysentery, lambliosis, etc.

b) *transmissive* diseases are transferred through a biological vector, which carries the pathogenic agent. There are obligatorily transmissive and facultative transmissive diseases. The diseases that can be transferred only via vector are called *obligatory transmissive* (e.g., malaria is transmitted only by *Anopheline* mosquitoes, leishmaniosis is transmitted through sand flies). While, facultative transmissive diseases can transmit with or without the help of a vector, for example, plague is a contagious bacterial disease that can infect either through flea bite affected from rodents (transmissive rout), or through direct contact with rodents, their affected fur or patients (non-transmissive rout).

5. From ecological aspect a special group of parasitic diseases is defined. These are called ***natural endemic*** diseases. As proposed by Russian epidemiologist *Pavlovsky* these diseases are characterised by following features:

a) they exist in nature independently of human,
b) there is a reservoir of infection, which are wild animals,
c) along with pathogenic agent a vector is required for transmission of the disease,
d) they are prevalent only in specific ecosystems with characteristic ecologic and geographic conditions. For example, Rhodesian sleeping sickness, which is caused by *Trypanosoma brucei rhodesiense,* is spread only in East and Central Africa, the reservoir hosts are the bushbuck antelopes and the specific vector is *tse-tse* fly (*Glossina morsitans*).

However, there are other diseases that are also referred to as endemic diseases, though they are not spread through a vector (non-transmissive). For example, some helminthoses as broad fish tapeworm disease (diphyllobothriosis).

Scheme followed in parasitological studies

Here is what should be covered in studies of the parasites and the diseases induced by them:

1. Name of the parasite
2. Name of the disease
3. Characteristics of the disease
4. Geographical distribution
5. Habitat in the human
6. Morphology
7. Life cycle
8. Pathogenic effects, symptoms, complications
9. Diagnosis
10. Prevention

1. **Name of the parasite** (binomial classification = genus name + species name), e.g. *Leishmania donovani.*
2. **Disease name** (parasite genus name + osis/asis), e.g. *Leishmania donovani* causes disease called leishmani*osis*.
3. **Disease characteristics:**
   - anthroponosic/anthropozoonosic
   - endemic/non-endemic
   - transmissive/non-transmissive
4. **Geographical distribution** can be worldwide or endemic. Ecological factors (temperature, humidity, endemic vectors or reservoir hosts), social/religious customs, habits should be considered.
5. **Habitat** is the specific place where the parasite is found in the host (lumen, blood, tissue, etc.) after penetration, depending on its receptors. The organ of habitat is usually harmed by the pathogenic effects of the parasite.
6. **Morphology**: stages of development, size, specific morphological adaptations. These are important for pathogenic effects caused by parasite as well as for its diagnosis.
7. **Life cycle** (pattern of reproduction, hosts, vector, route of infection, invasive stage).
8. **Pathogenic effects** show mechanisms of the harm which determine the patterns of clinical manifestation - the symptoms and complications. They majorly depend on the morphology and habitat of the parasite.
9. **Diagnosis** means to identify the cause of disease. Depending on habitat, find the parasite based on its specific morphological feature:

a) **observation (scopy)** of the parasite (any stage) either directly (*scopy* after elimination or endoscopy) or indirectly (imaging methods). This can be done by:

- *microscopy*: observation of any of the parasite morphological stages from habitat sample (blood, feces, tissue biopsy, liquid puncture);
- *endoscopy* of luminary organs (find a large parasite in the lumen or microscopy of the small parasite/small stage in endoscopic sample);
- *radiology* (imaging) methods (sonography, X-ray, CT-scan, MRI).

b) immunological (**serological**) **method** - find antigens of or antibodies to the parasite in blood plasma.

c) PCR - identify DNA of the parasite removed from habitat (mostly for very small – intracellular, hardly detectable parasites, e.g. leishmania, plasmodium), though any species can be detected.

10. Prevention is the stopping of transmission of parasites. One has to recall the complete life cycle of the parasite (route of penetration, hosts, vectors) for effective prevention. Human hosts (both patients and carriers) should be treated, reservoir hosts should be treated or eliminated, vectors must be eliminated. Keeping proper hygiene is essential for prevention of gastrointestinal parasites.

A

1. A symbiosis, where one organism uses another for dwelling and nourishment without causing harm is called:
   A. commensalism
   B. mutualism
   C. parasitism
   D. predation
2. Which disease is an anthroposnosis?
   A. ameobiasis
   B. bird malaria
   C. tularemia
   D. plague
3. The free living organism which can live in parasitic manner also is said to be a … parasite:
   A. obligate
   B. facultative
   C. permanent
   D. true
4. What kind of disease is malaria? It is:
   A. infection
   B. facultative-transmissive
   C. obligatory-transmissive
   D. zoonosis
5. The rout of transmission for protozoan cysts and eggs of helminthes is:
   A. transovorial
   B. sexual
   C. dermal
   D. per os

B

1. Which of the followings is not an anthropozoonosis?
   A. ameobiasis
   B. leishmaniosis
   C. trypanosomosis
   D. plague
2. In which level the host organism cannot response to parasite?
   A. humoral
   B. neural
   C. cellular
   D. tissue
3. Which of the followings is not a strategy against host immune response?
   A. intracellular location of parasite
   B. cellular reaction of host
   C. antigenic masking
   D. different morphological stages of parasite in host organism
4. The parasite can not have the following effect on the host organism:
   A. mechanical
   B. hypervitaminosis
   C. anemia
   D. toxic
5. Which of the followings is not a commensal?
   A. E. gingivalis
   B. E. coli
   C. Trichomonas hominis
   D. E. histolytica

II

1. The branches of medical parasitology are:
   1. medical protozoology
   2. medical arachnoentomology
   3. medical virology
   4. medical helminthology
   5. microbiology

   A. 1,3,5 B. 1,2,4 C. 2,3,4 D. 3,4,5
2. The parasite in definitive host organism is:
   1. sexually mature
   2. reproduced by sexual way
   3. in larval stage
   4. reproduced by asexual way
   5. reproduced by sexual and asexual ways

   A. 1,2 B. 3,4 C. 1,2,5 D. 1,3,5
3. The types of hosts are:
   1. facultative
   2. temporary
   3. definitive
   4. intermediate
   5. reservoir

   A. 1,2 B. 3,4 C. 1,2,3 D. 3,4,5
4. The vectors can be the following types:
   1. temporary
   2. specific
   3. obligate
   4. facultative
   5. mechanical

   A. 2,5 B. 2,3,4 C. 1,2,3 D. 1,2
5. The adaptation of parasite to parasitism is expressed by:
   1. behavioral changes of host
   2. sexual reproduction
   3. synchronization of life cycles
   4. toxic effect
   5. high fertility

   A. 1,2,4 B. 3,4,5 C. 1,3,5 D. 2,4,5

Chapter 16
Medical Protozoology
Medical Protozoology. General Characteristics of Protozoa. Class Sarcodina

Protozoa (Greek - "*proto*" first, *"zoa"* animals) are unicellular eukaryotic organisms. The protozoa have the following characteristics.

Morphology. *Shape.* Protozoa exhibit a wide variety of morphological features. Shapes range from the ever-changing forms of amoeba to relatively rigid forms with ordered cytoskeletons. Many protozoan species exhibit complex life cycles with multiple morphological stages. For example, most of amoebae and paramecia develop two morphological forms: ***trophozoite*** or ***vegetative form*** (actively feeding stage, *trophos* - feeding) and ***cyst*** (survival and spreading stage). The cyst is dormant and environmentally resistant stage for spreading (*invasive stage*).

Size. Protozoa are unicellular organisms. Thus, the vast majority of protozoa are microscopic. The present species range in size from about 1 mkm to several mm. Most of the organisms discussed in this course will be 3-50 mkm. The parasitic protists that have the sizes 2-5 mkm locate intracellularly, e.g., toxoplasma, plasmodium, leishmania.

Metabolism. Predatory protozoa feed on other organisms (e.g. bacteria, smaller protozoa), so they are ***heterotrophic*** and simply absorb solutes from their media (osmotrophy), while some ingest solid material (phagotrophy). Some protozoa are photosynthetic and can capture the energy of the sun and convert it to usable chemical energy (i.e., ***autotrophic***). Many protozoa are not restricted to a single feeding mechanism and can utilize combinations of the above (i.e., ***mixotrophic***).

Motility. The motility of protozoa resulted in their classification as "animals", which were distinguished from the non-motile "plants". However, motility is not a universal feature of protozoa and different protozoa utilize different mechanisms for their movement. In fact, protozoa were initially classified based on their mechanism of motility.

Classification of protozoa based on modes of motility.

Protozoa Class	Motility mechanisms
Sarcodina	Pseudopodia (amoeboid movement)
Flagellates	Flagella
Ciliates	Cilia
Sporozoa	Gliding motility

Flagella and *cilia* are subcellular structures which propel protozoa through a fluid medium.

In contrast to the swimming exhibited by flagellates and ciliates, ameobas are protozoa that move by pseudopodia comprised of actin and myosin.

Sporozoa (or Apicomplexa) perform "gliding motility". They usually have intracellular forms and penetration to the host cell involves this *gliding motility*, which is realized by an apical complex ("Apicomplexa" comes after this complex) located in cytoplasm.

Reproduction. The asexual reproduction patterns in protozoa are ***binary fission***, ***budding*** and ***multiple fission*** (***schizogony)***. Many protozoa (e.g., Sporozoa) exhibit also ***sexual reproduction***, which can involve the ***copulation*** (production and fusion of gametes) in processes

similar to higher organisms. The Ciliates undergo a ***conjugation*** in which two individuals will pair and directly exchange genetic material. Sometimes sexual reproduction is an obligatory step in the life cycle, whereas in other cases the organism can reproduce asexually with an occasional round of sexual reproduction.

Class Sarcodina

Sarcodina species are the amoebas. Their body does not have a certain shape since they lack pellicle. The cytoplasm divides into hyalinic peripheral part – *ectoplasm*, and granular part – *endoplasm*. The endoplasm contains single nucleus and food vacuoles. Sarcodina move by pseudopodes. Reproduction pattern is only asexual – binary fission.

These protozoa can be free-living or parasitic. A few of the free-living amoebae can act as human pathogens (facultative parasites, e.g. *Naegleria fowleri, Acanthamoeba*). The obligate parasite is *Entamoeba histolytica*. Non-pathogenic commensals are *Entamoeba coli* and *Entamoeba gingivalis.*

Entamoeba histolytica

E. histolytica causes ameobiasis or ameobic dysentery, which is an anthroponosic, non-transmissive disease.

Geographical distribution. Its prevalence is worldwide, but is more common in hot regions with poor sanitation.

Habitat. Trophozoites of *E. histolytica* live in the large intestine tissue of human.

Morphology. It has a cyst and two trophozoite forms (*forma magna* and *forma minuta*). The size ranges from 30-50 mkm. The nucleus is placed acentrically in the cytoplasm, its dense part – the *karyosome*, has a central position in the nucleus and is dot-like. The motility of *E. histolytica* is progressive and directional, and is realized by multiple pseudopodes.

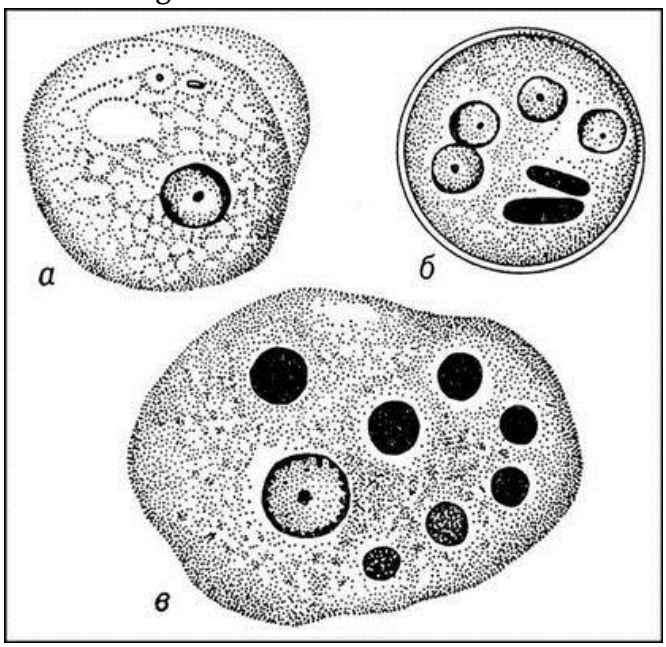


Fig. Morphology of Entamoeba histolytica: а) forma minuta, б) cyst, в) forma magna with ingested RBCs

The encystation (making a cyst stage) occurs in the large intestine when the trophozoite covers with cyst membrane. Cyst is about 10-15 mkm. Mature cysts contain four nuclei (quadrinucleate). Just before the excystment (releasing trophozoite from cyst) that follows ingestion of cysts the four nuclei divide and eight tiny amoebulae get released into the lumen of intestine.

Life cycle. *E. histolytica* passes its life cycle only in one host – human. The cyst is the invasive form, and man is infected by ingestion of cysts through fecal contamination of water, vegetables and fruits. House flies, cockroaches support in mechanical transmission of cysts from feces onto unprotected food stuff. On ingestion, excystation occurs in large intestine and eight young amoebulae develop into *forma minuta*, which are commensals and are non-pathogenic

forms feeding only on bacteria and intestinal nutrients. However, in favourable conditions (low immune defense, coexisting infections, stress, malnutrition) *forma minuta* can transform into pathogenic *forma magna*, which secretes histolytic (*histos* – tissue, *lytic* - destructing) enzymes. The proteolytic enzymes cause destruction and necrosis of surrounding tissues leading to ulcerations. Destruction of deeper layers of intestinal wall may rupture also blood vessels, through which the trophozoites can spread from large intestines to other organs (liver, lungs, CNS, skin).

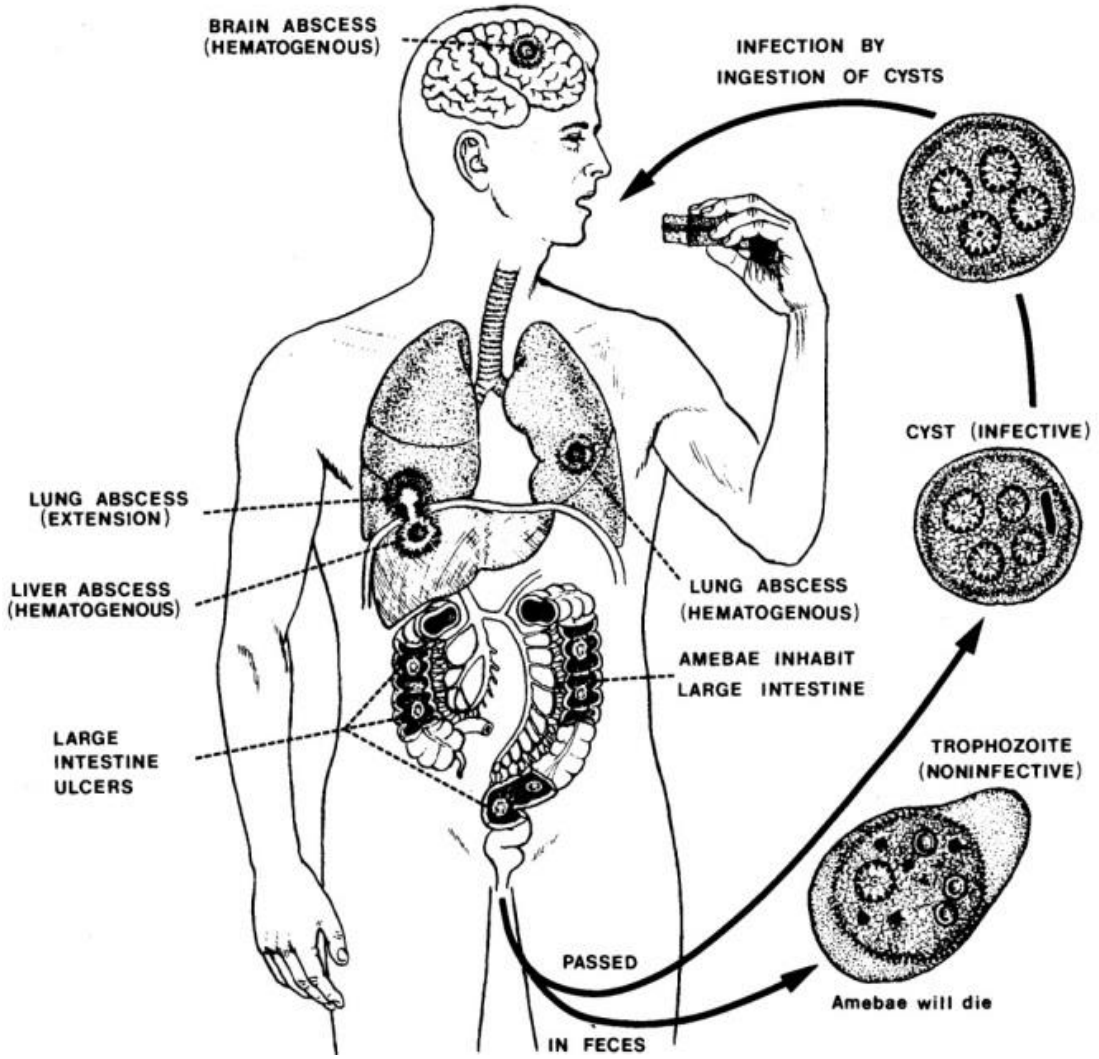


Fig. Life cycle of Entamoeba histolytica.

Pathogenesis. Clinical features. *Forma magna* trophozoite produces proteolytic enzymes which destruct the wall of large intestine and form a bleeding ulcer. *Forma magna* feeds on RBCs from ruptured blood vessels (it is hematophage). The ulcer size ranges within few mm, it is flask-shaped (with a broad base and narrow neck) and has smooth margins. The base is filled up with necrotic material (pus and blood).

Ameobiasis is commonly known as ***amoebic dysentery***, since the classical manifestation of this disease is ***dysentery*** (inflammation and ulceration of the bowel, characterized by loose stool with mucus and blood). Defecation may occur up to 6-10 times daily. There is a ***toxic effect*** (fever), dehydration (loosing water). ***Tenesmus*** (feeling a constant desire to evacuate bowels, although there may be nothing to throw off except a little mucus and blood) is a feature

that results from penetration of parasites to deeper layers of intestinal wall, where they irritate periodically the nerve ganglia causing intestinal contractions (peristalsis).

Complications. Intestinal ameobiasis may be complicated with:

a. abscess (accumulation of pus - necrotized tissue cells and leukocytes, in an enclosed tissue space) of liver, lungs, brain, skin;
b. anemia (due to bleeding ulcers);
c. peritonitis (inflammation of peritoneum due to perforation of intestinal ulcer);
d. ameoboma (tumour-like formation of large intestine caused by pathogenic amoeba).

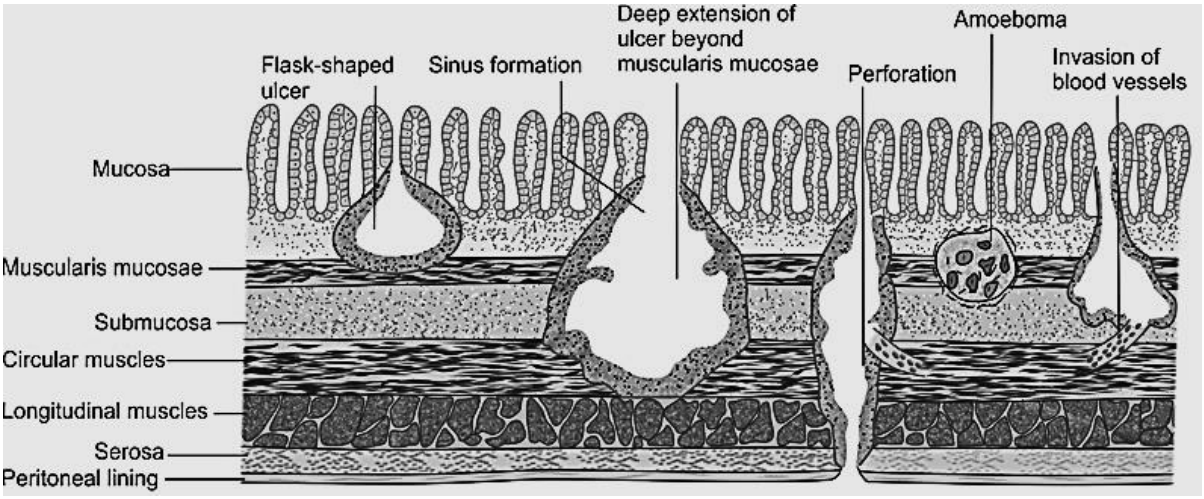


Fig. Patterns of affection of large intestine by Entamoeba histolytica.

Diagnosis. Microscopic demonstration of *E. histolytica* in stool. The *forma magna* with ingested RBCs confirm the diagnosis, while the cyst forms are discharged in *asymptomatic carriers* (people infected with a parasite but expressing no symptoms). Identification of such persons is important from epidemiological standpoint, as they are constant source for spreading the disease among society.

Ulcerations of the large intestine can be viewed using colonoscopy (endoscopic examination of large intestine). Detection of ulcers often is followed by taking and examining the ulcer material to find *f. magna* of *E. histolytica*.

Prevention. Protection of food and water from being contaminated with human excreta. Proper washing of vegetables and water boiling can help to remove the parasites. Detection and treatment of carriers and their exclusion from food handling occupations (e.g. cooks, vegetable vendors) and medical personnel. Other measures include fly-control, sewage disposal, proper water supply.

Non-pathogenic commensal amoeba:
Entamoeba gingivalis and *Entamoeba coli.*

E. gingivalis is a commensal of mouth, resides in caries teeth, pyorrheal pockets between the teeth and gums. It lacks the cyst form, trophozoites measure about 10-20 mkm.

Entamoeba coli resembles very closely to *E. histolytica*. The trophozoite measures about 20-40 mkm, and cysts measure 15-30 mkm. It resides in large intestine, does not have histolytic enzymes and is usually found in stool along with *E. histolytica*, from which it must be differentiated.

1. The cytoplasm of *E. coli* frequently contains many food vacuoles.
2. RBCs are not ingested, instead it feeds on WBCs.

3. *E. coli* is sluggish in its movement if compared to the progressive and directional motility of *E. histolytica*. It projects a single pseudopode.
4. The karyosome is of eccentric position.
5. The number of nuclei may vary from one to 8 (octanucleate).

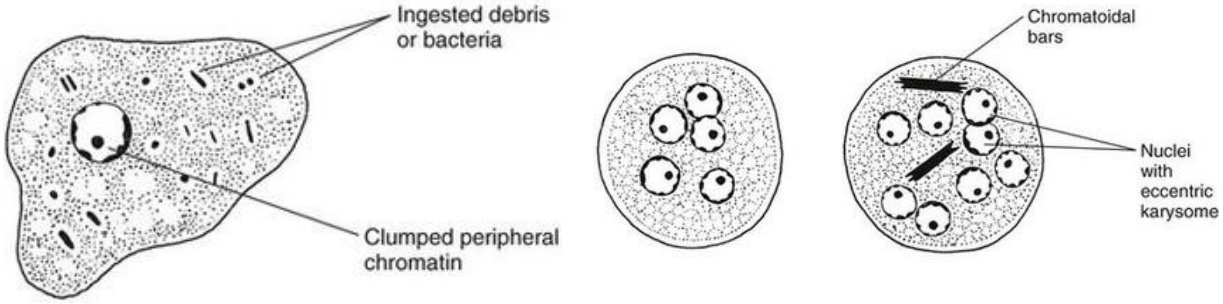


Fig. Trophozoite and two cysts of *Entamoeba coli.*

Faculatative parasite species of Sarcodina: *Naegleria fowleri* and *Acanthamoeba castellani*

These amoebae live freely in soil and fresh waters, but they may become dangerous parasites when occasionally introduced to humans. They are also referred to as opportunistic parasites since they cannot leave the human host after the infection, and the humans cannot infect other hosts (***dead end***).

Naegleria fowleri

Naegleria fowleri exists in 3 morphological forms: ameoboid trophozoite, flagellated trophozoite and cyst. In almost all cases, *N. fowleri* enters the body by being inhaled or splashed onto the nasal (olfactory) epithelium when swimming. In some cases infection takes place by inhaling cysts from dust. The amoebae then travel up the olfactory nerve to the brain causing meningoencephalitis (inflammation of brain and brain membranes), which can be very

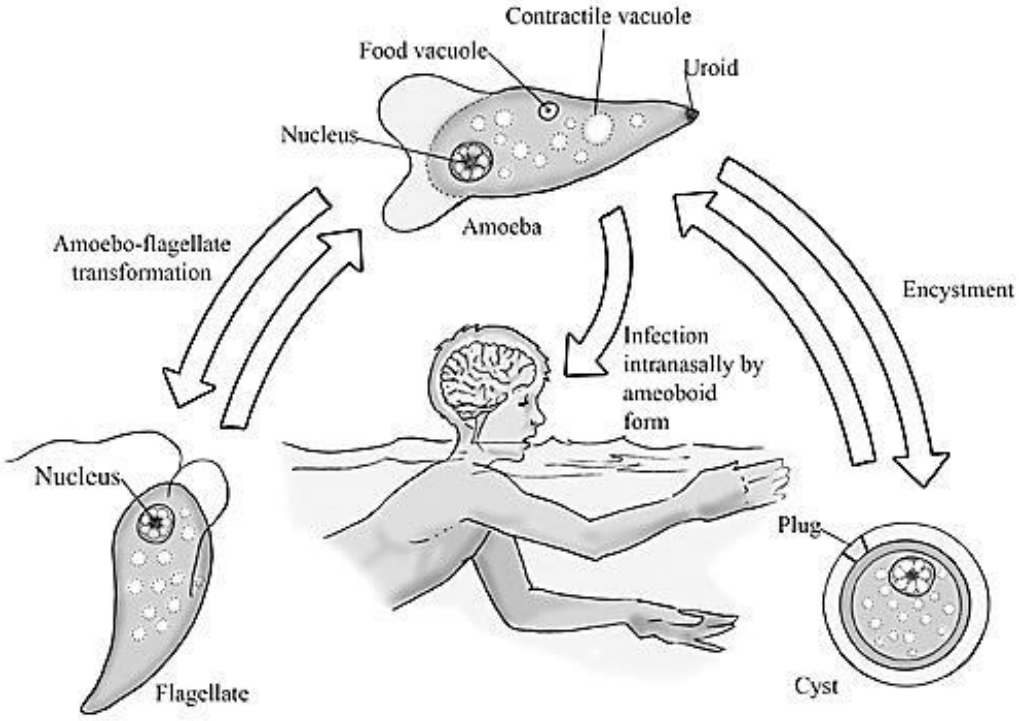


Fig. Life cycle of Naegleria fowleri.

acute (about 4-5 days).

The disease usually occurs in children and young adults in good health who have recently swum in warm water. It can be diagnosed by microscopic examination of Naegleria trophozoites in few drops of fresh cerebrospinal fluid. But the diagnosis more often is confirmed after death (*post mortem*) on histological sections of brain tissue that show trophozoites.

Acanthamoeba castellani

Acanthamoeba castellani is presented in trophozoite and cyst stages. It usually acts as opportunistic pathogen, taking advantage of depressed immunity.

Acanthamoeba can penetrate through respiratory tract (by the inhalation of aerosols or dust containing cysts) or injured skin during swimming. Spreading to the CNS is through blood. Amoebic keratitis is usually associated with improper sterilization of soft contact lenses.

Diagnosis is similar with Naegleria, both trophozoites and cysts can be visible in brain biopsy (*post mortem*).

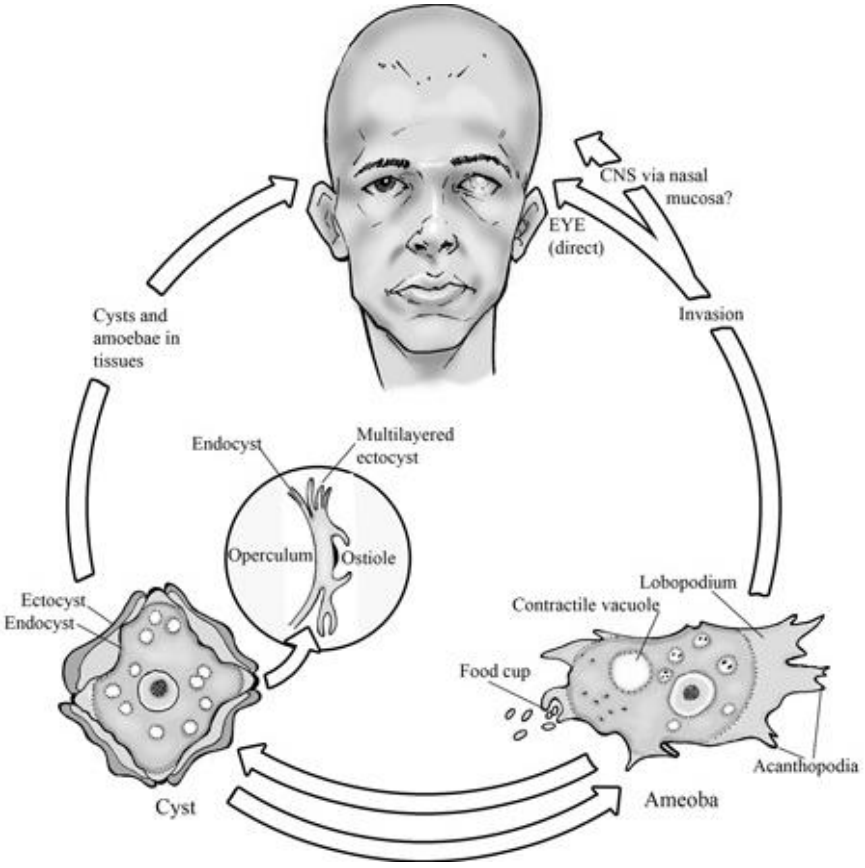


Fig. Life cycle of Acanthamoeba castellani.

A

1. Which of the following organelles has special function?
   A. mitochondria
   B. digestive vacuole
   C. Endoplasmic reticulum
   D. ribosome
2. Saprophitic protozoa are:
   A. living in the multicellular organism
   B. living in human organism
   C. feeding on organic substances of living organisms
   D. feeding on excretions of organisms living in the same environment
3. Heterotrophic protozoa that have pseudopodes are feeding:
   A. by phagocytosis
   B. through cytostome
   C. via mixotrophic way
   D. by osmosis
4. Sexual reproduction in protozoa is:
   A. schizogony
   B. binary fission
   C. copulation
   D. budding
5. Entamoeba coli is:
   A. a parasite
   B. causing diarrhea
   C. a commensal
   D. causing intestinal bleeding

B

1. What does not occur during copulation?
   A. fusion of gametes
   B. formation of zygote
   C. exchange of genetic material
   D. formation of germ cells
2. Cysts are not found in:
   A. Entameoba histolytica
   B. Entameoba coli
   C. Entameoba gingivalis
   D. Naegleria fowleri

3. Which statement is wrong for E. histolytica? It:
   A. lives in human large intestine
   B. can cause ameobic abscesses
   C. produces proteolytic enzymes
   D. has octanucleate cyst

4.Which of the following statement does not characterize Entameoba coli? It:
   A. lives in human large intestine
   B. dose not damage intestinal tissues
   C. causes ameobic abscesses
   D. is commensal

5.Which stage is absent in life cycle of Acanthamoeba?
   A. amoeboid trophozoite
   B. flagellated trophozoite
   C. vegetative form
   D. cyst

II

1. Which of the followings are facultative parasites?
   1. Entamoeba gingivalis
   2. Entamoeba coli
   3. Acantamoeba castellani
   4. Entamoeba histolytica
   5. Naegleria fowleri

   A. 1,2,3 B. 2,3,4 C. 3,4 D. 3,5
2. Sexual reproduction ways in protozoa are:
   1. schizogony
   2. copulation
   3. conjugation
   4. fertilization
   5. binary fission

   A. 1,2,4 B. 2,3 C. 3,4,5 D. 1,4,5
3. The complications of amoebiasis are:
   1. amoebic meningoencephalitis
   2. keratitis
   3. perforation of intestinal wall
   4. peritonitis
   5. amoebomas of large intestine

   A. 1,5 B. 2,3 C. 1,3,4,5 D. 4,5

Which of the followings can characterize Entameoba coli? It:
   1. lives in human large intestine
   2. is a commensal
   3. is a parasite
   4. has eccentric karyosome

5. does not produce cysts

A. 3,4,5 B. 1,2,4 C. 1,2,5 D. 3,5

4. In life cycle of Naegleria fowleri there are:
   1. forma magna
   2. flagellated form
   3. forma minuta
   4. amoeboid form
   5. cysts

A. 2,4,5 B. 1,2,3 C. 1,5 D. 3,4,5

Chapter 17
Class Flagellata. Blood and tissue flagellates (Trypanosoma, Leishmania)

Class Flagellata

The protozoa in this group are so named because of the presence of one or more flagella used for motility. Some species have a flagellum, which arises anteriorly and runs the middle or the posterior end of the body as an *undulating membrane.*

Flagellates can be classified according to their habitat as:

1. blood and tissue flagellates,
2. lumen-dwelling flagellates (oral, intestinal, urogenital).

Blood and tissue flagellates may possess a single flagellum (uniflagellate), while lumen-dwelling species have more than one flagellum (multiflagellate).

Blood and tissue flagellates (haemoflagellates)

In this family there are two genera pathogenic to human: ***Trypanosoma*** and ***Leishmania***. Following characteristics are common for them:

1. inhabit the blood or tissues of man or other animals.
2. are spread through vectors and cause transmissive diseases.
3. may have more than one morphological stages in their life cycle, which are characterized by single nucleus and a *kinetoplast* (a modified mitochondrion providing with energy for the flagellum starting from it). The morphological stages are following:

a. *Amastigote* or *leishmanial* form – 2-5 mkm (intracellular location), there is a single nucleus, it has no flagellum, is oval shaped, is common for all leishmanial species and Trypanosoma cruzi.
b. *Promastigote* form – 15-20 mkm, kinetoplast is anterior to the nucleus, from where the free flagellum starts, does not form an undulating membrane. It is invasive stage for humans in leishmaniosis.
c. *Epimastigote* form – 15-30 mkm, kinetoplast is anterior to nucleus, from where the flagellum arises and forms a short undulating membrane.
d. *Trypomastigote* or *trypanosomal* form – 15-30 mkm, kinetoplast is posterior to nucleus, the flagellum forms a long undulating membrane. Is found in the blood of definitive hosts of Trypanosomes.
e. *Metacyclic* form – resembles trypomastigote with difference that there is no or little part of free flagellum; is present in the vector hosts of Trypanosoma (tse-tse fly, kissing bug) and is invasive stage for human.

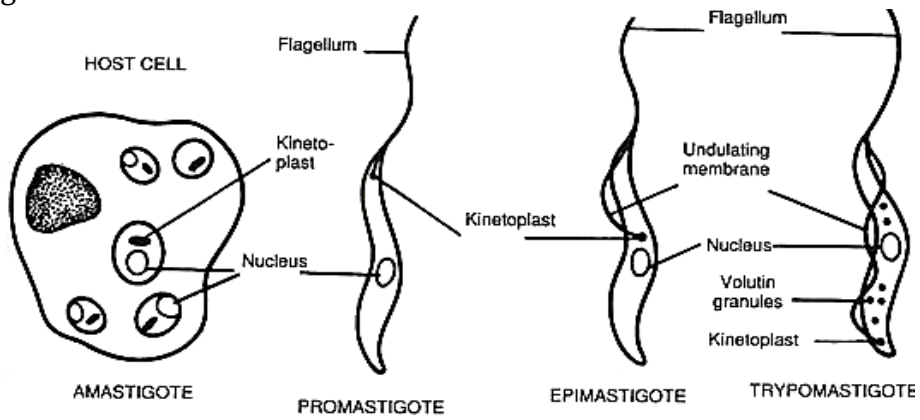


Fig. Morphological forms of haemoflagellates.

Genus Trypanosoma

Trypanosoma infecting the man are ***Trypanosoma brucei gambiense, Trypanosoma brucei rhodesiense*** and ***Trypanosoma cruzi.*** They cause different types of trypanosomosis, which are endemic, anthropozoonosic, obligate transmissive diseases. The first two species cause trypanosomosis known as African sleeping sickness, and the third is the agent of American sleeping sickness, or Chagas' disease.

Trypanosoma brucei gambiense

T. b. gambiense causes West African (Gambian) sleeping sickness.

Geographical distribution. West and Central Africa.

Habitat. Through the bite of tse-tse fly it firstly locates in the inoculation site from where it enters the bloodstream and reaches lymph nodes, cerebrospinal fluid and brain.

Morphology. Trypomastigote form of *T. brucei* exists in the definitive host. Metacyclic form develops from trypomastigotes in the vector tse-tse fly.

Life cycle. *T. brucei* passes its life cycle in two hosts: vertebrate host is the definitive host (man, animals), and the intermediate host is the species of tse-tse fly (*Glossina palpalis*). The reservoir hosts are some domestic animals (dog, pig, horse).

During a blood meal tse-tse fly injects metacyclic forms (invasive stage) of trypanosomes into skin, from where the parasites enter the bloodstream, here transforming into trypomastigotes and are carried to other sites: lymph, spinal fluid, brain (extracellular location). In tsetse fly, when taking a blood meal on an infected human, the trypomastigotes transform

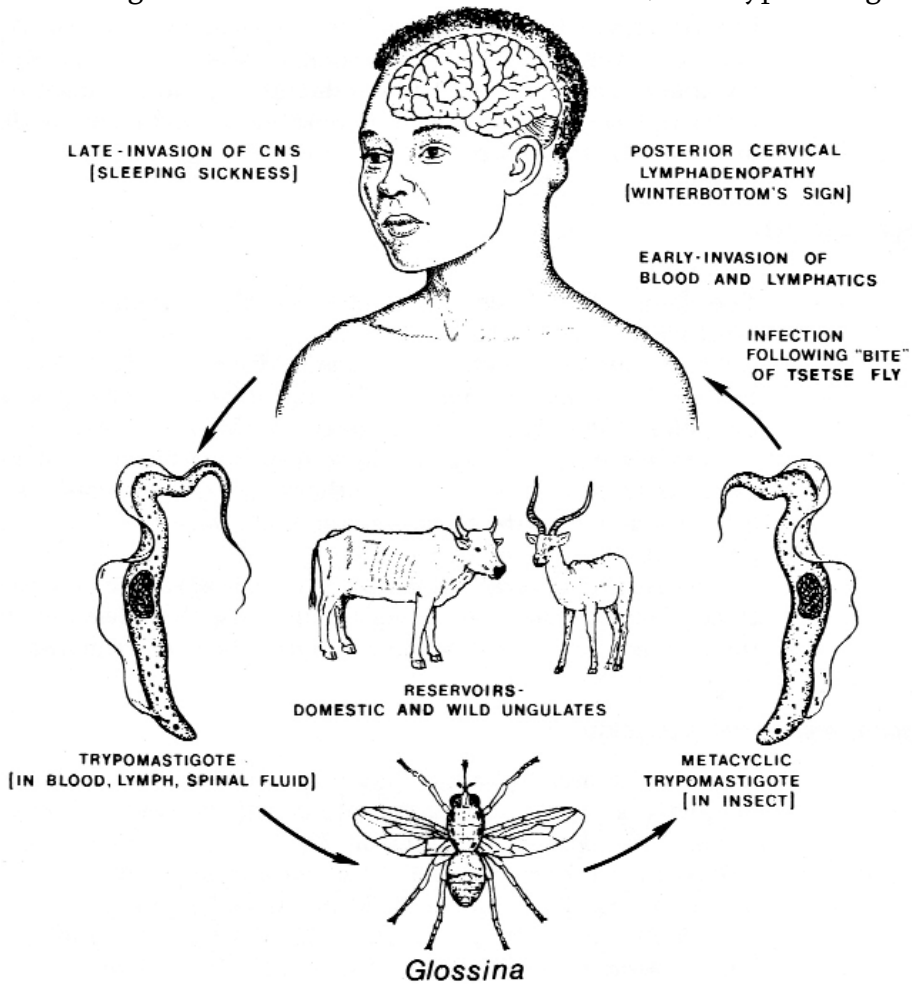


Fig. Life cycle of Trypanosoma brucei.

into invasive metacyclic stage.

Pathogenicity. Clinical features. Following the bite of tse-tse fly there is skin ulceration with formation of painful "*trypanosomal chancre*", which slowly disappears. Trypanosomes are found in a number of locations within the vertebrate host, including blood, lymph nodes, cerebrospinal fluid (CSF), brain.

During the first 1-2 weeks of infection a patient experiences toxic effect, and the fever attacks may repeat due to ***antigenic variation*** of the parasite. It is followed by enlargement of lymph nodes. In several years the brain becomes affected (encephalitis). It considers weakness, apathy, headache and *somnolence* (sleeping sickness), finally culminating in coma and death.

Diagnosis. Detection of trypomastigote stage in the trypanosomal chancre, lymph nodes, peripheral blood and CSF (lumbar puncture). In addition, immunological tests have also been developed (detection of specific antibodies in blood).

Prevention. The principle methods of control are:

a. trapping of tse-tse fly by means of insecticides (chemicals that kill insects), wearing protective clothing with dull colors and use bed nets in areas with tse-tse flies,
b. removing reservoir host from the area and breeding resistant stock animals,
c. treatment of patients.

Trypanosoma brucei rhodesiense

T. b. rhodesiense causes East African (Rhodesian) sleeping sickness. The distribution of *T. b. rhodesiense* is much more limited, with the species found in East and Southeast Africa.

Morphologically this trypanosome does not differ from the Gambian subspecies. The life cycle is the same, with difference that bushbuck antelopes are the main reservoir of *T. b. rhodesiense*, and *Glossina morsitans* is the main vector for *T. b. rhodesiense*.

In Rhodesian sleeping sickness the infection results in an acute form of disease, which progresses so rapidly that the classical symptoms of sleeping sickness rarely develop, and, if untreated, the patient dies very soon after being infected.

Diagnosis and prevention are also the same for rhodesian sleeping sickness as for West African trypanosomosis.

Trypanosoma cruzi

It causes American sleeping sickness or Chagas' disease, which is a transmissive, anthropozoonosic, endemic disease.

Geographical distribution. Central and South America.

Habitat. Blood (serum), heart, skeletal muscles, neural tissue (brain, nerve ganglia), and also phagocytic cells (blood, lymph nodes, liver, spleen).

Morphology. *T. cruzi* is found in the peripheral blood (serum) as *trypomastigote*. In the tissues (muscles, brain, phagocytes) the parasite occurs as an *amastigote*.

Life cycle. *T. cruzi* develops by alternation of hosts. Definitive host is the man or reservoir animals (armadillo, opossum, raccoon, cats, dogs). The vector host is the *reduviid* bug (kissing bug). It usually bites at night, on the fine parts of skin - the face (hence the name, kissing bug). After blood meal the bug defecates on host skin causing itching and scratching, which is followed by transmission of metacyclic stage to blood through the injured capillaries of skin.

The parasites affect blood macrophages, where they differentiate into amastigotes, multiply by binary fission, rupture cells and release into blood serum again where they differentiate into trypomastigotes. From here they can penetrate to target organs and vector.

Transmission may also occur from man to man by blood transfusion and transplacental route.

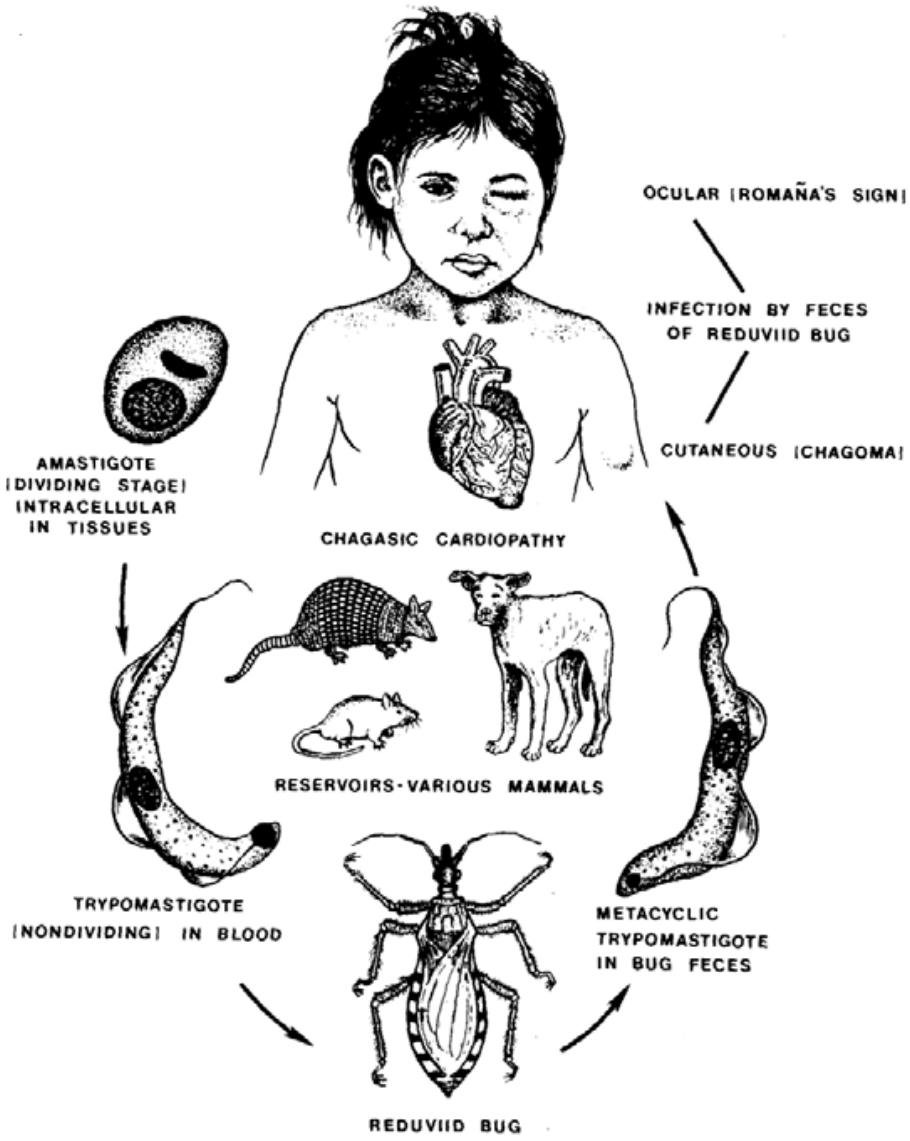


Fig. Life cycle of Trypanosoma cruzi.

Pathogenicity. Clinical features. Primary lesion, *chagoma* is formed at the bite site (face, eyelids, cheek, lips or the conjunctiva).

Acute form (1-2 weeks after infection) is common in children. It is characterized by toxic effects, *enlargement of lymph nodes*, *hepatomegaly* (enlargement of liver) and *myocarditis* (inflammation of cardiac muscle). Chagas' disease may develop also *meningoencephalitis* and coma (sleeping sickness). Death may occur due to brain affection or cardiac failure.

Some of the patients develop a chronic disease. It is accompanied by *cardiomegaly* (cardiac enlargement), dilation and abnormal function of the hollow organs (affection of nerve ganglia in these organs), particularly the esophagus (*megaesophagus*) and colon (*megacolon*) with further intestinal obstruction (*ileus*).

Diagnosis. Microscopic demonstration of trypomastigotes in blood smear, and the amastigote forms found in lymph nodes and muscles through biopsy.

Antibodies are often detectable by immunological tests.

Heart and brain tissue biopsy to find amastigotes can be done after death (*post mortem*) only.

Prevention. Control of *reduviid* bugs (using insecticides, repairing cracked wooden dwellings that shelter the vectors), sometimes it is possible to prevent inoculation of parasites to blood if immediately disinfect the skin (e.g. by iodine) after the bite and not allow scratching. Treatment of patients and elimination of reservoir hosts are also important preventive measures.

Genus Leishmania

Several species of Leishmania are pathogenic for man:

Leishmania donovani including different subspecies (*L. d. donovani, L. d. infantum*) causes visceral leishmaniasis (kala-azar, tropical splenomegaly). *Leishmania infantum* causes Mediterranean or infantile visceral leishmaniosis.

Leishmania tropica (*L. t. major, L. t. minor*) and *L. mexicana* cause cutaneous leishmaniosis.

Leishmania braziliensis is the agent of mucocutaneous leishmaniasis.

Leishmania donovani

It is the causing agent of visceral leishmaniosis that also is widely known by its Indian name kala-azar (black disease). It is an anthropozoonosic (in India – anthroponosic), endemic, transmissive disease.

Geographical distribution. *L. donovani* is found in South-East Asia, India, Pakistan, Mediterranean, North and Central Africa, South and Central America.

Habitat. Inside human the parasite is always intracellular occurring in the amastigote form within phagocytic cells of blood and visceral organs: spleen, liver, lymph nodes, bone marrow (immune system organs).

Morphology. Two stages of leishmania are seen: amastigote (leishmanial form) is present inside human cells. The promastigote occurs in vector (sand fly) and in culture.

Life cycle. Dogs and rodents are common reservoirs. In India leishmaniasis is anthroponosic (humans are reservoir hosts). Sand flies of genus *Phlebotomus* are the vectors. Leishmania are transmitted by the bite of sand fly which carries the promastigote (invasive stage). During the bite the parasites gain access to blood macrophages, monocytes where they transform into amastigotes and divide until the infected cell ruptures. The released organisms infect other cells. Amastigotes in blood cells are invasive for sand fly.

Pathogenicity. Clinical features. The amastigote forms of leishmania are localized and multiply in the phagocytic cells responsible for cellular immunity. They produce anti-oxidase enzymes, which suppress infected macrophage lysosomes. This allows *Leishmania* to multiply and eventually rupture the phagocytes. Further proliferation of the phagocytes leads to massive enlargement of the affected organs. The symptoms in kala-azar are following:

1. ***toxic effect*** (high fever, weight loss).
2. enlargement of liver and spleen (***hepatosplenomegaly***).
3. enlargement of lymph nodes (***lymphadenopathy***) (not in Indian kala-azar).
4. ***skin hyperpigmenation*** ("*kala-azar*" means black disease).

5. suppression of *hemopoiesis* in affected bone marrow expressing in decrease of all blood cells RBC, WBC and platelets (known as *pancytopenia*). Low RBC count results in anemia, and low count of WBCs leads to ***immunosuppression,*** which mediates ***secondary bacterial*** and ***protozoal infections***. This may lead to death in about 2 years if not treated (mortality rate in untreated cases ranges 75%-90%).

Complication: ***Postkalaazar dermal leishmaniosis (PKDL)*** is a cutaneous lesion which develops in few kala-azar patients due to incomplete treatment or its absence.

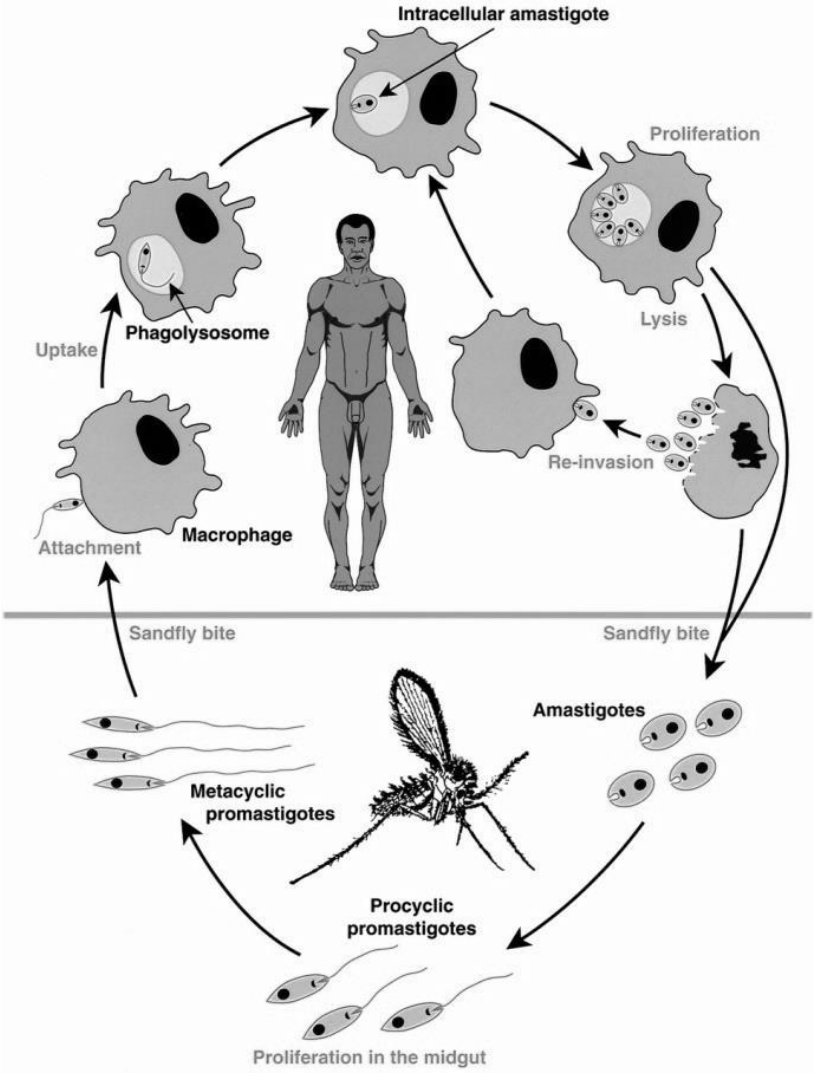


Fig. Life cycle of Leishmania.

Diagnosis. Definitive diagnosis of kala-azar is based on:

a. demonstration of amastigotes in bone marrow punctate (sternal puncture), blood macrophages, biopsy of lymph nodes. Spleen puncture could be an effective method if not the risk of rupturing it.
b. promastigotes of leishmania can be present in culture.
c. immunological tests
d. PCR.

Prevention. Elimination of reservoir animals, *Phlebotomus* sand fly. Using of mosquito nets is recommended. The patients should be diagnosed and treated.

Leishmania tropica. Leishmania mexicana

Dermal leishmaniosis spread in the Old World is also known as Oriental sore, Delhi ulcer or Aleppo boil. It is caused by leishmania belonging to the *Leishmania tropica* complex: *Leishmania tropica major, Leishmania tropica minor.*

New world cutaneous leishmaniosis that is prevalent in South America, is caused by *Leishmania mexicana*.

Geographical distribution. *L. tropica minor* is found in Mediterranean, India, Pakistan (urban distribution), and *L. t. major* is spread in Central Asia (Turkmenistan, Kazakhstan, Uzbekistan), Iran (rural distribution). *L. mexicana* species are distributed in Central and South America.

Habitat. The parasites are found within skin phagocytes.

Morphology. Structurally these parasites are similar to *L. donovani.* Amastigote forms occur in man, while the promastigotes are found in sand fly and in culture.

Life cycle. It is like the life cycle of *L. donovani,* but *L. t. major* is anthropozoonosic and the reservoir animals are desert rodents (gerbil, hamster), while *L. t. minor* causes anthroponosic dermal leishmaniasis.

Pathogenicity. Clinical features. Cutaneous lesions are found usually on the exposed parts of the body (face, extremities). The lesion initially presents as a raised red papule, which may itch intensely and reaches about 2 cm in diameter. It eventually ulcerates, and the center of the ulcer encrusts. The lesion has a smooth margin with elevated hard edge, where the parasites are found. The ulcer is self-healed in about a year even without treatment, since permanent immunity develops in dermal leishmaniasis. This allows specific prevention by vaccination.

Diagnosis. The diagnosis of cutaneous leishmaniasis is based on demonstration of amastigotes in the material obtained by a puncture of the hardened edge of the skin sore. The leishmania grown in culture are present as promastigotes. Immunological skin test is positive. PCR is a sensitive diagnostic test.

Prevention. Specific prevention method is the vaccination of population in endemic regions. Bed nets should be offered to those most at risk: the families and neighbors of infected people**.** Elimination of reservoir hosts is necessary.

Leishmania braziliensis

This parasite causes mucocutaneous leishmaniosis or *espundia*.

Geographical distribution. Central and South America.

Habitat. It occurs as amastigotes inside the macrophage cells of the skin and mucous membranes of the nose and buccal cavity.

Morphology, life cycle and prevention are same as in *L. donovani* and *L. tropica*.

Pathogenicity. Clinical features. Skin ulcer is followed by involvement of mucocutaneous area of the nose and buccal cavity. Entire mucosa of the nose, hard and soft palates can be ulcerated.

Diagnosis. Demonstration of amastigotes in skin and mucocutaneous lesions.

A

1. What is located close to the base of flagellum?
   A. axostyle
   B. pellicle
   C. kinetoplast
   D. cuticle
2. The agent of Gambian trypanosomiasis is:
   A. Trypanasoma brucei rhodesiense
   B. Trypanosoma brucei gambiense
   C. Trypanasoma cruzi
   D. Glossina palpalis
3. The agents of Chagas' disease can be transmitted by:
   A. Glossina palpalis
   B. Glossina morsitans
   C. Reduviid bug
   D. Phlebotomus sand fly
4. Leishmaniasis is:
   A. a facultative-transmissive disease
   B. spread worldwide
   C. an obligatory-transmissive disease
   D. spread by mosquitoes
5. The agent of visceral leishmaniasis is:
   A. Leishmania tropica minor
   B. Leishmania tropica major
   C. Leishmania infantum
   D. Leishmania mexicana

B

1. Which of the following symptoms is not found in leishmaniasis?
   A. skin ulcers
   B. inflammation of mucous layers
   C. diarrhea
   D. destruction of tissues
2. Trypanosoma brucei gambiense can not:
   A. cause African sleeping sickness
   B. have undulating membrane
   C. cause Chagas' disease
   D. be found in cerebrospinal fluid
3. Which of the followings does not characterize Trypanosoma cruzi? It:
   A. is distributed in Central and South America
   B. locates inside human cells
   C. has amastigote form in life cycle
   D. has reservoir host as antelope
4. Which of the followings is not a transmissive disease?
   A. Chagas' disease
   B. dermal leishmaniasis
   C. visceral leishmaniasis
   D. ameobiasis
5. What is not characteristic for agent of mucocutaneous leishmaniosis?

A. it is an intracellular parasite inhabiting in skin and mucous membranes of the nose
B. affected tissue puncture is used to diagnose the disease
C. it causes inflammation and tissue destruction
D. diagnosis is made by demonstration of promastigotes in skin and mucocutaneous lesions

II

1. The agent of African sleeping sickness has:
   1. amastigote form
   2. 2-5mkm sizes
   3. a flagellum
   4. an undulating membrane
   5. 15-30mkm sizes

   A. 1,2,3 B. 1,4,5 C. 3,4,5 D. 2,4
2. What is common in Chagas' disease?
   1. skin ulcers
   2. high temperature
   3. sleeping disorders
   4. intestinal ulcers
   5. affection of heart

   A. 1,2,3 B. 2,3,4 C. 4,5 D. 2,3,5
3. The agents of dermal leishmaniasis are:
   1. Leishmania donovani
   2. Leishmania tropica major
   3. Leishmania tropica minor
   4. Leishmania infantum
   5. Leishmania mexicana

   A. 2,3,4 B. 1,5 C. 2,3,5 D. 1,2,4
4. In visceral leishmaniasis the following symptoms are seen:
   1. fever
   2. affection of the open parts of the body
   3. enlargement of spleen and liver
   4. anemia
   5. cardiomegaly

   A. 1,2,5 B. 2,3,5 C. 3,4,5 D. 1,3,4
5. Trypanasomes:
   1. belong to class Sarcodina
   2. have 8 flagella
   3. have a single flagellum
   4. may have an undulating membrane
   5. belong to class Flagellata

   A. 3,4,5 B. 1,2,4 C. 1,4,5 D. 1,3

Chapter 18
Gastrointestinal and Urogenital Flagellates. Class Infusoria. Class Sporozoa (*Toxoplasma gondii*)

Gastrointestinal Flagellates

Among intestinal flagellates there are both pathogenic and commensal members. They have more than one flagellum, an axostyle and no kinetoplast. *Lamblia intestinalis (Giardia lamblia)* is an obligate parasite of small intestine, *Trichomonas hominis* and *Trichomonas tenax* are commensals of large intestine and mouth, respectively.

Lamblia intestinalis

Lamblia intestinalis or *Giardia lamblia*, causes lambliosis (or giardiasis). It is an anthroponosic, non-endemic, non-transmissive disease.

Geographical distribution. Worldwide.

Habitat. Trophozoites are found in the small intestine (duodenum), covering the intestinal villi, and are found sometimes in the gall bladder and in the biliary tract.

Morphology. The parasite has trophozoite and cyst stages. The trophozoite is pear-shaped, 15-20 mkm long, has a bilateral symmetry, meaning that all the structures are paired: 2 nuclei, 2 axostyles (body skeleton), 4 pairs of flagella. The ventral surface forms a *sucking disk*, which serves for attachment to intestinal epithelium without lysing it. The cysts are ovoid, 8-15 mkm, have 4 nuclei, 4 median bodies, no flagella.

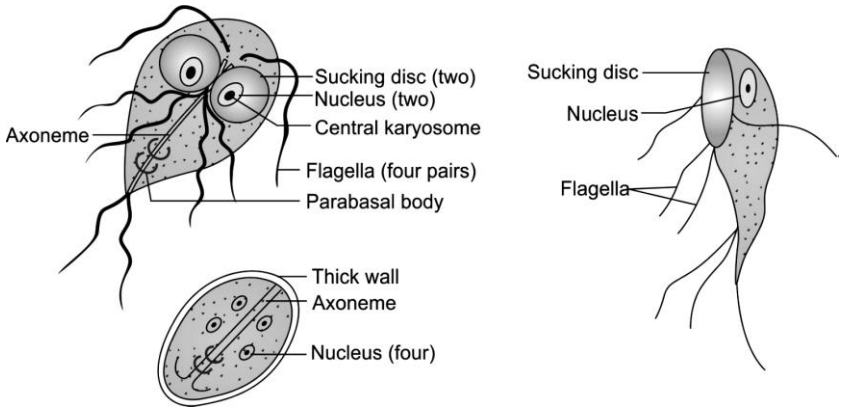


Fig. Morphology of Lamblia intestinalis.

Life cycle. The only host is human. Infection occurs by ingestion of cysts (invasive stage) via contaminated food, water. Mechanical vectors often carry the cysts. Trophozoites are released into duodenum, sometimes reach the gall bladder.

Pathogenicity. Clinical features. The parasite attaches itself to the surface of small intestine villi by the sucking disk and prevents absorption of nutrients. In addition. *Lamblia* is characterized by antigenic variation, which helps the parasite to escape from the host immune system and resist to intestinal digestive enzymes.

Infection is more common in children. The symptoms involve: abdominal pain, anorexia (lack of appetite), diarrhea, *steatorrhea* (loose yellowish stool in which there is excess of fats due to malabsorption), weight loss, allergic reactions.

Diagnosis. 1. microscopic examination of stool to demonstrate trophozoites and cysts.

2. finding of *Giardia* trophozoites also in bile aspirate following the duodenoscopy (***duodenage***).

3. immunological tests.

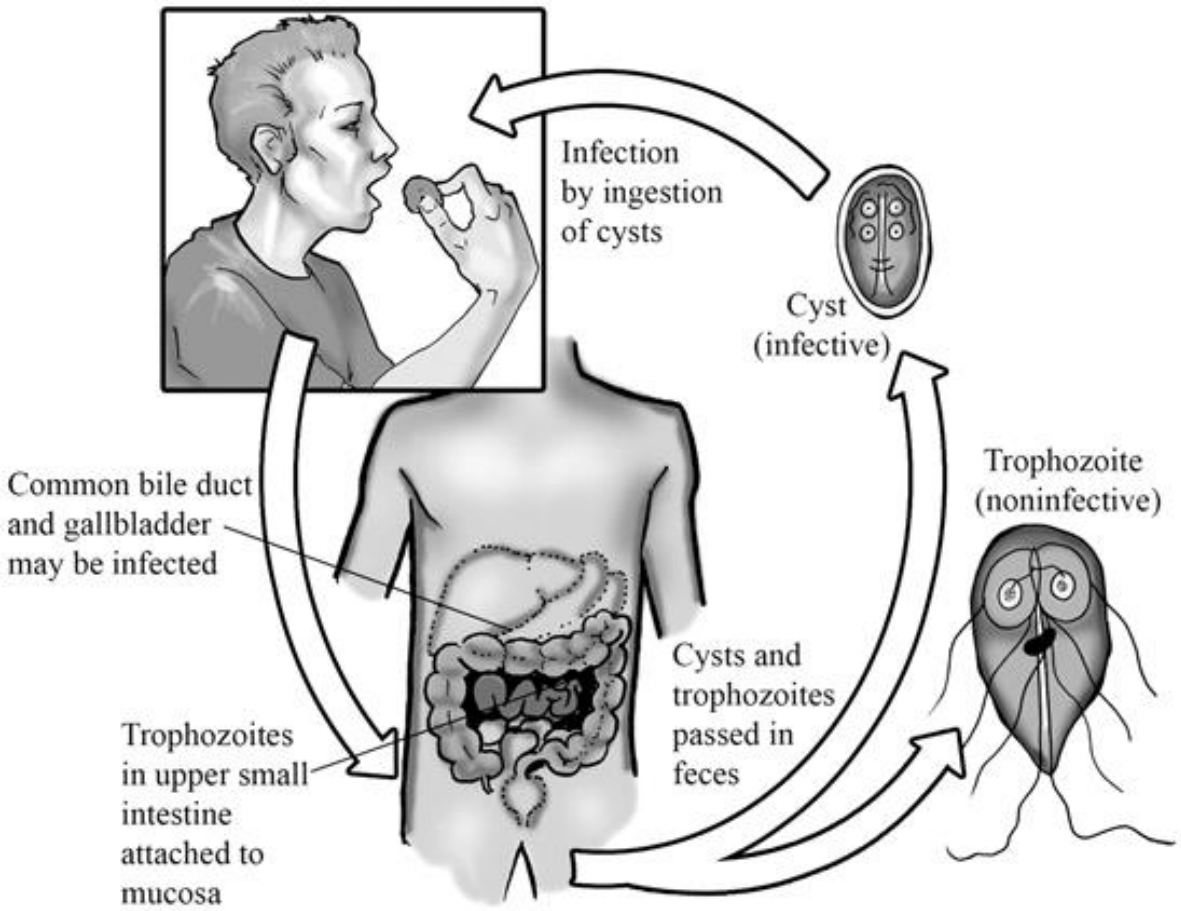


Fig. Life cycle of Lamblia intestinalis.

Prevention. To avoid the infection proper disposal of fecal material, use of safe water supply and keeping hygienic conditions (washing vegetables, fruits, using boiled water) are required. Protection of water sources from contamination. Fight against mechanical vectors.

Trichomonas tenax

It is a commensal of oral cavity (periodontal pockets, carious tooth cavities, tonsillar crypts), the size is about 5-10 mkm, no cyst stage. *T. tenax* is transmitted by kissing, salivary droplets.

Trichomonas hominis

T. hominis is found as a commensal in the cecum, it is 8-12 mkm in size. It has 3-5 anterior flagellae. The undulating membrane extends over the full length of the body. Its axostyle protrudes through the end of the body. Cysts are not formed. In immunocompromised people they may cause some damage leading to loose stool.

Urogenital Flagellate

Trichomonas vaginalis

T. vaginalis causes trichomoniasis, a sexually transmitted disease (STD), which is anthroponosic, non-endemic, non-transmissive.

Geographical distribution. Worldwide.

Habitat. In females: vulva, vagina, urethra, urinary bladder; in males: mainly urethra, occasionally urinary bladder, prostate.

Morphology. Only trophozoite stage is present, no cysts are formed. Trophozoite is pear-shaped, 10-12 mkm, has single nucleus, axostyle, four free anterior flagella and a fifth flagellum located in the undulating membrane that extends about halfway across the body. This flagellum is supported by a cytoskeleton structure - *costa*.

Mode of transmission. Trichomoniasis is a sexually transmitted (or veneral) disease. Invasive stage is the trophozoite. Transmission is usually through sexual contact though it can rarely be contracted non-venerally: for example, through common use of contaminated underwear by mother and daughter.

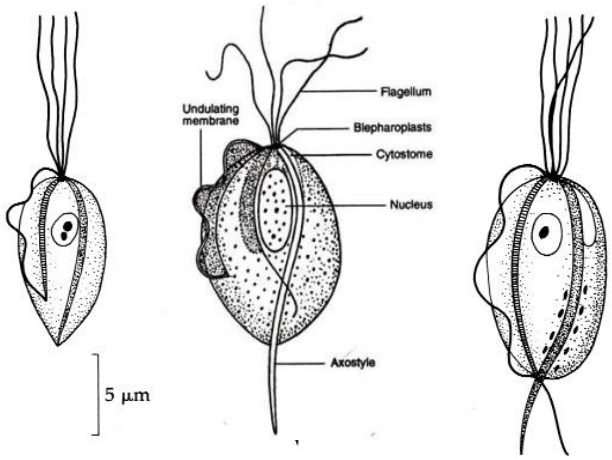


Fig. Morphology of Trichomonas tenax, Trichomonas vaginalis and Trichomonas hominis.

Pathogenicity. Clinical features. Trichomoniasis is symptomatic mainly in females, causing a vulvovaginitis. The symptoms include malodorous, yellow-green, frothy vaginal discharge, itching and burning sensation in urogenital region, lower abdominal discomfort. In addition, it may cause inflammation of urethra (urethritis), urinary bladder (cystitis) which express in dysuria (disorder of urination).

In males the infection is mainly asymptomatic or there may be urethritis, cystitis, prostatitis.

Diagnosis. Microscopic examination of trophozoites in the smear of vaginal discharge, and urethra of male patients.

Immunodiagnostics is applicable as well.

Prevention. Keep sexual hygiene. Avoid accidental sexual contact.

Class Ciliata

Ciliates are parasites which are covered by cilia as organs for locomotion. The only ciliate that infects man is *Balantidium coli*.

Balantidium coli

Balantidiasis is an anthropozoonosic, non-endemic, non-transmissive disease.

Geographical distribution. It is spread world-wide. Because pigs are an animal reservoir, human infections occur more frequently in areas where pigs are raised.

Habitat. The parasites inhabit in large intestine. They are chiefly lumen-dwellers, but may penetrate the intestinal mucosa to cause ulceration.

Morphology. The parasite has stages of trophozoite and cyst. *B. coli* is the largest protozoan, the trophozoites reaching up to 200 mkm (in average 60-70 mkm), the body is oval shaped, covered by cilia. The cell has specialized parts for ingestion: cell mouth (*cytostome*), a short *cytopharynx* and anus (*cytopyge*). It has two nuclei: macro- and micronucleus. The cysts are about 50-75 mkm, without cilia. The micronucleus takes part in conjugation (sexual reproduction). Macronucleus controls all the vital functions. Asexual reproduction occurs through binary fission.

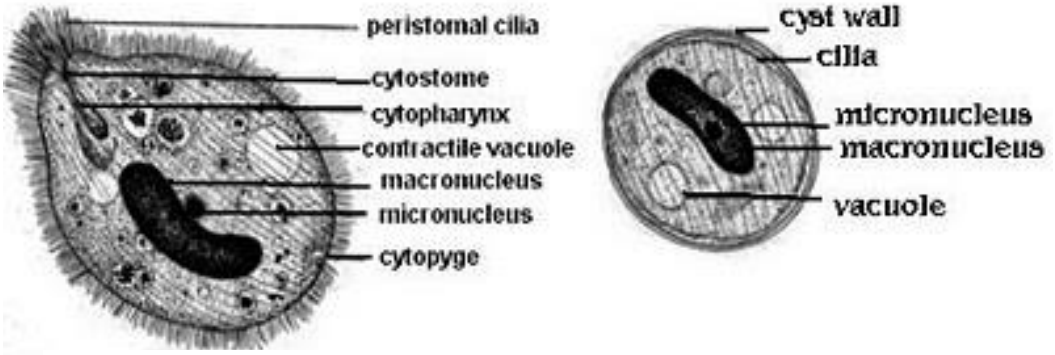


Fig. Morphology of Balantidium coli: trophozoite and cyst.

Life cycle. Balantidium affects humans and pigs, which are the reservoir hosts. Humans are infected on ingestion of cysts with contaminated food and water.

The trophozoites liberate from cysts in large intestine and may remain in the lumen or destruct the wall forming ulcers. Trophozoites and cysts are released with feces.

Pathogenesis. Clinical features. *B. coli* usually resides in the lumen of large intestine, but trophozoites can invade the mucosa of cecum and colon and cause ulcerations by proteolytic enzymes. The ulcers are not as deep as in ameobiasis, the bottom of the ulcer is not filled with pus and blood, the margins are star-shaped rather than smooth.

Many patients are asymptomatic carriers of infection. Clinically expressed cases may closely resemble severe amoebic dysentery. Liver abscess and peritonitis are usually not common compared to *E. histolytica*. Dysentery due to hemorrhaging (bleeding) can lead to anemia.

Diagnosis. Microscopic examination of feces, where trophozoites and cysts can be detected. *Balantidium coli* is passed periodically, therefore stool samples should be collected frequently and examined immediately.

Trophozoites can also be detected in large intestinal tissue through endoscopic examination of colon (colonoscopy).

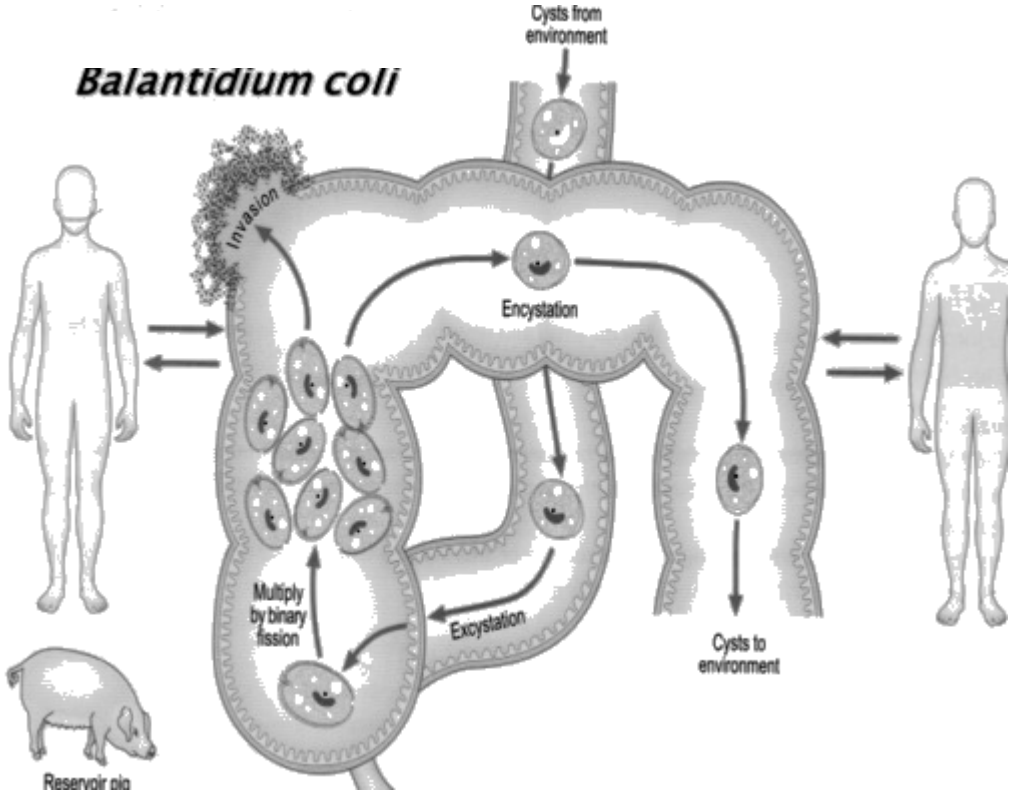


Fig. Life cycle of Balantidium coli.

Prophylaxis. Improved hygiene, using properly washed fruits and vegetables, water sanitation, and proper disposal of feces, fight against house flies, treatment of patients and asymptomatic carriers.

Class Sporozoa

The Sporozoa species are obligate intracellular parasites, which locate in tissue cells (*Toxoplasma*) or red blood cells (*Plasmodium*). They have no motility organelles but develop gliding motility and can penetrate into the cells due to the enzymes of their apical complex (*conoid*). Hence, they are referred to as also *Apicomplexa*.

Toxoplasma gondii

T. gondii belongs to order *Coccidia*. Toxoplasmosis, an anthropozoonosic non-transmissive, non-endemic disease.

Geographical distribution. *Toxoplasma gondii* is widely distributed in man and animals all over the world.

Morphology. *Toxoplasma gondii* trophozoite is 2-4 mkm (intracellular parasite), crescent-shaped, has a single nucleus, and an *apical complex* containing a *conoid* for penetration to host cell. Within a host cell the trophozoites reproduce asexually and form a ***pseudocyst***. When the host cell ruptures, trophozoites are released into extracellular space to multiply and now form a ***tissue cyst***.

Habitat. Mainly the brain, eye, muscles, lymph nodes, liver, lungs.

Life cycle. Cat is the definitive host, and can become also intermediate host; human and wide variety of mammals (pigs, beef, sheep, goat, rabbits) and birds serve as intermediate hosts.

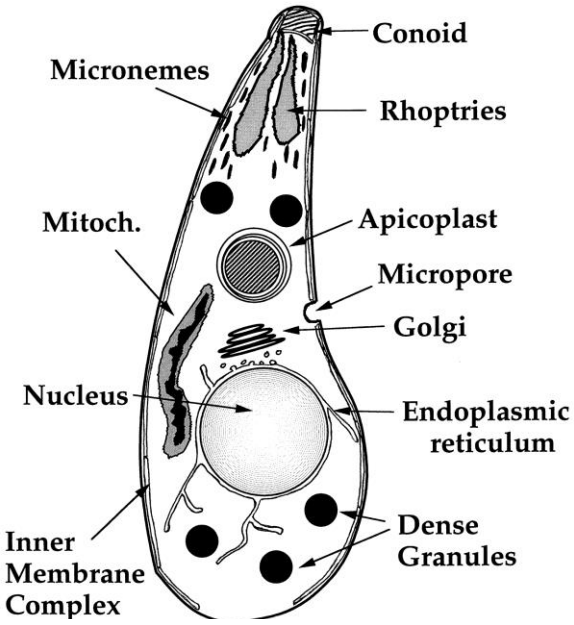


Fig. Morphology of Toxoplasma

Within cat organism the *Toxoplasma* can undergo both sexual and asexual stages. The sexual development occurs inside epithelial cells of small intestine. *T. gondii* first produces schizonts, merozoites, then gametocytes, gametes, and finally *oocysts* formed following fusion of male and female gametes (copulation – sexual reproduction). The oocysts are passed out through feces onto soil where they get mature in about 5 days when *sporogony* occurs, which forms 2 *sporocysts*. Each sporocyst gives rise to 4 *sporozoites*. Mechanical vectors can spread oocysts containing sporozoites (invasive stage).

Asexual development of *Toxoplasma* can occur both in the cat and intermediate hosts. After penetration *per os* or transplacentally, the trophozoites enter blood circulation and develop into a pseudocyst, then a tissue cyst in the visceral organs. The tissue cyst will later be covered by connective tissue capsule that can calcify (enriched by calcium salts).

Intermediate hosts, including human, are infected by toxoplasmosis in following modes:

1. transplacental transmission is the most important for humans (congenital toxoplasmosis).
2. through consumption of uncooked infected meat of domestic animals containing tissue cysts or pseudocysts; milk, eggs.
3. via ingestion of oocysts containing sporozoites (contaminated water, vegetables, fruits as well as children sandboxes contaminated by cat excrements) spread also by mechanical vectors.

Cats can also be infected by all these routes. *Canibalism* (feeding on the same species organisms) can spread the infection among intermediate hosts (e.g., mice, rats).

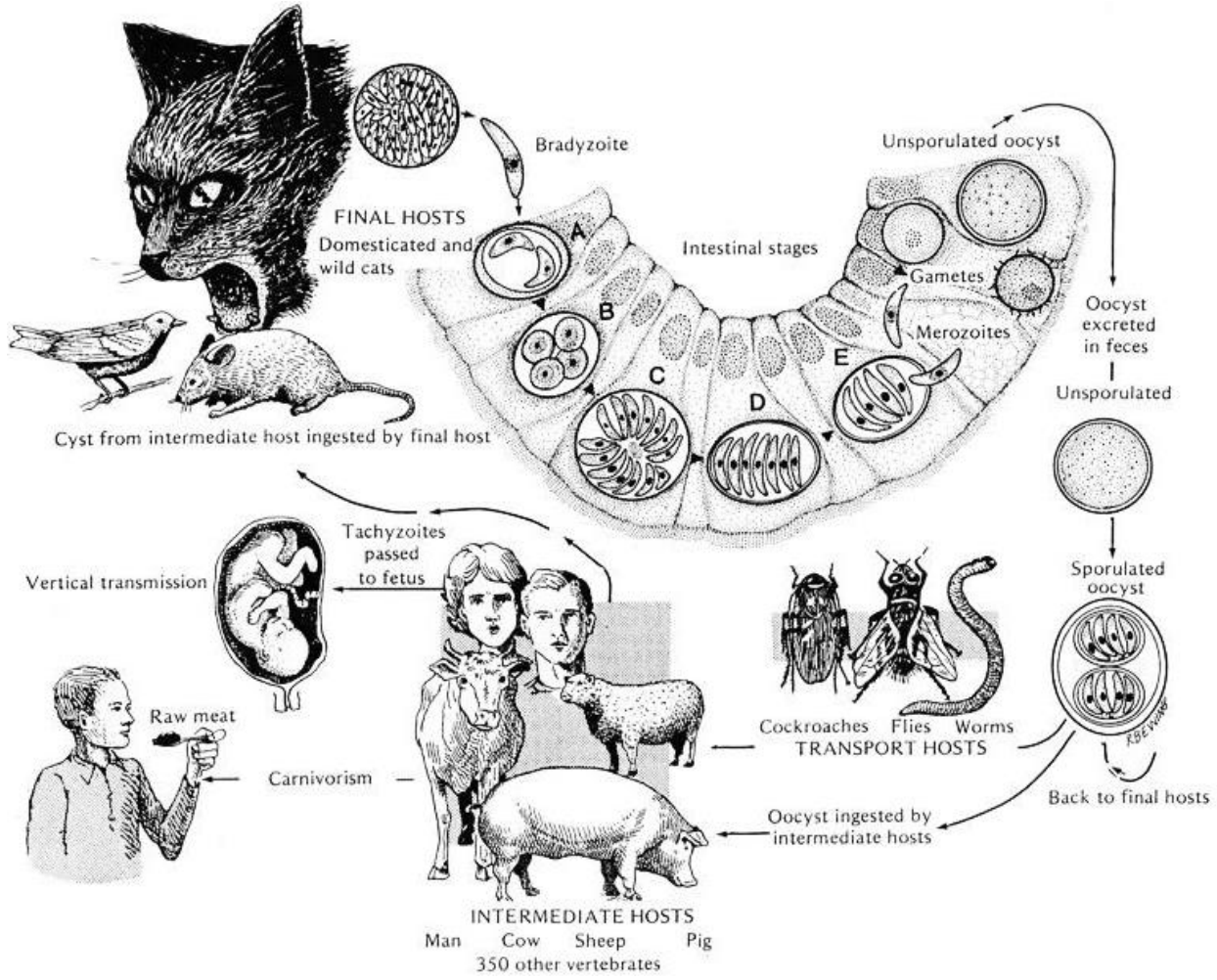


Fig. Life cycle of Toxoplasma gondii.

Pathogenesis. Clinical features. *Toxoplasma* usually parasitizes both definitive and intermediate hosts without producing clinical signs. In humans, severe disease is usually observed only in congenitally infected children and in immunosuppressed individuals and depends on the organs affected.

Congenital toxoplasmosis manifestations depend on the transmission period during pregnancy – the sooner the infection, the more severe the course is. Various inborn malformations can develop in early infections (teratogenic effect - *phenocopy*). *Toxoplasma* often infects the brain and eye retina.

Postnatally acquired infections in an organism with normal immunity develop toxic effects and lymphadenitis, which resolve in few weeks leading to asymptomatic carrier condition. The immunocompromized patients may present also with symptoms of affection of brain, eye, liver, heart, lungs.

Diagnosis.

- Microscopic examination of biopsy specimens from infected organs to find pseudocysts or tissue cysts.
- Immunological tests.

- PCR.
- X-ray and computed tomography techniques (CT-scan).

Prevention. Meat should be cooked and the milk boiled properly, and raw meat should never be fed to cats. Keeping hygiene for home cats. Washing vegetables, fruits, control of mechanical vectors. Children's sandboxes should be covered when not in use. Pregnant women should avoid exposure to cat and undercooked meat.

1. Which of the following parasites inhabits in large intestine?
   A. Trichomonas tenax
   B. Trichomonas hominis
   C. Lamblia intestinalis
   D. Trichomonas vaginalis
2. Trichomonads have:
   A. one flagellum
   B. four flagella
   C. 4 free flagella and an undulating membrane
   D. eight flagella
3. The disease caused by Lamblia intestinalis is:
   A. transmissive
   B. natural endemic
   C. infection
   D. anthroponosic
4. Balantidium coli inhabits in:
   A. large intestine
   B. duodenum
   C. mouth cavity
   D. genital tract
5. Trophozoites of Toxoplasma gondii:
   A. cause intestinal bleeding
   B. cause malabsorption of fat
   C. develop in intestinal epithelium of cat
   D. inhabit in duodenum

B

1. Infection of urogenital trichomoniasis is not caused through:
   A. sexual contact
   B. cysts
   C. common use of underwear
   D. not proper sterilized gynecological equipment
2. Lamblia intestinalis does not cause:
   A. inflammation of urinary bladder
   B. inflammation of intestinal mucus layer
   C. diarrhea
   D. malabsorption of fats
3. Which of the following is not common for Ciliata?
   A. encystations
   B. reproduction by sexual and asexual ways
   C. axostyle
   D. cytostome
4. Which of the following is not a clinical feature of balantidiasis?
   A. intestinal ulcers
   B. abdominal pain
   C. diarrhea
   D. muscle pain
5. Toxoplasmosis can not be diagnosed by:
   A. immunological reaction
   B. PCR
   C. duodenage
   D. finding antibodies in blood serum

II

1. Trichomonas vaginalis has:
   1. oval or pear-shaped body
   2. 4 free flagella
   3. 8 free flagella
   4. an undulating membrane
   5. sucking disk

   A. 1,2,4 B. 2,3,4 C. 3,4,5 D. 4,5
2. Lamblia intestinalis has:
   1. pear-shaped body
   2. bilateral symmetry
   3. axostyle
   4. 2 nuclei
   5. 8 flagellum

A. 1,3,4 B. 3,4,5 C. 1,4,5 D. 1,2,3,4,5

3. Balantidium coli:
   1. inhabits in small intestine
   2. causes bleeding ulcers of large intestine
   3. causes diarrhea
   4. causes inflammation of urinary bladder
   5. is intracellular parasite

   A. 1,4,5 B. 2,3 C. 2,4,5 D. 1,2,4
4. Human gets infection of toxoplasmosis through:
   1. infected meat of domestic animals

2. sexual contact
3. the bite of Phlebotomus sand fly
4. placenta
5. blood transfusion

A. 1,2,3 B. 1,4,5 C. 3,4,5 D. 3,5

5. Toxoplasmosis can be diagnosed by:

1. immunological reaction
2. examination of cerebrospinal fluid
3. stool examination
4. duodenage
5. aspiration of lymph nodes

A. 3,4 B. 3,4,5 C. 1,2,5 D. 1,

Chapter 19
Plasmodium species. Malaria

There are four species of malaria which infect man. *Plasmodium vivax, Plasmodium ovale*, *Plasmodium falciparum* and *Plasmodium malariae.* Malaria is an anthroponosic, transmissive disease.

Plasmodium species and malaria types in regard to fever periodicity.

Plasmodium species	Type of the malaria caused
P. vivax	Benign tertian
P. ovale	Ovale tertian
P. falciparum	Malignant tertian
P. malariae	Quartan

Geographical distribution. Malaria is non-endemic disease but parasites are found in areas with favourable humidity and temperature (above 16°C) conditions for breeding of the mosquito vector and development of the parasite in mosquito.

Habitat. The malarial plasmodium first develops in the liver cells, then the RBCs.

Life cycle. Plasmodium completes its life cycle in two hosts: *Anopheles* mosquito is a definitive host (copulation as the sexual reproduction of plasmodium occurs) and human as intermediate host (schizogony as asexual reproduction occurs).

Cycle of Plasmodium in human involves four stages: ***pre-erythrocytic, erythrocytic, exo-erythrocytic cycles*** and ***gametocytogony.***

Infection begins when the mosquito injects *sporozoites* (invasive stage for human) directly into the blood stream, from where they reach the liver starting the ***pre-erythrocytic stage (hepatic schizogony)***. The sporozoites invade hepatocytes (liver cells) and become a hepatic *trophozoite*. The young trophozoite is often called a *ring form* due to its morphology in a stained blood smear. The young trophozoite grows and divides by schizogony to give a hepatic *schizont* which develops many *merozoites*. After the hepatocyte is destructed, the merozoites pass to blood. In peripheral blood the ***erythrocytic cycle*** starts within RBCs, where the ring trophozoite grows and reproduces by schizogony to form a schizont. When the infected RBCs rupture, the merozoites are released into blood and invade new RBCs restarting the cycle. The growing trophozoite feeds on haemoglobin, which is broken down to give an iron haem pigment (*hemozoin*).

Each cycle of erythrocytic schizogony lasts for 48 hours for *P. vivax and P. ovale*, 36-48 hours (irregular course) for *P. falciparum* and 72 hours for *P. malariae*. The rupture of RBCs following the schizogony is accompanied by release of merozoites and destructed RBC particles into blood, which triggers toxic effect, that is the fever attack, which has the periodicity of 3 days (after every 48 hours) or 4 days (after every 72 hours) respective to the Plasmodium species.

After several erythrocytic cycles ***gametocytogony*** takes place: some of the trophozoites develop not into merozoites, but into *gametocyte.* The male gametocyte (*microgametocyte*) is smaller than female one, which is known as *macrogametocyte.* Gametocytes are invasive stage for the mosquito.

Exo-erythrocytic cycle: In *P. vivax* and *P. ovale* species some merozoites released through hepatic shcizogony in liver may re-enter the hepatocytes and remain dormant ("sleeping") for long time (about 2-3 years) as *hypnozoites*. This hypnozoite can reactivate and again undergo hepatic schizogony at a later time resulting in a ***relapse***; the merozoites appear in peripheral blood circulation and malarial attacks are reactivated.

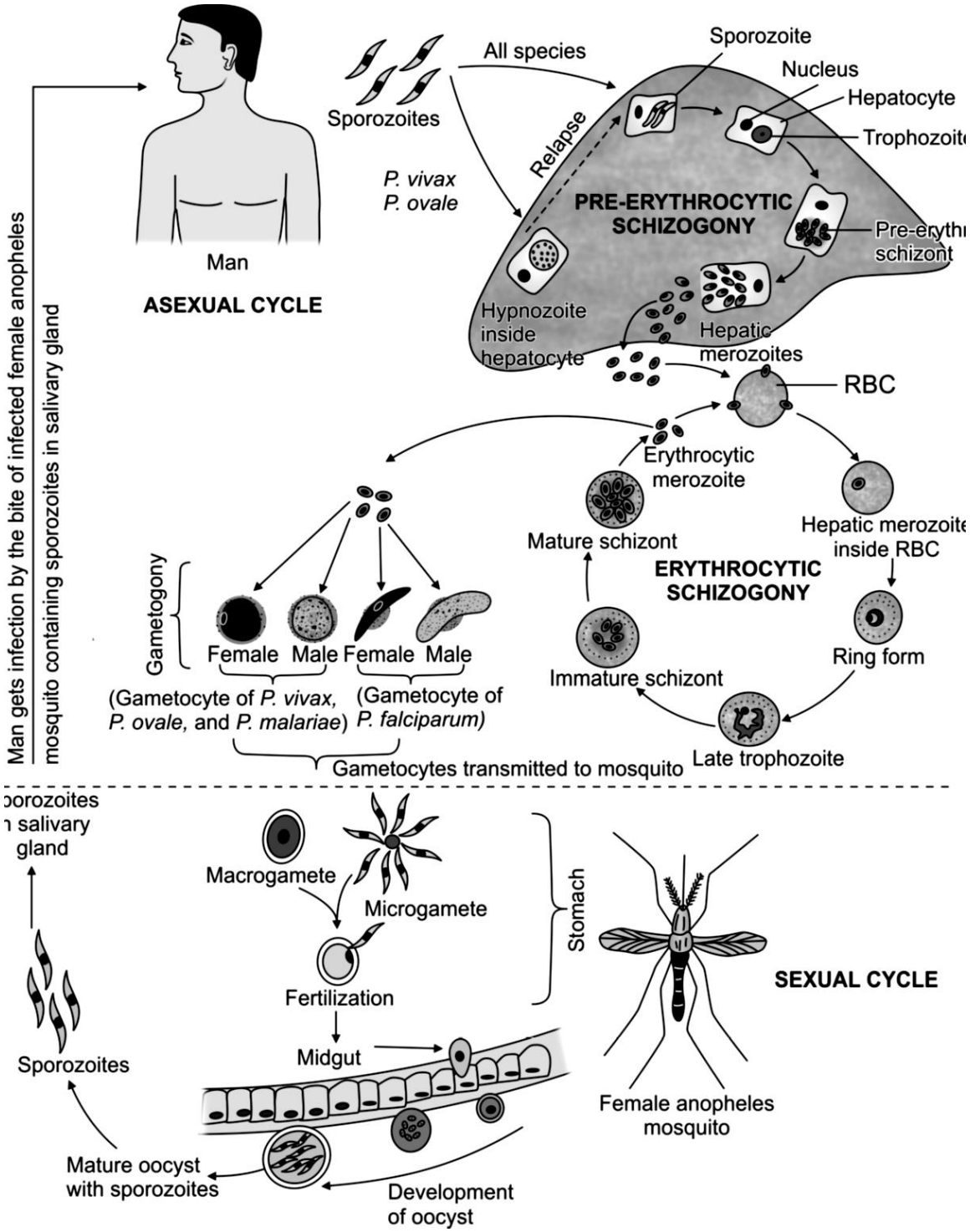


Fig. Life cycle of Plasmodium.

Cycle in mosquito: During the bite of female *Anopheles* mosquito gametocytes are taken up and mature into *macro-* and *microgametes* (***gametogony***). Gametes fuse to form a *zygote* (***copulation***), then a motile *ookinete* and finally an *oocyst*, in which the ***sporogony*** starts. The

oocyst divides and forms thousands of *sporozoites*. On the burst of oocyst the sporozoites migrate to salivary glands of mosquito and penetrate to human through the saliva of mosquito during the bite.

In addition to transmissive route, malaria can be transmitted also during blood transfusion or through placenta (transplacental route).

Pathogenicity. Clinical features. Pathology associated with all malarial species is related to the rupture of infected RBCs and release of parasites, their metabolites, hemozoin pigment and destructed RBCs into blood. All these cause a toxic effect that is manifested in periodic rise of temperature, or *fever paroxysms*.

Clinical manifestation involves: periodic fever paroxysms (attacks), anemia and hepatosplenomegaly.

Fever paroxysm involves *3* stages*: cold stage* - the patient feels cold and shivers (about an hour); *hot stage:* the temperature rises up to 40-41°C (for about 1-4 hours); s*weating stage* (for 2-4 hours) leads to temperature fall. Periodicity of paroxysms depends on schizogony duration in the given plasmodium species and is either at every next third or fourth day (tertian and quartan types, respectively). The period between 2 paroxysms (*apyrectic period*) corresponds to schizogony duration and lasts for either 48h or 72h.

Anemia is caused mainly due to hemolysis of RBCs parasitized by plasmodium.

Hepatosplenomegaly develop due to deposition of hemozoin pigment in the macrophage cells of spleen and liver, which leads to their enlargement.

Complications. are associated usually with *P. falciparum*. Higher pathogenicity of *P. falciparum* compared to other malarial species is provided by:

a) its schizogony in the capillaries of visceral organs (brain, heart, kidney, lung, etc.) and affection of theses organs due to abnormal blood supply;

b) antigenic variation;

c) affection of a single RBC by more than one plasmodium ring stages (multiple infection), which develops higher parasitemia and more toxic effect.

1. Cerebral malaria: It develops because of *P. falciparum* schizogony in cerebral capillaries, and can rapidly progress to coma and death if untreated.

2. Blackwater fever: It is characterized by sudden, massive hemolysis followed by fever and hemoglobinuria (hemoglobin from destructed RBCs leaves through injured renal capillaries to urine). The urine turns black, when next passed.

3. Hyperparasitemia: In common course of malaria about 2%-3% of RBCs are being affected. The parasitemia that exceeds affection of 10%-20% of the RBCs (hyperparasitemia) has a very high mortality rate from toxic shock if not treated immediately.

Immunity in malaria

There is no permanent immunity **acquired** after malarial infection, since it is *species-specific* (is effective only to certain species) and *stage-specific* (every morphological stage of plasmodium in human presents with specific sets of antigens).

Certain genotypes and genetic diseases are associated with decreased malarial infection or disease, and provide **innate immunity.** These are hemoglobinopathies (sickle-cell anemia, thalassemia), deficiency of glucose-6-phosphate dehydrogenase enzyme (an enzyme in RBCs), and Duffy-negative blood group. In first three cases Plasmodium cannot reproduce within RBCs

with abnormal structure, while Duffy-negative blood group people (mainly Africans) miss the RBC antigen, which should help penetration of *P. vivax*.

Diagnosis. Plasmodium can be identified by microscopic examination of thick and thin blood smears, where all morphological stages can be found. Blood smear is taken usually during fever attack or shortly after that. While a thick film is for the quick detection of the parasite, a thin smear helps in the differentiation and identification of the species. It is important to identify infection caused by *P. falciparum* from other 3 species because *P. falciparum* causes highly pathogenic and requires a specific treatment.

Immunological tests and PCR can also be used in malaria diagnosis and for differentiation of species.

Morphological characteristics of Plasmodium species in blood smear

P. falciparum

a. presence of only ring forms and gametocytes in peripheral blood. This is because schizogony occurs in capillaries of internal organs.
b. ring stages of *P. falciparum* tend to be slightly smaller than the other species and are generally 2-3 within one RBC (multiple infection).
c. number of merozoites developed from a schizont: 20-24 (up to 36).
d. gametocytes are crescent-shaped ("*falx*" means sickle), they sometimes seem to extend the margins of erythrocyte.

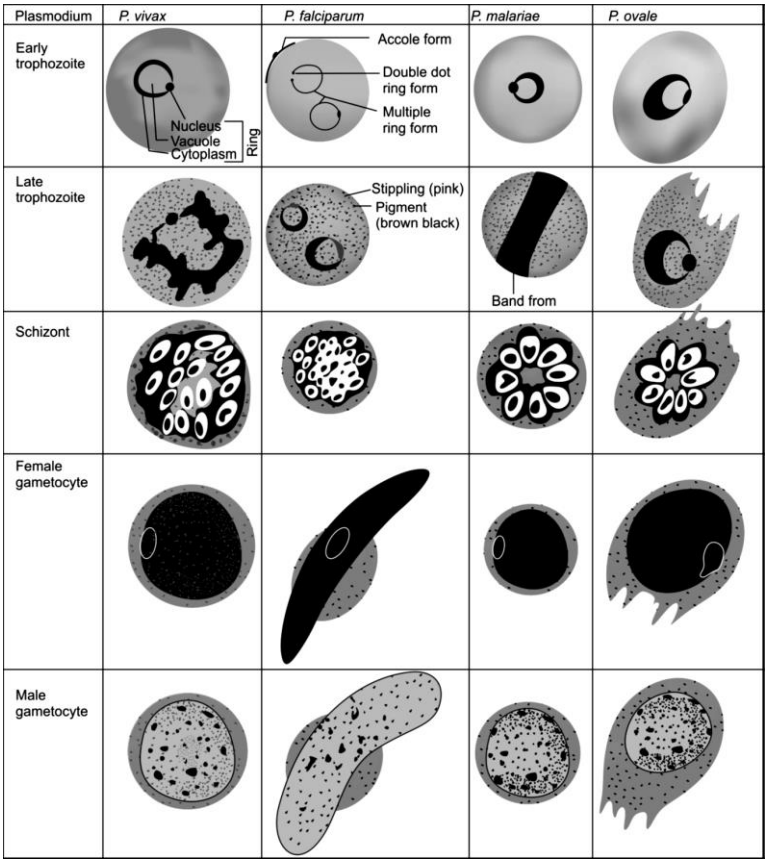


Fig. Morphological stages of development of Plasmodium species in RBCs.

P. vivax

a. infected erythrocytes are enlarged
b. growing trophozoite of *P. vivax* often has an amoeboid appearance
c. number of merozoites: 20-24.

P. ovale

a. enlarged oval-shaped erythrocyte with ragged margins
b. number of merozoites: 12-18.

P. malariae

a. the infected erythrocytes are not enlarged
b. elongated trophozoites stretch across the erythrocyte and are called *band* forms
c. number of merozoites: 6-12, arranged in a rosette pattern.

Prevention and Control. Strategies for preventing and controlling malaria involve three different approaches:

1. avoid the bite of mosquitoes by:

a) bed nets, repellents.
b) using insecticides,
c) elimination of mosquitoes by draining the swamps and marshes (the breeding sites of mosquitoes).
d) introduction of *Gambusia* fish feeding on larvae of mosquito to breeding sites of the insect,
e) introduction of bacteria whose toxins kill mosquito larva,
f) covering the aquatic media with oil to kill the larvae of mosquitoes (they require oxygen).

2. detection and treatment of patients (quinine).

3. chemoprophylaxis: systemic use of antimalarial drugs started prior to travel to an endemic area.

A

1. The definitive host of malarial parasite is:
   A. Glossina palpalis
   B. Glossina morsitans
   C. Anopheles mosquito
   D. Phlepotomus sandfly
2. The human gets malarial infection through the bite of:
   A. sand fly
   B. tse-tse fly
   C. reduviid bug
   D. mosquito
3. Which stage of Plasmodium is infective for human?
   A. merozoite
   B. hepatic schizont
   C. sporozoite
   D. erythrocytic schizont
4. How many hours take erythrocytic schizogony of P. vivax?
   A. 72
   B. 48
   C. 24
   D. 12
5. Inside of oocyst occurs:
   A. sporogony
   B. schizogony
   C. budding
   D. amitosis

B

1. Which stage is not found in Plasmodium?
   A. sporozoies
   B. merozoites
   C. amastigotes
   D. schizonts
2. Which stage is absent in life cycle of P. vivax?
   A. ring form schizont
   B. amoeboid schizont
   C. merozoit
   D. band form schizont
3. Which of the followings can not characterize P. falciparum?

A. it causes malignant malaria
B. erythrocytic schizogony occurs in capillaries of visceral organs
C. it causes disorders of blood circulation of brain
D. erythrocytic schizogony lasts for 72 hours

4. Which of the followings is not a clinical feature of malaria?
   A. periodic fever paroxysms
   B. somnolence
   C. anemia
   D. hepatomegaly
5. Which of these morphological peculiarities can not characterize P. malariae?
   A. sizes of affected erythrocytes are not changed
   B. mature schizont gives arise to 6-10 merozoites
   C. number of merozoites in mature schizont is 12-24
   D. large granules of pigments is found in gametocytes

II

1. Malaria is:
   1. obligatory-transmissive disease
   2. facultative-transmissive disease
   3. anthroponosis
   4. anthropozoonosis
   5. spread in hot and humid regions

   A. 1,3,5 B. 2 C. 3,4 D. 2,3,5
2. P. vivax can:
   1. enlarge the sizes of RBC
   2. produce 6-12 merozoites
   3. produce 20-24 merozoites
   4. have band form schizont
   5. have ring form schizont

   A. 2,5 B. 1,4 C. 1,3,5 D. 1,2,4
3. What is the way of human malarial infection?
   1. transmissive
   2. transplacental
   3. per os
   4. blood transfusion
   5. transovorial

   A. 1,2,3 B. 2,3,4 C. 1,2,4 D. 4,5
4. Innate immunity to malaria is based on:
   1. glucose-6-phosphate dehydrogenase enzyme deficiency
   2. injection of antibodies
   3. lack of Duffy antigens
   4. multiple infections of malaria
   5. transplacentar infection

   A. 3,4,5 B. 1,4,5 C. 3,5 D. 1,3
5. Which of the following protozoa inhabit in large intestine?
   1. Lamblia intestinalis
   2. Balantidium coli
   3. Trichomonas tenax
   4. Trichomonas hominis
   5. Entamoeba histolytica

   A. 1,2,3 B. 1,3,5 C. 2,4,5 D. 3,5

Chapter 20

Medical Helminthology

The term *helminth* derived from *Greek* language meaning worm. The helminthes are multicellular, bilaterally symmetrical parasites having three germ layers – ectoderm, mesoderm and entoderm.

The characteristic features of helminthes are following:

1. The outer covering, known as cuticle is tough. It is resistant to intestinal digestion and may be armed with spines or hooks.
2. Digestive system is absent or underdeveloped.
3. Nervous system is primitive.
4. Reproductive system is well developed. The parasites may be monoecious (hermaphrodite) or dioecious (sexual dimorphism).
5. They produce eggs in great amounts to help them survive and infect a suitable host.
6. They do not possess organs of locomotion. They generally move by muscular contraction and relaxation.

Classification of Helminthes

The helminthes of medical importance are classified into two phylums:

1. *Phylum* *Platyhelminthes (Flat worms)*
   Classes: Cestoda (Tape worms)
   Trematoda (Fluke worms)
2. *Phylum Nemathelminthes (Round worms)*
   Class: Nematoda (Round worms)

Diseases caused by helminthes are generally referred to as **helminthoses** (*sing.* helminthosis).

In regard to the life cycle there are mainly two types of helminthes: **geohelminthes** and **biohelminthes**. Geohelminthes start their life cycle in soil (***geo*** - soil) and complete it in one host organism. Biohelminthes pass the life cycle only in living hosts (***bios*** - life), two or more hosts are required for completion of whole cycle. All the flat worms are biohelminthes, and the round worms have both biohelminth and geohelminth species.

A specific group of helminthes is defined, whose life cycle is completed in one host as with geohelminthes, however, their eggs do not require soil for maturation as with biohelminthes. These worms infect humans through hand contact (e.g., dwarf tapeworm *Hymenolepis nana*, pinworm or *Enterobius vermicularis*), and the diseases are known as ***contact helminthosis***.

Pathology of Helminthoses

An important difference between infestation with helminthes and infection with bacterial, viral or protozoan parasites is that the helminth parasites do not increase in numbers within their host after infection. That is, each larval helminth that infects the definitive host will give rise to only one adult parasite. Exceptions are the cases of autoinfection (reinfection with egg or larvae produced by helminthes already in the body) which can increase the parasite burden.

All of the helminthes are endoparasites. Pathology with infection of helminthes may be due to a number of reasons, including:

1. **Mechanical affection**. Obstruction of the gut (*Ascaris*) and causing *ileus*. Some helminthes may also press surrounding tissues in their larval stage (e.g., hydatid cyst of *Echinococcus*).
2. **Depletion of nutrients and vitamins.** For example, undernourishment caused by intestinal helminthes that have large sizes reaching more than 10 m; vitamin B_{12} depletion, leading to anaemia with infection by *Diphyllobothrium latum*; hypovitaminosis A in *Ascaris* infection).
3. **Anaemia** caused by helminth-parasites feeding on blood (for example, infection with hookworms, *Trichuris trichiura*)
4. **Allergic responses** to adult, larval or egg stages of the helminth lifecycle (for example with the *Echinococcus*, *Ascaris*). Larval stages of human species of helminthes that migrate during their life cycle cause both local inflammatory alterations in the organs through which they pass (e.g., *Ascaris* causes lung inflammation - pneumonitis) and general allergic reactions.
5. **Toxic effect** is common for many helminthes, especially Ascaris, tapeworms.

Phylum Platyhelminthes (Flat worms)

Class Trematoda (Fluke worms)

The flat worms are identified in respect to dorso-ventrally flattened body, which is either leaf-shaped (Trematoda) or tape-shaped (Cestoda).

Morphology of Trematoda

Trematodes or fluke worms are members of phylum Platyhelminthes (flat worms). Their body is flat, leaf-shaped, the size ranging between few millimeters and centimeters. Usually two muscular suckers (oral and ventral) are present. The alimentary tract is incomplete, starting with mouth and having no anus (intestines end up blind). Reproductive system is highly developed. Trematodes are hermaphrodites except for blood flukes (schistosomes). The eggs of most trematodes are operculated (have a lid) except for schistosomes.

Reproductive System: In monoecious trematodes there are both female and male reproductive systems. Female reproductive organs consist of single ovary and its duct, two vitellaria (yolk glands) and vitelline ducts on either side, vagina, uterus, seminal receptacle, ootype and Mehli's gland. Fertilization occurs in the ootype. The male reproductive system consists of two testes, seminal vesicle, cirrus. Sperms are discharged into female reproductive system by cirrus, which serves as the organ for copulation.

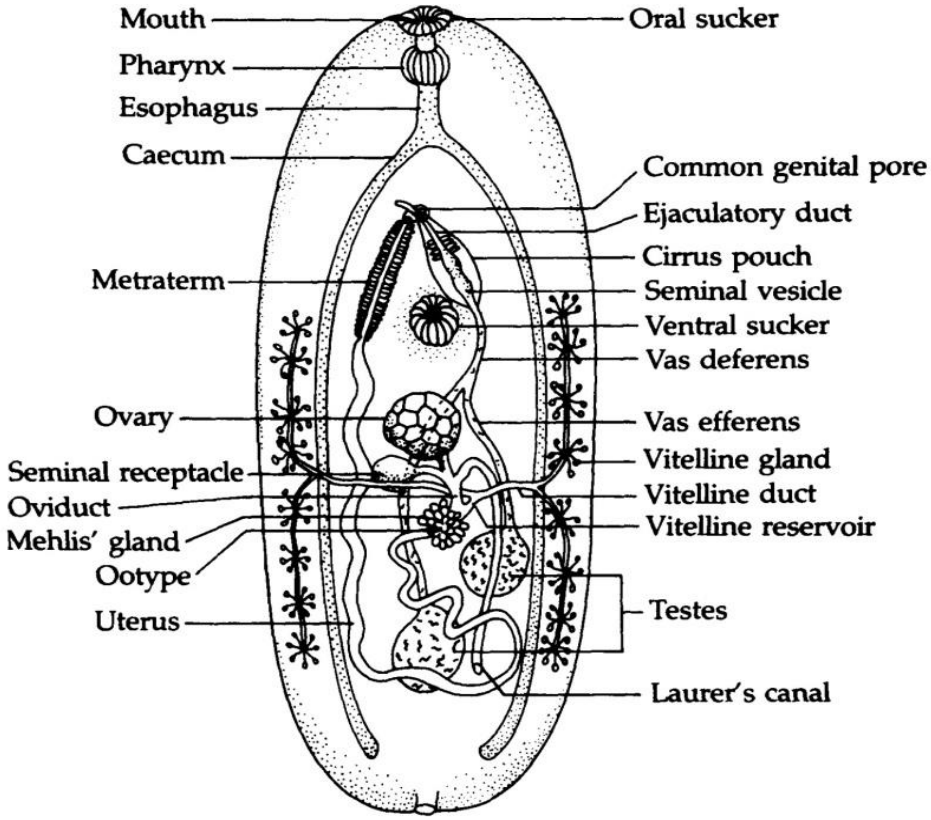


Fig. General morphology of a trematode.

General Life Cycle of Trematoda

All Trematode species are biohelminthes and develop by alternation of hosts and develop adult, egg and larval stages. Definitive hosts can be the humans and sometimes animals (mammals) which harbour the adult worm called ***marita***. The first or the only intermediate host is the freshwater snail. A second intermediate host (fish, crab or ant) in the life cycle of some flukes is sometimes required.

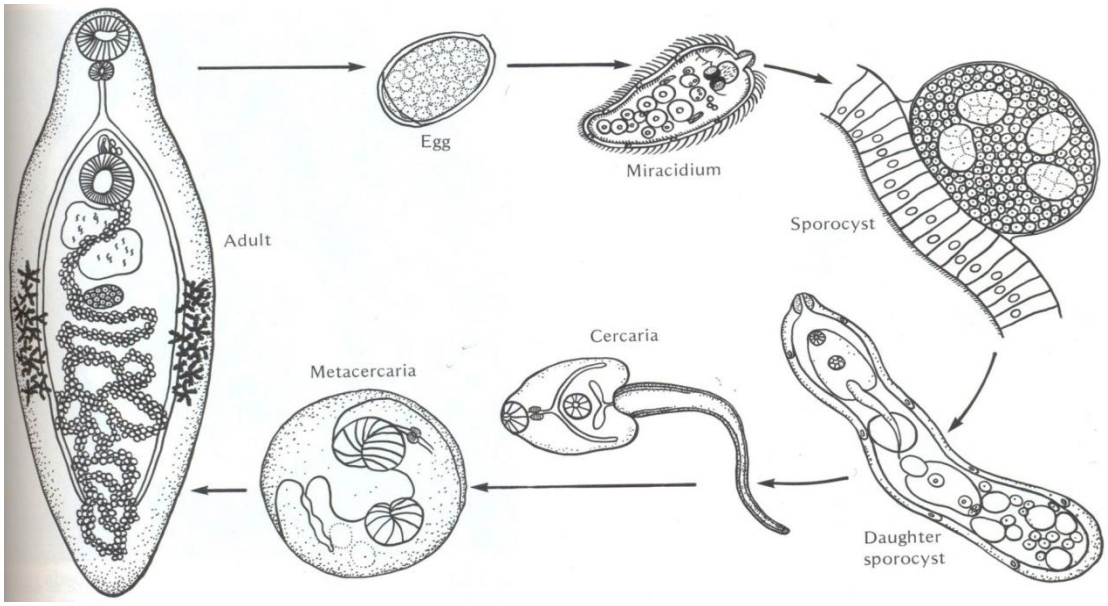
The eggs liberated by the definitive host usually pass to water. A ciliated embryo called *miracidium* develops from the egg. It enters the intermediate host (snail), where larval stages of *sporocyst, redia* and *cercaria*. The *cercaria* escapes from the snail into the water and, depending on the species, may:

- encyst on aquatic vegetation transforming into *adolescaria*,
- enter the second intermediate host (if present) and transform into *metacercaria*,

- directly infect definitive host in case of Schistosomes.

Man is infected by one of these invasive stages depending on the species.

On entering the definitive host, the young worms proceed to their sites of localization to grow into *marita* (adult worm), become sexually mature and repeat the cycle.



The trematodes are **classified** according to the habitat in the definitive host. They are as following:

1. Liver flukes (*Fasciola hepatica, Clonorchis sinensis, Opisthorchis felineus, Dicrocoelium lanceatum*).
2. Lung fluke (*Paragonimus westermani*).
3. Blood flukes (*Schistosoma mansoni, Schistosoma haematobium, Schistosoma japonicum*).

Liver Flukes

Fasciola hepatica

Fasciolosis is an anthropozoonosic, non-endemic disease. Fasciola hepatica or sheep liver fluke is common parasite of herbivores, it is rare in humans.

Geographical distribution. Worldwide.

Habitat. The parasite lives in bile passages of liver.

Morphology. The adult worm is a large leaf-shaped fluke, measuring 3-4 cm. Eggs are large (about 140 mkm), ovoid, and operculated.

Life cycle. Definitive hosts are herbivorous animals (sheep, cattle, goat), occasionally man. Intermediate host is freshwater snail. In definitive host the eggs are laid in the bile ducts of liver, from where they reach the intestine and pass out by feces. Invasive stage for definitive host is *adolescaria*. Humans are infected by using water or aquatic plants contaminated by adolescaria. In bile passages the adult worm develops, and the eggs are liberated in the feces through the bile.

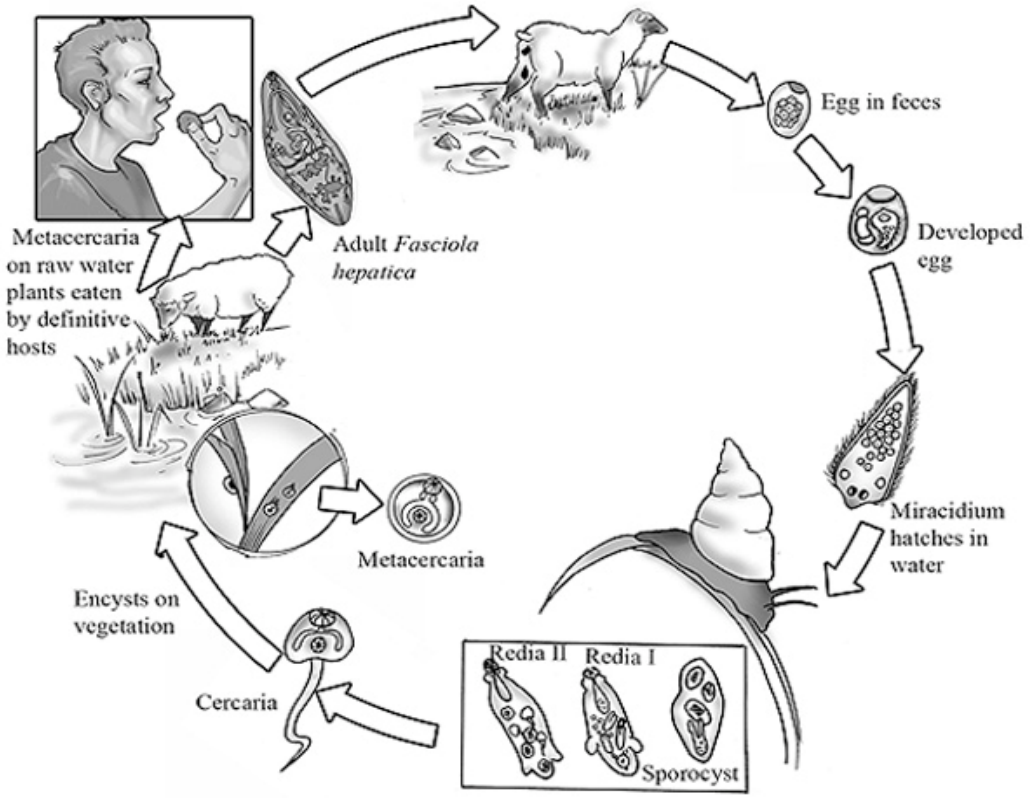


Fig. General life cycle of trematodes.

Pathogenicity. Clinical symptoms. Nausea, vomiting, fever, pain, allergic reactions, diarrhea and hepatomegaly. If the flukes block the bile ducts then obstructive jaundice may develop. In complicated cases fasciola may lead to liver cirrhosis (replacement of destructed liver tissue with connective tissue) and hepatic failure.

Diagnosis. Demonstration of eggs in stool or bile obtained by duodenal intubation. False diagnosis may be made when "*transient eggs*" are found in feces of people who consume raw infected liver of animals. For confirmation or rejection of the suspected diagnosis of fasciolosis the person is asked to stop eating raw liver for about a week, and the stool is re-examined again.

Prevention. Humans should avoid eating unwashed vegetables, fruits and drinking contaminated water. Eradication of the disease in the reservoir hosts, draining fields to prevent snails.

Clonorchis sinensis

The Chinese liver fluke, *Clonorchis sinensis* causes clonorchosis, which is endemic and anthropozoonosic.

Geographical distribution. China, Japan.

Habitat. Bile ducts.

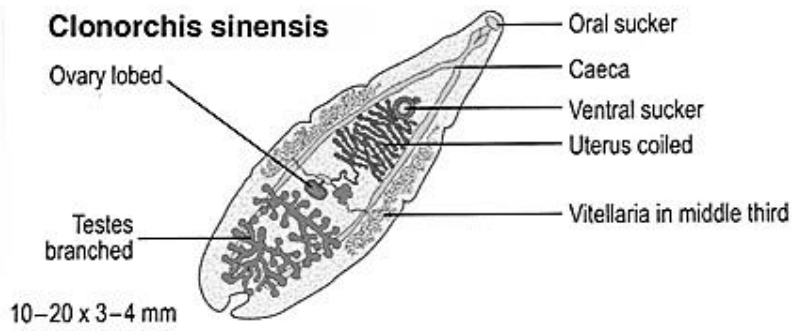


Fig. Morphology of Clonorchis sinensis.

Morphology. The adult worm is about 1 cm, narrower than *F. hepatica*. The egg is operculated, measures 25-30 mkm.

Life cycle. Definitive host is man, dog, cat and pig. First intermediate host is freshwater snail, the second intermediate host is fresh water fish. The eggs are passed out in feces and are

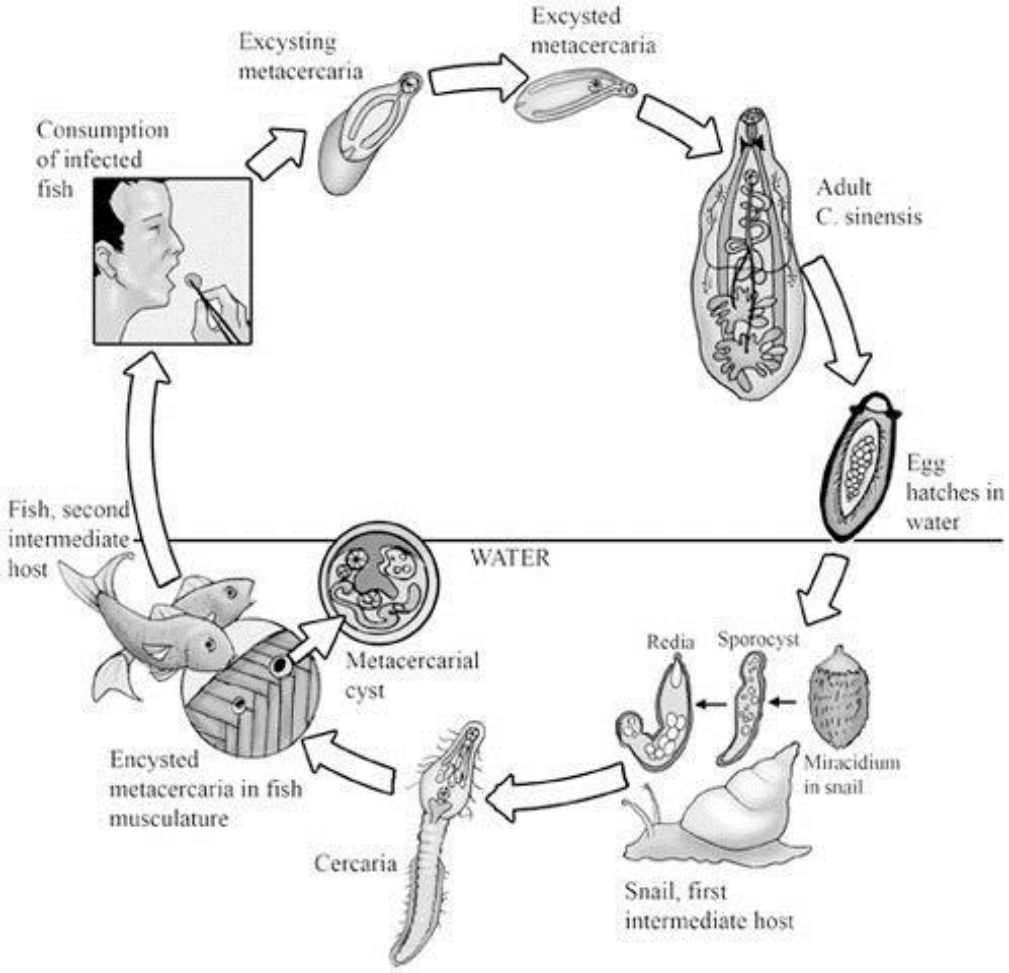


Fig. Life cycle of Clonorchis sinensis.

ingested by snail. In the freshwater fish the cercariae transform into *metacercariae*, which are invasive for definitive host. Humans are infected when ingesting raw, slightly salted, frozen or undercooked fish. The young flukes excyst in the duodenum from where they migrate to the bile ducts.

Pathogenicity. Clinical features. Light infections are asymptomatic but numerous parasites in liver can lead to diarrhea, hepatomegaly, allergic reactions. Obstruction of bile passages may result in obstructive jaundice, cholecystitis (inflammation of gall bladder), formation of bile stones, pancreatitis.

Diagnosis. Demonstration of eggs by microscopical examination of feces and also during duodenage.

Prophylaxis. Prevention of water pollution with feces of humans and reservoir hosts, eradication of snails, proper cooking of fish.

Opisthorchis felineus

As the name suggests, *Opisthorchis felineus* parasitizes mainly cats (cat liver fluke), so it is an anthropozoonosis. In humans it is a cause of opisthorchosis.

Geographical distribution. Central and Eastern Europe, Siberia.

Habitat, morphology, life cycle, clinical symptoms, diagnosis and prevention. are likewise similar with Clonorchis. The adult *O. felineus* differs from *C. sinensis* only in some minor details: the testes of cat liver fluke are not branched.

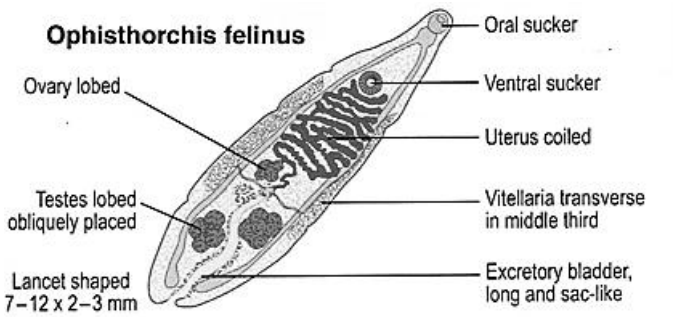


Fig. Morphology of Opisthorchis felineus.

Dicrocoelium lanceatum

Dicrocoelium lanceatum is a parasite of mainly herbivorous animals and is uncommon in humans (anthropozoonosic).

Geographical distribution. *D. lanceatum* is prevalent in many parts of the world.

Habitat. *Dicrocoelium* locates in bile tract of liver in herbivores (sheep) and occasionally human.

Morphology. Adult worms are 0.5-1.5 cm long, characteristic feature is the anterior location of testes. Eggs are about 40 mkm, asymmetric, dark-brown and have an operculated shell.

Life cycle. Definitive hosts are mainly herbivores, human is infected rarely. First intermediate hosts is the land snail, second is the ant. The eggs that are liberated by adult flukes and eliminate with feces. Land snails release the cercariae in slime balls on the grass where the ants eat the cercariae that develop into metacercariae within their abdominal cavity.

The infected ants change their behavior by climbing and attaching themselves to the tops of grass blades, where they can be easily ingested by herbivorous definitive hosts. Human infection is rare and occurs after accidental ingestion of infected ants.

Clinical symptoms. *D. lanceatum* is similar to *Clonorchis* as regards pathogenic lesions it produces.

Diagnosis is based on observation of eggs in feces, bile or duodenal fluid. Transient eggs in "false" infection should be excluded.

Prevention. Avoid accidental ingestion of infected ants.

Lung Fluke

Paragonimus westermani

The disease caused is known as paragonimosis, which is endemic and anthropozoonosic.

Geographical distribution. India, China, Japan, Korea.

Habitat. Adult worm resides in small bronchi (bronchioles) of human.

Morphology. Adult fluke is about 1 cm, reddish-brown, thick, oval-shaped. The eggs are yellow-brown, oval, with operculum.

Life cycle. The definitive hosts are humans, cats, dogs and wild carnivores. First intermediate host is freshwater snail, second intermediate host is freshwater crab or crayfish. Eggs are passed either directly in the sputum when coughing, or may be swallowed then passed in the feces. The cercariae penetrate the crab or crayfish where they encyst as metacercaria, which is the invasive stage for human. Infection of the humans takes place by eating raw or pickled crabs or crayfish. The metacercaria excyst in the duodenum, young flukes penetrate through the intestinal wall into the abdominal cavity, from where they migrate to the diaphragm directly and enter the lungs. Eggs are discharged into bronchioles and are coughed out with the sputum.

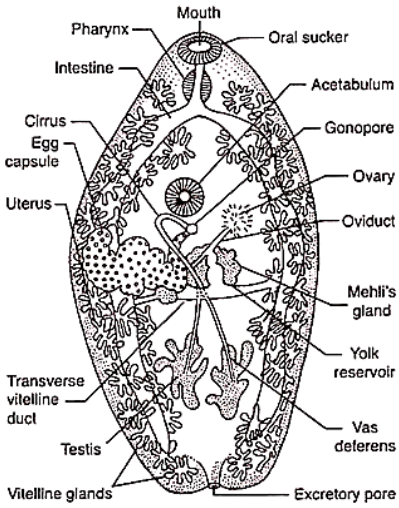


Fig. Morphology of Paragonimus westermani.

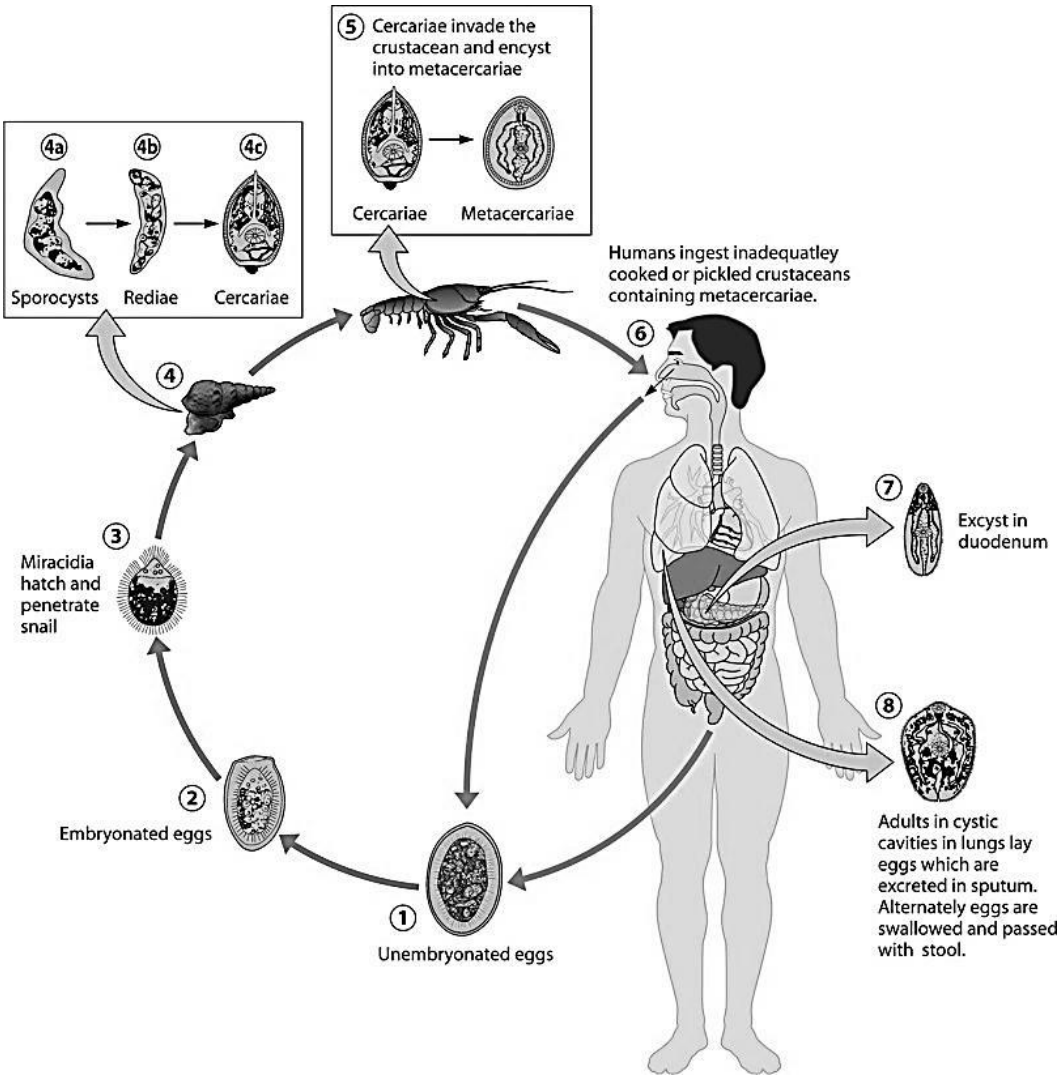


Fig. Life cycle of Paragonimus westermani.

Pathogenicity. Clinical features. The adult worms are encysted in pairs and cause "burrows" in lungs. The eggs may retain in the lung tissue and along with adults cause lung inflammation – pneumonia.

The initial symptoms include fever, cough, chest pain, shortness of breath, allergic reactions. The sputum is usually blood-stinged (***hemoptysis***), and this symptom may closely resemble pulmonary tuberculosis.

In complicated cases the fluke may enter other parts of the body such as brain *(cerebral paragonimosis)*, spinal cord, subcutaneous tissues, liver, and here eggs are discharged.

Diagnosis. Identification of eggs in sputum or feces. The pulmonary paragonimosis should be differentiated from pulmonary tuberculosis. In the latter no eggs are found in sputum, and eosinophilia is absent.

Prevention. Proper cooking of crabs and crayfish, diagnosis and treatment of infected individuals, destruction of freshwater snails as intermediate hosts.

Chapter 21
Blood Flukes (Schistosomes).
Class Cestoda (Diphyllobothrium latum, Taenia solium)

Blood Flukes (Schistosomes)

There are three major species of schistosome infecting humans: *Schistosoma mansoni, Schistosoma haematobium, Schistosoma japonicum. Schistosoma mansoni* and *S. haematobium* are found in Africa and the schistosomosis caused by these two species is known also as *bilharziasis*.

General characteristics of Schistosomes

Morphology

1. Schistosomes are dioecious (have two sexes), with the female being longer and more slender than the male. Average size is 1-2 cm. The species are identified by tuberculations on the male adults.
2. The groove (gynecophoric canal) created by the fold in the male schistosome provides a place for mating with the female.
3. Their flat body is curled up cylindrically to fit the shape of the blood vessels.
4. Schistosomes live in the veins draining the abdominal organs (mesenteric veins and the portal vein) or pelvic plexus. Antigenic masking and molecular mimicry help them to escape from host's immune response. They attach themselves to the walls of the blood vessels by means of their suckers and, after mating, lay their eggs into the blood stream.

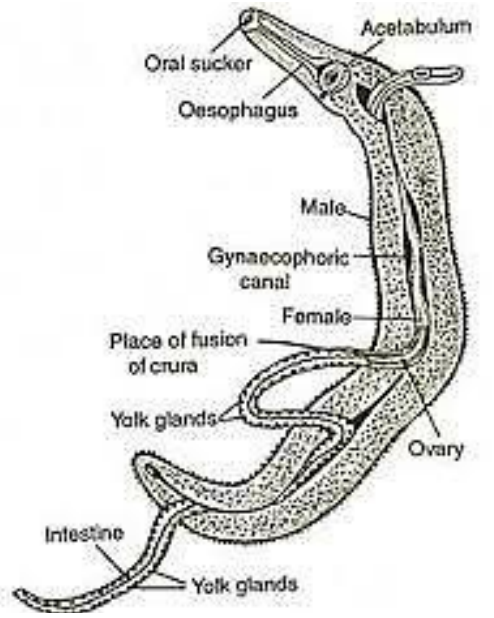


Fig. Morphology of Schistosomes.

5. Schistosome eggs are transparent, are non-operculated, instead they have a spine which perforates the wall of blood vessel, and the eggs gradually move through the tissue until they pass out with the feces or urine.

Life cycle

The fork-tailed cercariae are invasive for humans and emerge from the snail (single intermediate host) in water penetrating actively the skin of the definitive host. The females deposit eggs in the small venules of portal system and venules that collect blood from urinary system. Oviposition occurs during hot day time (usually after noon) when the swimming of definitive hosts is most probable in the warmed-up water of ponds (synchronization of parasite and host activities).

The eggs move toward the lumen of intestine (*S. mansoni* and *S. japonicum*) or urinary bladder (*S. haematobium*), and are eliminated into water with feces or urine, respectively. The eggs release miracidia, which swim and penetrate the snail. After two sporocyst stages cercaria develop in snail (redia are absent) and release into water, actively penetrating through skin of

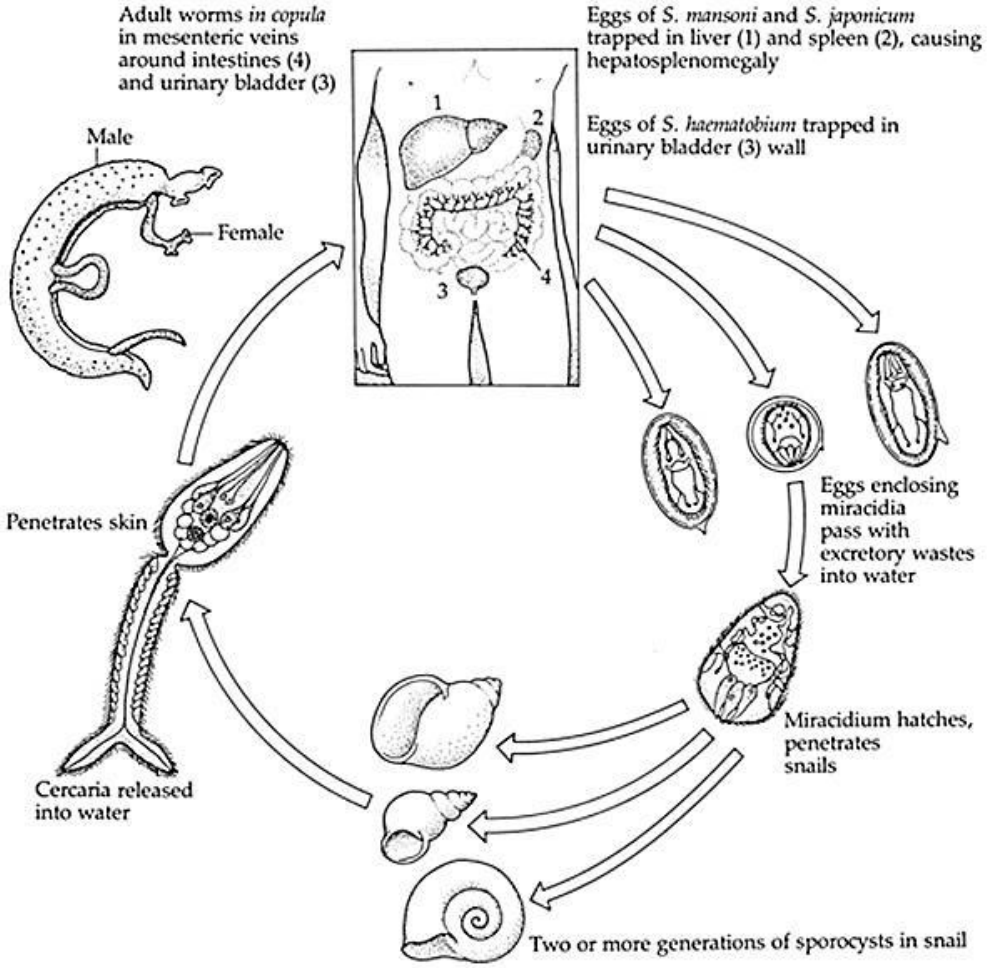


Fig. Life cycle of Schistosomes.

the human. From peripheral blood the young flukes reach the liver veins where adults mature and move to the veins of specific habitat (intestines or urinary bladder).

Pathogenicity and Clinical Symptoms. The pathogenic effects in all types of schistosomosis are divided into three groups:

1. Symptoms caused by cercariae, which at the site of penetration induce local allergic reaction known as *swimmers' itch*.

2. Pathology caused by toxic metabolites liberated during the growth of schistosomes in the liver develops during acute stage of infection. General allergic and toxic reaction characterized by fever, skin rash, eosinophilia, enlarged liver and spleen.

3. Egg-induced effects develop in chronic stage of the infection when the schistosome eggs are trapped trigger in the wall of intestine or urinary bladder and trigger granular tissue overgrowth and formation of benign tumors (polyps) around the eggs lodged. Complicated

schistosomosis presents with malignization of polyps and development of intestinal or cystic cancer.

Prevention. Treatment of the disease in humans, prevention of pollution of water with human excreta, avoidance of swimming, bathing, or washing in infected water, elimination of snails.

Schistosoma mansoni

It is the cause of intestinal schistosomosis (bilharziasis), which is endemic, anthroponosic disease.

Geographical distribution. South America, Central Africa, and the Middle East.

Habitat. Adult worms reside in the veins of large intestine.

Morphology. Females are 1.5-2 cm long. The cuticle in male is grossly tuberculated. The eggs are the largest among three species, with a large lateral spine.

Pathogenicity, clinical symptoms. Acute stage is the same as in any schistosomosis (see above). During chronic stage the pathology is associated with formation of granulomas around trapped eggs lodged in the intestinal wall. Rupture of intestinal vessels by the eggs leads to *dysenteric* attack. Intestinal polyps may develop in chronic stage and later may malignize if not treated.

Diagnosis. Demonstration of eggs in feces is useful during acute stage of infection. In later period eggs may not be found in feces, and rectal biopsy is performed to demonstrate the eggs in the tissue of large intestine (rectum).

Schistosoma haematobium

It is the agent of urinary shcistosomosis or bilharziasis, an endemic, anthroponosic disease.

Geographical distribution. It has spread throughout Africa and Middle East.

Habitat. Veins of urinary bladder.

Morphology. Adult females may reach 2 cm, and the males 1.5 cm. The male body is finely tuberculated. The eggs have a terminal spine.

Pathogenicity. Clinical features. Species-specific symptoms of *S. haematobium* are provided by eggs, which cause inflammation of urinary bladder (cystitis) and erode the blood vessels causing cystic hemorrhage leading to *hematuria* (blood in urine). When the eggs deposit in the bladder wall they cause cystic polyps. The benign polyps may undergo malignant transformation leading to cancer of the urinary bladder.

Diagnosis. Microscopic examination of urine for finding eggs (urine sample is taken at day-time), biopsy following the cystoscopy (endoscopy of urinary bladder) and revealing eggs in the mucosa of urinary bladder.

Schistosoma japonicum

It causes *schistosomosis japonica* or *intestinal and hepatic schistosomosis*, which is an endemic, anthropozoonosic disease.

Geographical distribution. Far East (Japan, China, Philippines).

Habitat. The adult worms reside in portal vein (liver), veins of small and large intestines.

Morphology. The female may reach 2,5-3 cm, the male is smaller, its body is smooth, without tuberculations. The eggs are smaller and more rounded compared to previous two species, and they have a very minute lateral spine and are laid in batches.

Life cycle. In addition to general life cycle described, *S. japonicum* is anthropozoonosic and is found in virtually all mammals (cat, dog, pig, cattle, monkeys) exposed to infected water.

Pathogenicity. Clinical features. Acute stage of follows general patterns described. Chronic stage is associated with formation of granulomas around eggs trapped in the intestinal wall or in the liver, respectively. Intestinal form presents with abdominal pain, diarrhea, dysentery. The hepatic form manifests in hepatosplenomegaly. In severe cases liver cirrhosis and hepatic failure develop. This species is more pathogenic since the eggs of *S. japonicum* can migrate to lungs and brain.

Diagnosis. Same as described for *S. mansoni*.

Prevention. In addition to the general measures, prevention of *S. japonicum* involves also elimination of reservoir animals.

Class Cestoda

Tapeworms are all hermaphrodite biohelminthes with segmented tape-like body, the size ranging between few *millimeters* and *meters*. They develop in three stages: adult, egg and larva.

Morphology

1. Adult worms have three distinct parts: head or ***scolex***, ***neck*** and the body called ***strobila***. The strobila is segmented and the segments are called ***proglottides***. The scolex possesses organs of attachment such as *bothria* (sucking grooves), or four circular *suckers* with or without hooks.

2. The neck is the growth zone, from where the *proglottides* are budded off. Three types of proglottides are present: ***immature, mature*** and ***gravid***. Immature segments are close to the neck and do not yet have sex glands, mature ones are hermaphrodite (both male and female reproductive organs are present in each proglottide) and locate in the midpart of strobila, and gravid proglottides contain uterus filled with fertilized eggs and are in the terminal part of strobila.

3. The cestodes lack gastrointestinal tract and do not produce digestive enzymes, and must absorb already digested nutrients, therefore their habitat is restricted to the lumen of the small intestine in the definitive host.

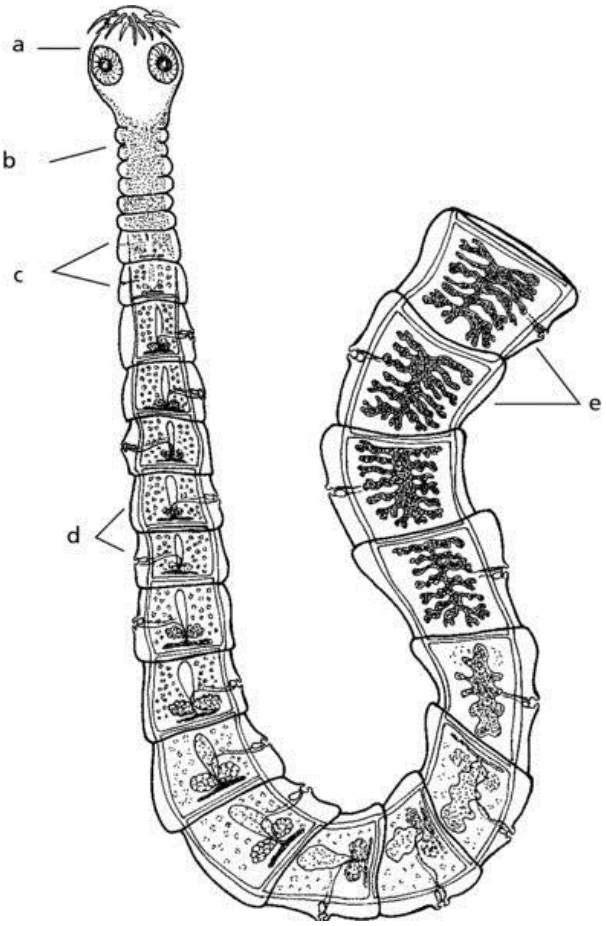


Fig. Adult tapeworm (Taenid): a – scolex with hooks and suckers; b – neck; c – immature proglottides; d – mature proglottides; e – gravid proglottides.

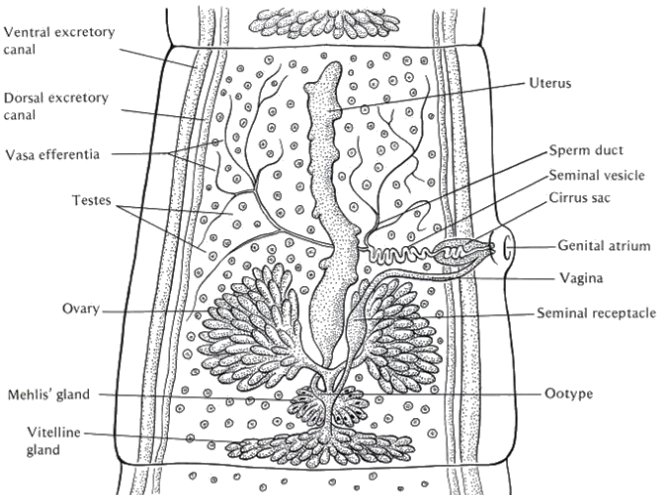


Fig. Structure of a mature proglottide.

4. The male and female reproductive systems follow the general platyhelminth pattern (recall Trematoda).

In the tapeworms possessing suckers, gravid proglottides have a uterus without any uterine pore, and the eggs are retained in the uterus, so that the mature segments just contain a greatly expanded (branched) uterus. In some cestodes such as the Taeniids, the whole gravid proglottides shed out in the feces either

singly or in short chains and can crawl actively. In others the segments rupture in the intestine so eggs are found just in the feces (*Hymenolepis*). In the cestodes that possess bothria on the scolex, gravid proglottides have a uterus with a uterine pore and continuously discharge fertilized eggs into environment. Their proglottides are not shed out usually.

Life cycle

Cestodes are biohelminthes, their life cycles involve definitive and intermediate hosts. Humans can be definitive or/and intermediate hosts for the parasite. In most cestode infestations (e.g., *Taenia solium*, *Taenia saginata*, *Diphyllobothrium* species, *Hymenolepis*) humans are the definitive hosts. Adult worms survive inside their small intestine. In the remaining cestodes (e.g., *Echinococcus*, *Alveococcus*), humans function as intermediate hosts. Larvae exist within the tissues and migrate through different organ systems. *Hymenolepis* species and *T. solium* are the cestodes for which humans can function as both definitive and intermediate hosts.

The intermediate host is infected by ingesting eggs that contain a *hexacanth oncosphere* (six-hooked embryo), which may develop following types of larvae in the tissues of the intermediate host depending on the species of cestode:

1. Plerocercoid. A larval form of *D. latum*. In the life cycle of this parasite there are two intermediate hosts, the plerocercoid being found in the second of them (fish). These are elongated larvae with solid bodies.

2. Cysticercus. A larval form of *Taenia solium, Taenia saginata.* It is a vesicle with the invaginated scolex and a central cavity containing a little fluid.

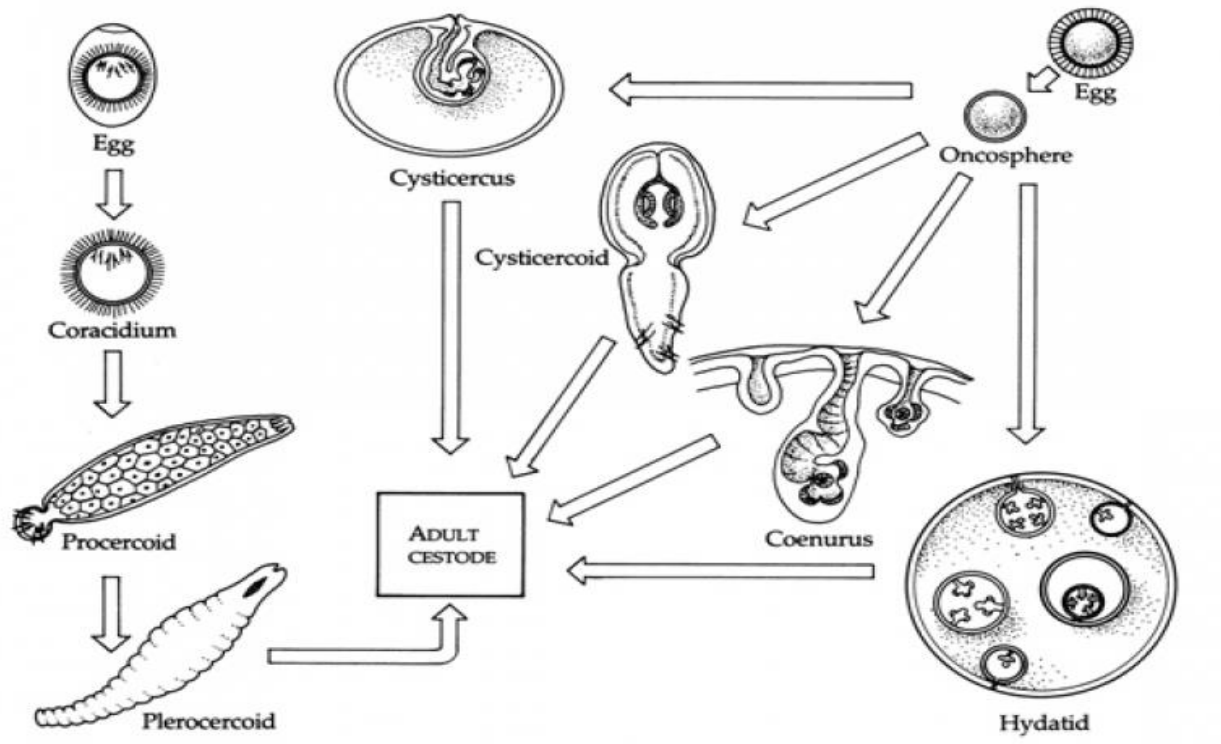


Fig. Larvae of Cestodes.

3. Cysticercoid. A larval form of *Hymenolepis nana*. A smaller bladder with an invaginated scolex and a tail-like appendage.

4. Hydatid Cyst. A larval form of *Echinococcus.* The hydatid cyst is typically a unilocular (single locus) and fluid-filled. It is surrounded by double-membrane. The outer layer is smooth, and the inner one is germinal layer, which gives rise to daughter hydatids filled with daughter scolices and cyst fluid. The hydatid fluid is highly toxic and allergenic.

5. Alveococcal hydatid cyst resembles the echinococcal hydatid cyst with a difference that it is multi-chamber and the germinal layer provides bidirectional growth (exogenous and endogenous) of daughter cysts.

Taenia solium

Taenia solium is the pork tapeworm or armed tapeworm. Taeniosis is a non-endemic, anthroponosic disease.

Geographic distribution. Worldwide except in Jews and Mohammedans who are not generally pork-eaters.

Habitat. The adult worm lives in small intestine, and the larva – in tissues of human.

Morphology. *T. solium* has three stages: egg, cysticercus larva and adult. Adult worm measures 2-3 m, the scolex has 4 suckers and a rostellum with hooks, for which it is named an armed tapeworm. The mature proglottides have trilobed ovaries (third lobe is accessory), a uterus with 7-12 lateral branches. Gravid proglottides are passed through feces in chains of 5-6 segments passively. The eggs are oval-shaped or rounded, yellowish, the shell has characteristic radiations.

Life cycle. The human is definitive host (cysticercus larva is invasive stage), and the intermediate host is pig. However, the man can be also an intermediate host, when ingesting the eggs (***cysticercosis***).

The embryonated eggs are ingested by the pig and liberate the oncosphere, which penetrates the intestinal wall and passes to blood stream and reaches the muscles, where the cysticercus larva develops. People become infected by eating "*measly*" pork. The scolex of cysticercus attaches to the small intestine wall and gives rise to adult worm through the growth of proglottides.

Occasionally, the human may serve also as an intermediate host for *T. solium*. He is infected the same way as the pig: ingestion of eggs either by drinking the contaminated water or by eating uncooked vegetables. Besides this, a patient with taeniosis may autoinfect himself either by reverse peristalsis of intestines whereby the gravid proglottides with eggs are thrown back to the stomach or due to poor hygiene (ingestion of eggs when taking unwashed hands into mouth). The cysticerci develop mainly in subcutaneous tissue, skeletal muscles, eyes or brain.

Pathogenicity. Clinical symptoms. Adult worms may cause abdominal discomfort, nausea, vomiting, diarrhea alternating with constipation, allergy. It is possible for the patient to detect the segments of the tapeworm in the feces or on his own body, clothings.

Human affection with cysticercus larva is called *cysticercosis*. The clinical manifestation of cysticercosis involves significant allergy and depends on the organ affected (brain, eye, muscles, subcutaneous tissue). Frequently the cysticerci die and become calcified.

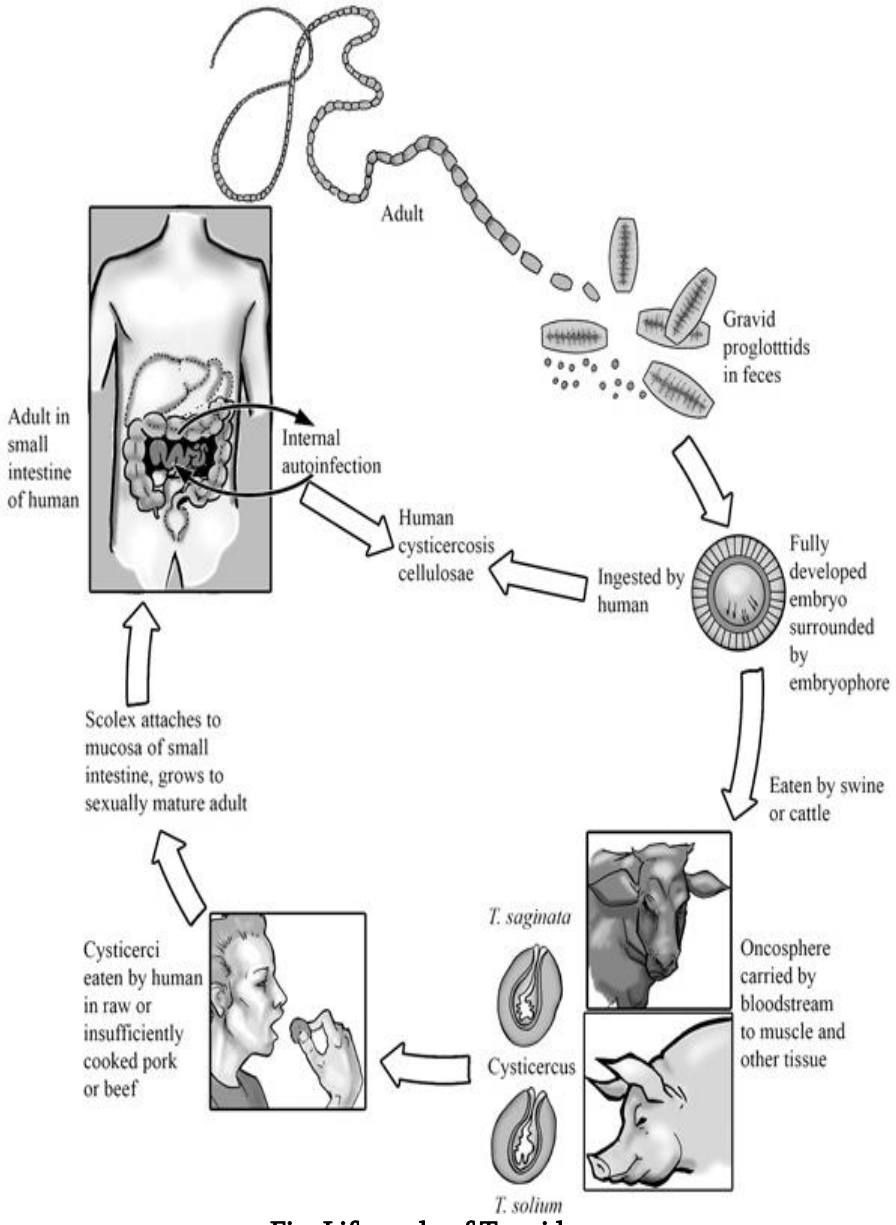


Fig. Life cycle of Taenids.

Diagnosis. Stool examination and finding of gravid proglottides with characteristically branched uterus, as well as eggs released from degraded proglottides. Cysticercosis is diagnosed by surgical removal of subcutaneous or intracranial cysts, muscle biopsy, X-ray, computed tomography (CT-scan), immunodiagnosis. A history of intestinal taeniosis often helps in the diagnosis of cysticercosis.

Prevention. For taeniosis – avoidance of eating uncooked pork meat, adequate meat inspection in the slaughterhouse; for cysticercosis – eradication of the adult worm from the

organism (treatment of taeniosis), keeping hygienic conditions and proper washing of fruits and vegetables that can be contaminated by *T. solium* eggs.

Taeniarhynchus saginatus (Taenia saginata)

Common names are the beef tapeworm or unarmed tapeworm. It causes taeniarhynchosis, which is non-endemic and anthroponosic disease.

Geographical distribution. Worldwide. In India it is not generally found amongst Hindu population.

Habitat. Adult worm lives in the small intestine of human.

Morphology. The adult tapeworms have an average length of 5-10 m, but may grow up to 20-24 m in length occasionally, and are therefore longer than the adult forms of *Taenia solium*. The scolex has 4 suckers and no hooks (unarmed). The ovary is bilobed. The branches in the uterus of a gravid proglottide are 17-35. The larva (cysticercus) and eggs of similar with those in *T. solium*.

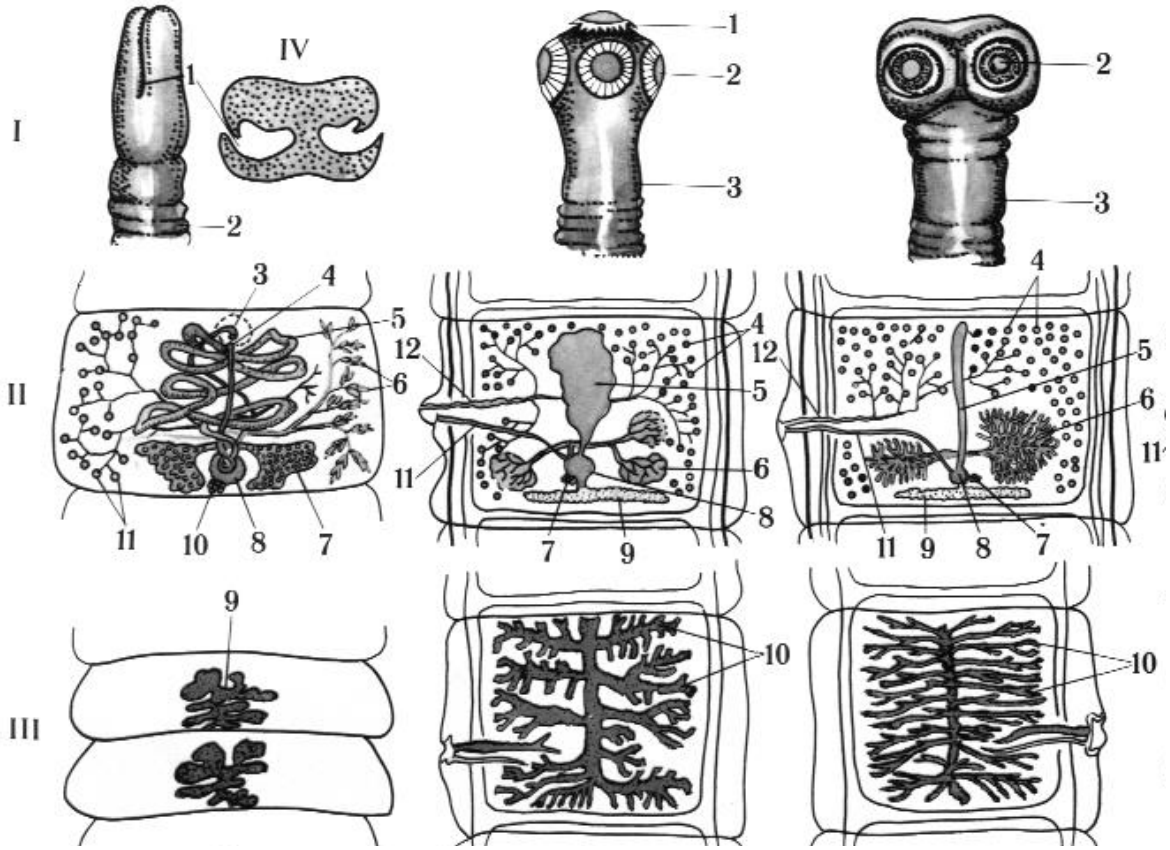


Fig. Scolices and proglottides of D. latum (left), T. solium and T. saginata: I. scolex, II. mature proglottide, III. gravid proglottide, IV. cross section of a scolex with two bothria.

Life cycle. Humans are the only definitive hosts. The intermediate hosts are cattle, which harbour the cysticercus larva within muscles. In the small intestine of human gravid proglottides detach from the adult tapeworm and crawl to the anus or are passed in the stool singly. The eggs can release from destructed proglottides and pass with feces, or the proglottides

actively crawl out from the anus to deposit eggs around the perianal region. Cattle become infected by ingesting vegetation contaminated with eggs. Humans become infected by ingesting raw or undercooked infected meat ("measly" beef). Cysticercosis caused by cysticercus larva does not develop in human, since he is only a definitive host.

Pathogenicity. Clinical symptoms. The symptoms are as outlined for pork taeniosis. However, clinically the condition is more apparent than that caused by *T. solium*, which is related to the larger sizes of *T. saginata*. Intestinal obstruction is more common complication than in pork tapeworm disease due to larger sizes of beef tapeworm.

Diagnosis. This is carried out by stool examination and finding of gravid proglottides with characteristic branching of the uterus. Since the eggs, which are morphologically indistinguishable from those in *T. solium,* are rarely found in stool. The eggs can be demonstrated also in perianal scrapings collected by cellophane method.

Prevention. The prophylaxis is the same as in *T. solium* infection (avoid eating undercooked "measly" beef).

1. Which infection the human can get by eating uncooked fish?
   A. taeniosis
   B. diphyllobothriosis
   C. taeniarhynchosis
   D. dicroceoliosis
2. In life cycle of broad tapeworm there is larva:
   A. miracidium
   B. cercaria
   C. plerocercoid
   D. cysticercoid
3. Eggs of which trematode can be found in urine?
   A. Paragonimus westermani
   B. Fasciola hepatica
   C. Schistosoma haematobium
   D. Opisthorchis felineus
4. Which trematodosis is anthroponosic?
   A. paragonimosis
   B. fasciolosis
   C. intestinal schistosomosis
   D. shistosomosis japonicum
5. Which cestodosis is diagnosed by finding proglottides in stool?
   A. hymenolepidosis
   B. teniosis
   C. cysticercosis
   D. sparganosis

1. Which of the following is not a disease caused by Cestodes?
   A. taeniosis
   B. taeniarhynchosis
   C. fasciolosis
   D. hymenolepidosis
2. Which of the followings is not a type of larva in Cestoda?
   A. cysticercus
   B. cercaria
   C. cysticercoid
   D. plerocercoid
3. Which of the following systems is not common for Cestodes?

A. nervous
B. digestive
C. excretory
D. reproductive

4. Taenia solium has not:

A. tape-like body
B. 4 suckers
C. hooks
D. 10m length

5. Taeniarhynchus saginatus does not have:

A. Tape-like body
B. brunched uterus
C. extra lobe of ovary
D. excretory system

II

1. The larval stages of Cestodes are:

1. cercaria
2. cysticercus
3. plerocercoid
4. metacercaria
5. cysticercoid

A. 1,2,3 B. 1,3,4 C. 2,3,5 D. 1,4

2. Schistosomes:

1. are hermaphrodites
2. are dioecious
3. have sexual dimorphism
4. reside in lumen of small intestine
5. reside in large veines

A. 1,4,5 B. 2,3,5 C. 1,3,4 D. 2,5

3. Because of parasitic life in Cestodes:
   1. tegument excretes anti-proteolytic enzymes
   2. digestive tract is absent
   3. the scolex has organs for attachment
   4. nervous and excretory systems are developed
   5. fertilization is cross

A. 1,3,5 B. 4,5 C. 2,3,5 D. 1,2,3

4. Which helminthes are dioecious?

1. Opisthorchis felineus
2. Dicrocoelium lanceatum
3. Schistosoma haematobium
4. Schistosoma mansoni
5. Taenia solium

A. 1,2 B. 1,3,5 C. 3,4 D. 4,5

5. Taeniarhynchus saginatus differs from Taenia solium in:

1. scolex has 4 suckers and no hooks
2. in mature proglottide the uterus is trilobed
3. in mature proglottide the branches of uterus are thinner and more
4. mature proglottides can crawl out of the anus
5. the uterus has 7-12 pairs of lateral branches

A. 1,3,4 B. 2,3,4 C. 3,5 D. 1,2,5

Chapter 22
Cestoda (Diphyllobothrium latum, Hymenolepis nana, Echinococcus granulosus, Alveococcus multilocularis). Nematoda. General characteristics.

Diphyllobothrium latum

Diphyllobothrium latum or the broad fish tapeworm causes diphyllobothriosis, which is an endemic, anthropozoonosic disease.

Geographical distribution. Northern areas (Siberia, Scandinavia, France, Germany, Alaska, Canada) where pickled or insufficiently cooked freshwater fish is used in the diet.

Habitat. Small intestine.

Morphology. The adults reach up to 10-15 m and each mature proglottide is up to 2 cm wide (the proglottides are wider than long, hence the name broad tapeworm). Scolex bears 2 bothria, the gravid proglottides have a rosette-shaped uterus with a uterine pore through which the eggs are passed to intestines. The eggs are oval-shaped, brownish and operculated.

Life cycle. *D. latum* has one definitive host (human or fish-eating mammals like bear, dog, cat, wolf) and two intermediate hosts (Cyclops and freshwater fish). Eggs passed through feces of an infected human must get into water, where they develop into ciliated *coracidium* larva containing an *oncosphere*. It changes into *procercoid* when ingested by Cyclops. If the infected Cyclops is then ingested by fish, the procercoid develops into *plerocercoid*, which is invasive for human. He becomes infected by eating raw fish. Plerocercoid attaches to small intestinal mucosa and matures to adult.

Pathogenicity. Clinical features. Large number of parasites may cause diarrhea, abdominal pain, allergy, fatigue, vomiting, dizziness, or numbness of fingers and toes may be present. Massive infections may result in intestinal obstruction.

Megaloblastic anemia is a classical sign of diphyllobothriosis. This is due to uptake and absorption of vitamin B_{12} by the worm. Vitamin B_{12} is considered as a hemopoetic factor. Its deficiency leads to decreased formation of mature RBCs and development of immature or blast RBCs which are larger than mature ones (*mega* - large). This leads to megaloblastic anemia.

Diagnosis. Finding of eggs, or proglottides (with the characteristic rosette-shaped uterus) in stool.

Prevention. Thorough cooking of fish, prevent defecation of human and animals into fresh water, treatment of sewage before it enters lake, elimination of reservoir hosts.

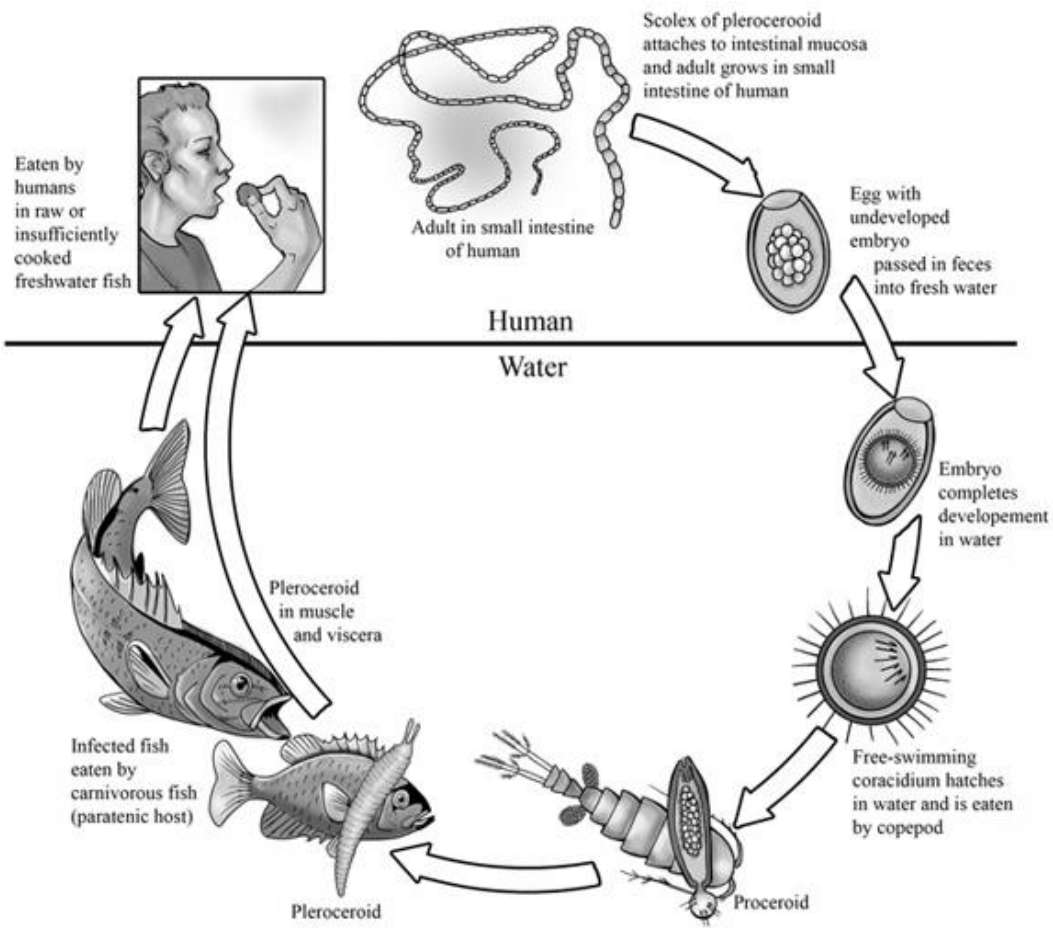


Fig. Life cycle of Diphyllobothrium latum.

Hymenolepis nana

Hymenolepis nana, or dwarf tapeworm, causes hymenolepidosis, which is a contact helminthosis (anthroponosic, non-endemic).

Geographical distribution. Worldwide, incidence is higher in children in the nursery schools.

Habitat. Small intestine.

Morphology. The adult is 1-4 cm, the scolex has 4 suckers and hooked rostellum. The cysticercoid larva also develops in small intestine of human.

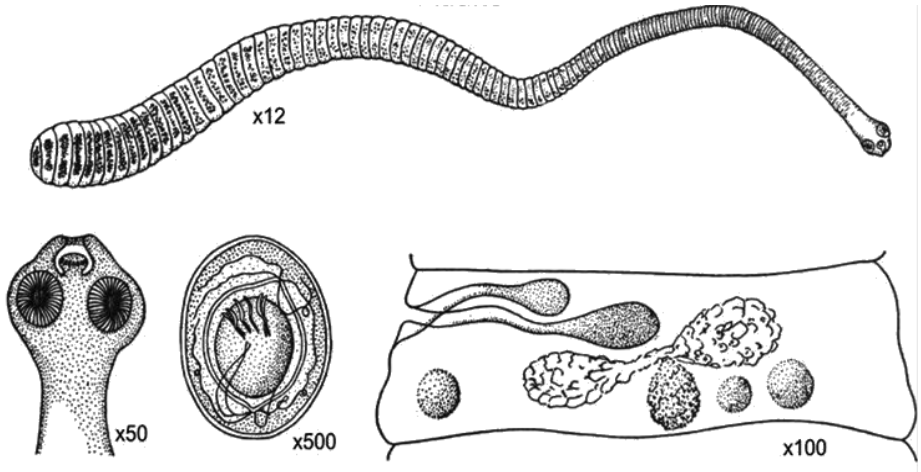


Fig. Morphology of Hymenolepis nana: adult (top), scolex, egg, mature proglottide.

Life cycle. Whole development of *H. nana* from egg to adult takes place in one host - the human, who is both definitive and intermediate host. It is prevalent in 3-5 year old children, and nursery schools are an important source of infection. Overcrowding and poor hygienic habits (e.g., taking unwashed hands to mouth) facilitate oral-fecal transmission of the contact helminthosis.

The first infection of children occurs through ingestion of food contaminated with eggs liberated by feces of infected man. The oncosphere liberates from egg and burrows into the villus of the intestinal mucosa transforming into a cysticercoid larva. It ruptures villi, comes out into the lumen of intestine and attaches itself to a lower part of the small intestine. There it develops and matures into adult worm. The gravid proglottides detach from the body while still in the lumen of intestine and release completely embryonated eggs with feces. When taking unwashed hands to mouth, the infected child may autoinfect himself (external autoinfection). In internal autoinfection (common in immunosuppressed children) eggs of *H. nana* hatch out in the intestine and without leaving through feces develop to cysticercoid larva, which finally matures to the adult worm. Internal autoinfection cycle may repeat many times and lead to high burden of worms in their intestines.

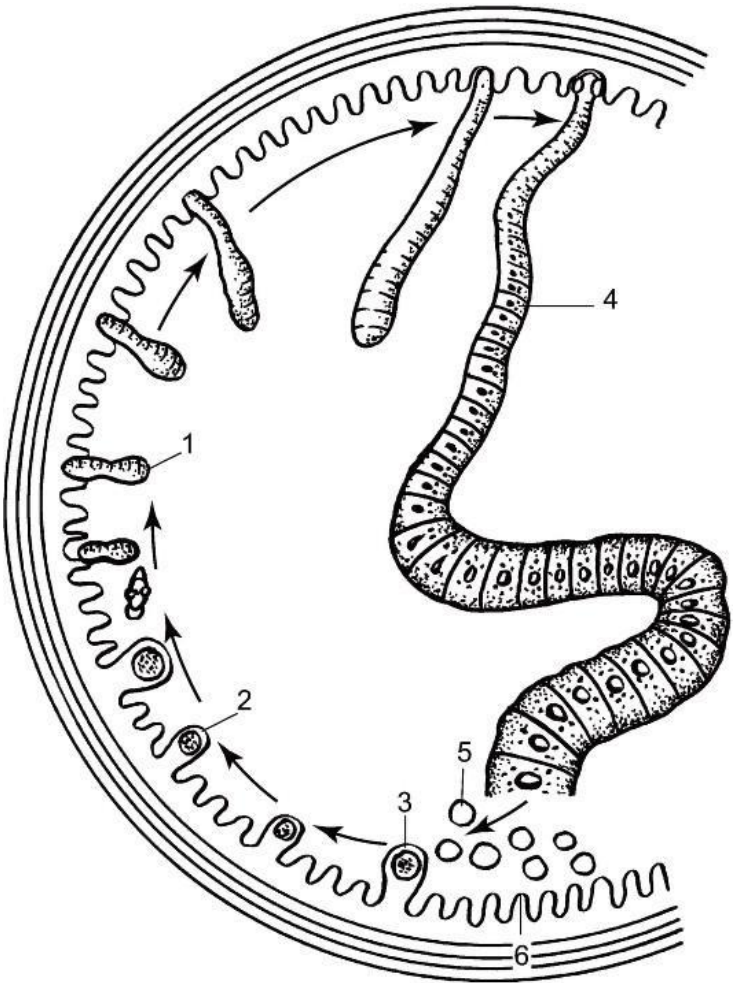


Fig. Life cycle of Hymenolepis nana: internal

Pathogenicity. Clinical features. Light infections are asymptomatic. Large numbers of worms may cause abdominal pain, nausea, vomiting, diarrhea, headache, dizziness, loss of appetite. Increased numbers of parasites may cause atrophy or necrosis of small intestine villi.

Diagnosis. Finding of characteristic eggs in a microscopic examination of feces.

Prevention. Improved personal hygiene in children and better environmental sanitation with proper disposal of human waste is essential for preventing transmission of infection.

Echinococcus granulosus

Echinococcus granulosus, or dog tapeworm, causes echinococcosis or hydatid disease in humans. It is an anthropozoonosic and non-endemic disease.

Geographical distribution. Worldwide, particularly in sheep-raising regions.

Habitat. The hydatid cyst locates in visceral organs of intermediate hosts (human, herbivorous animals). The adult worm is found in the intestines of definitive hosts – canines.

Morphology. Adult worm measures 3-6 mm. It has 3-4 segments (immature, mature, gravid). The scolex bears 4 suckers and a double-hooked rostellum. The uterus in gravid proglottide presents with protrusions (these are not as long as in Taenids). Larva is the hydatid cyst developing inside the intermediate host.

Life cycle. Definitive host is the dog. Intermediate hosts are humans and herbivores - sheep, pig, cattle, horse. The adult worm discharges eggs in dog feces. Eggs enter the intermediate host by ingestion of either from contaminated grass, vegetables, or in the case of man, by dog handling or fondling (common in children). The oncosphere penetrates intestinal wall, via portal blood system passes to liver, lungs, heart, and entering systemic circulation, from where it can spread to visceral organs. The cyst is ingested by the dogs along with the offal of dead cattle. Humans are considered as ***dead end*** in the cycle of *E. granulosus*, since the spreading of infection is stopped on humans (dogs are not infected from humans).

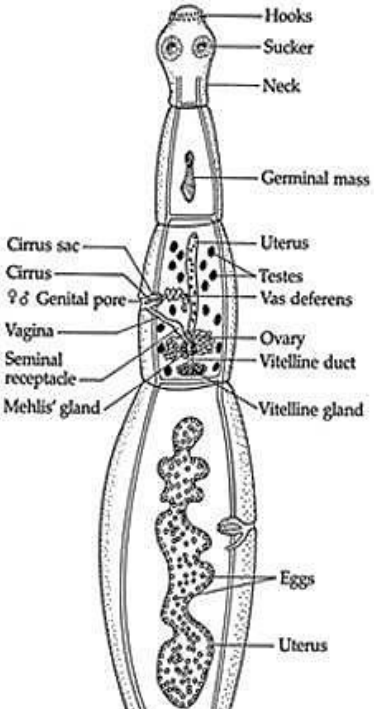


Fig. Morphology of Echinococcus granulosus.

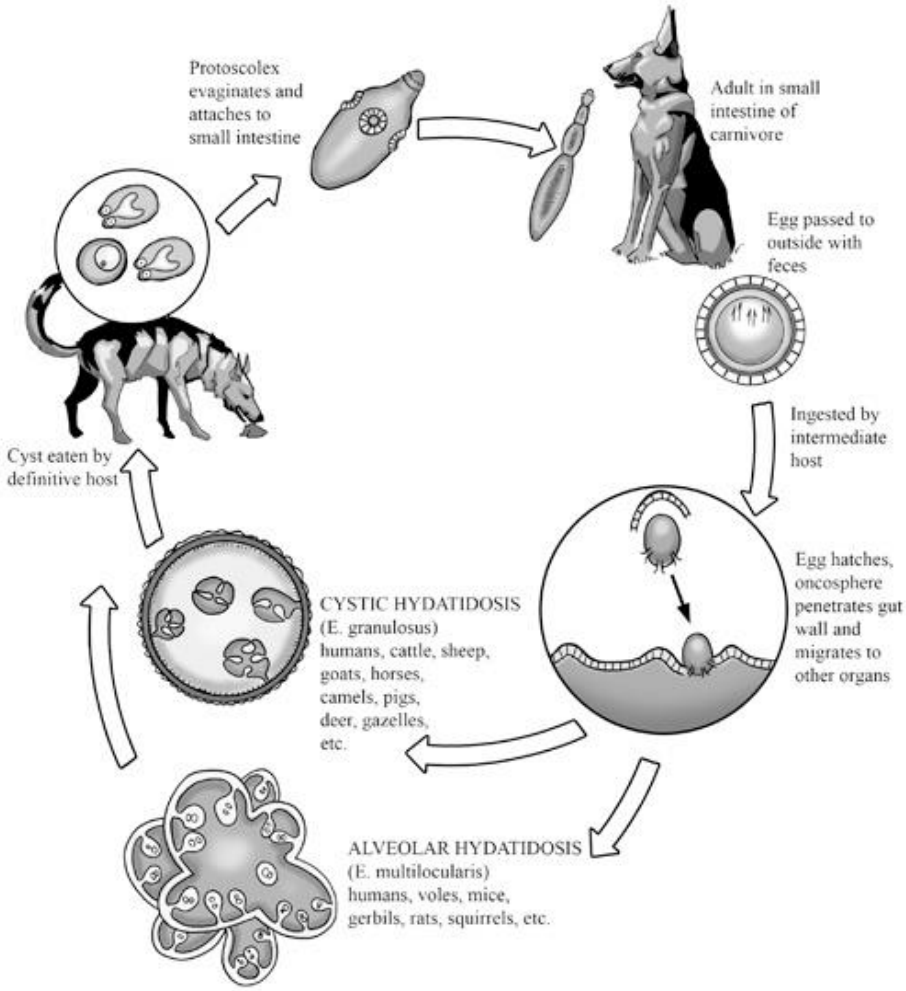


Fig. Life cycle of Echinococcus granulosus.

Pathogenicity.

Clinical symptoms. The hydatid cysts are found most commonly in the liver and lungs, but can be found in any other organ (brain, kidney, bone, peritoneal cavity).

Around the growing cyst the host tissue develops a fibrous capsule (tissue reaction). During the course of infection the cysts may either stop growing and die, or calcify. The growing cysts cause toxic and allergic effects due to hydatid fluid reabsorbed into blood, and mechanical pressure effect in visceral organs, thereby causing atrophy of the host tissues. A complication may arise if the cyst ruptures (trauma, surgery) causing anaphylactic and toxic shock leading to rapid death; or the liberated protoscolices may give rise to numerous secondary cysts throughout the body (*secondary echinococcosis*).

Diagnosis. Imaging methods (X-ray, sonography, CT-scan), immunodiagnostic tests.

Prevention. Denying dogs' access to offal of infected sheep, obligatory testing and treatment of all sheep dogs, prevention of contact of children with possibly infected dogs, washing vegetables, fruits.

Alveococcus multilocularis

Alveococcus multilocularis or alveolar hydatid tapeworm, causes alveococcosis – endemic, anthropozoonosic disease.

Geographical distribution. It is found mainly in Northern countries (North America, Siberia, China, Japan).

Morphology. The adult parasite is 1-2 mm, consists of 4-5 proglottides. The scolex bears suckers and rostellum with single row of hooklets. The uterus in gravid proglottide is spherical. The hydatid larva of Alveococcus is multilocular, grows invasively by external and internal budding. The numerous small daughter cysts contain very little fluid and grow very rapidly, in which they resemble a malignant tumor.

Fig. Morphology of Alveococcus multilocularis.

Life cycle. Similar to *E. granulosus*, but with more adaptations for colder climates. The definitive host is usually the fox, the intermediate hosts are small rodents, occasionally humans. The eggs are excreted in fox feces and infect humans through ingestion of food or water (especially hunters and fox fur handlers). The oncospheres hatch out of the eggs and are carried by portal circulation to the liver, where the larvae grow into a multilocular cyst.

Pathogenicity. Clinical symptoms. The multilocular cyst is highly pathogenic due to its fast growth rate and invasive nature, in extreme cases completely replacing liver tissue. The daughter cysts may detach and spread via blood circulation to various organs. This process resembles the metastasis in malignant tumours (cancer). The clinical symptoms of alveococcosis depend on the organs affected. This parasite is highly pathogenic, since almost all the organs can be involved and there may be 80% mortality.

Diagnosis. Same as in echinococcosis.

Prevention. Avoid eating contaminated food and water. Keeping appropriate control measures (e.g., hunters) when skinning or handling fox fur.

Class Nematoda

Nematodes or the round worms are thread-like helminthes, which include both parasitic and free living species.

Morphology

1) Size: from 1-2 mm in length up to 1 m, females being longer than males.

2) Are round in cross section because they maintain their body fluids under great pressure.

3) have a cuticle to contain this high pressure. Beneath the cuticle is a hypodermis and a layer of longitudinal muscles. The combination of the flexure of these muscles with the high pressure of the system produces a characteristic whip-like wriggle that Nematodes use to swim.

4) Body cavity contains the alimentary canal and reproductive organs.

5) The head part has a mouth with 3 lips, behind which some species have few teeth. The gut ends up with anus.

6) Have a developed nervous system: pharyngeal nerve ring made up from 4 nerve ganglia.

7) Are dioecious. Females may be termed ***viviparous*** when they give birth to larvae; ***oviparous*** when they lay eggs, or ***ovo-viviparous*** when the eggs layed contain larvae which immediately hatch out.

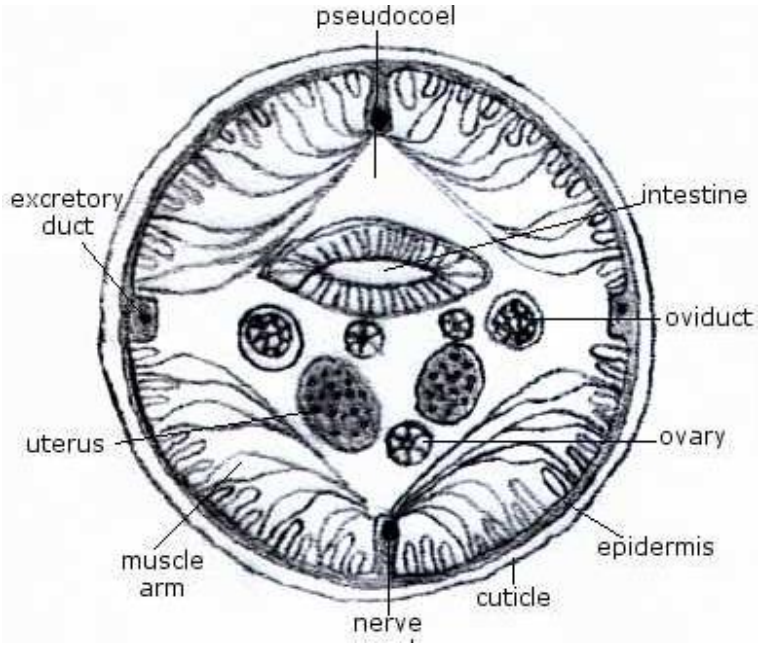


Fig. Cross section of a roundworm (female).

Young nematodes hatch from eggs and moult in larval stages before they become adults. There are two types of larvae according to the structure of their esophagus: *filariform* and *rhabditiform*.

Life cycle

Geohelminthes develop in a human as the only host. Their eggs mature in soil and affect human on maturation. During their life cycle the geohelminthes nematodes may either migrate

in the host organism (*Ascaris lumbricoides*, hook worms (*Ancylostoma duodenale, Necator americanus*)) or pass the cycle without migration (*Trichocephalus trichiurus*).

A single nematode (*Enterobius vermicularis* - pin worm) causes a ***contact helminthosis***.

Some nematodes that are ***biohelminthes*** (*Dracunculus medinensis*, *Trichinella spiralis* and *Filarial nematodes*), however, require more than one host to complete their life cycle.

1. The human in life cycle of Echinoncocus is:

A. dead end
B. reservoir host
C. definitive host
D. accidental host

7. Which of the following helminthes can cause metastasis?

A. Echinoncoccus granulosus
B. Alveococcus multilocularis
C. Ascaris lumbricoides
D. Opisthorchis felineus

3. Chose one helminth which can pass its life cycle only in human host:

A. Taeniarhynchus saginatus
B. Echinococcus granulosus
C. Hymenolepis nana
D. Diphyllobothrium latum

4. In what cestodosis re-infection can occur?

A. teniarhynchosis
B. diphyllobothriosis
C. hymenolepidosis
D. echinococcosis

5. What is common for Nematoda?

A. sexual dimorphism
B. blind alimentary canal
C. leaf shape
D. segmented body

B

1. What is not characteristic for Echinococcus granulosus?

A. uterus with extruding
B. 2-6mm length
C. spherical uterus
D. strobila has 3-4 proglottides

2. Which of these helminthes is not a Cestode?

A. Taenia solium
B. Alveococcus multilocularis
C. Diphyllobothrium latum
D. Enterobius vermicularis

3. What is not a method of diagnosing hydatid disease?

A. sonography
B. biopsy
C. X-ray
D. immunology tests

4. What is not common for hymenolepidosis?

A. diagnosis by stool examination
B. being a contact helminthosis
C. infection by eggs ingestion
D. infection by larva ingestion

5. What is not common for round worms?

A. body filled with fluid
B. cuticle
C. suckers
D. antidigestive enzymes

II

1. Hydatid cyst:

1. is covered by cuticle layer
2. has internal germinal layer
3. does not contain the fluid
4. grows out and produces metastasis
5. grows inside and gives rise to daughter cysts

A. 1,3,4 B. 3,4 C. 1,4,5 D. 1,2,5

2. Who can be intermediate hosts for dwarf tapeworm?

1. human
2. fish
3. flies
4. pig
5. cat

A. 1,2 B. 3,5 C. 1 D. 1,2,4

3. Dwarf tapeworm disease is prevented by:

1. avoidance to contact dogs
2. isolation of infected children
3. keeping hygiene
4. treatment of hymenolepidosis
5. treatment of echinococcosis

A. 1,4,5 B. 2,3,5 C. 2,3,4 D. 1,4

4. The symptoms of hydatid disease depend on:

1. size of helminth larva
2. size of adult helminth
3. toxins of larva
4. toxins of adult
5. location of adult helminth

A. 2,3 B. 1,4 C. 1,3 D. 3,5

5. The round worms can develop:

1. with migration
2. without migration
3. in soil
4. in vector
5. in several hosts

A. 1,2,3,4 B. 3,4,5 C. 1,2,5 D. 1,2,3,4,5

Chapter 23

Phylum Nemathelminthes.
Nematodes developing without and by migration in the host

Nematodes developing without migration in host

Trichuris trichiura (Trichocephalus trichiurus)

Trichuris trichiura, or the whipworm, causes trichocephalosis – anthroponosic, non-endemic disease.

Geographical distribution. The whipworm has a worldwide distribution but is more common in tropical areas and in regions where sanitation is poor.

Habitat. The adult worm inhabits the large intestine of man, preferably in cecum and appendix.

Morphology. Whipworm is so named because of its shape with a very thin hair-like head portion forming the lash (*trichos* –hair, *cephalon* - head), and thick posterior portion forming the stock. The size of female is about 3-5 cm, the males are smaller and have a curled up posterior end. The eggs are brownish, barrel shaped with two knobs on the poles.

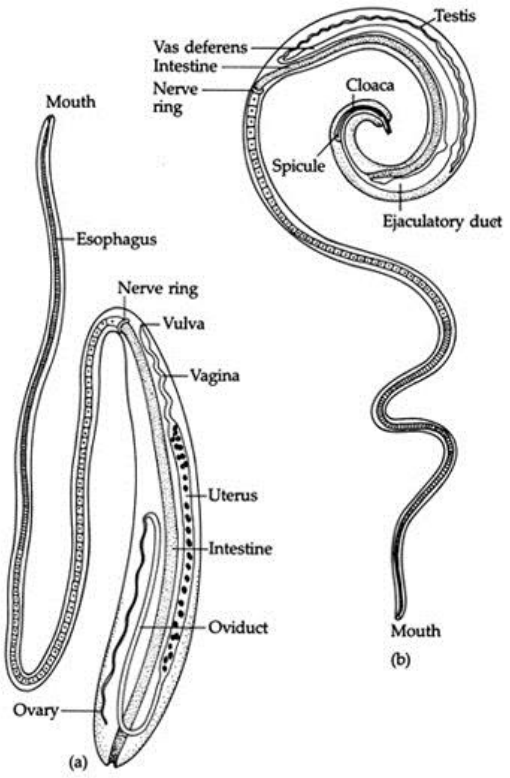


Fig. Morphology of whip worm.

Life cycle. There is a single host - man. It is a geohelminth, and the eggs get mature in soil. The infection is acquired by ingestion of the invasive eggs with contaminated food and water. The larvae hatch out and reach cecum (without migration), where they grow into adults and embed in the mucosa by their anterior portion, while posterior end hangs freely in the lumen of the intestine. Each female may produce about 10.000 eggs daily, which are passed with feces.

Pathogenicity. Clinical features. The whipworm is a hematophage. The anterior portion of the worm, which is embedded in the large intestine mucosa, can cause hemorrhages, in case of multiple infections the mucosa can be necrotized. The patient may be predisposed to bacterial and protozoal infections of intestines (e.g., *E. histolytica*).

Trichuriasis is usually asymptomatic. Heavy infections may be characterized by abdominal pain, dysentery, weight loss and weakness. Infections of 200 worms or more in children may cause anemia and growth retardation.

Diagnosis. Stool examination reveals characteristic eggs. Sometimes, endoscopy can demonstrate adult worms in colon.

Prevention. Trichuriasis can be prevented by proper disposal of human feces and avoiding consumption of unboiled water and unwashed vegetables and fruits.

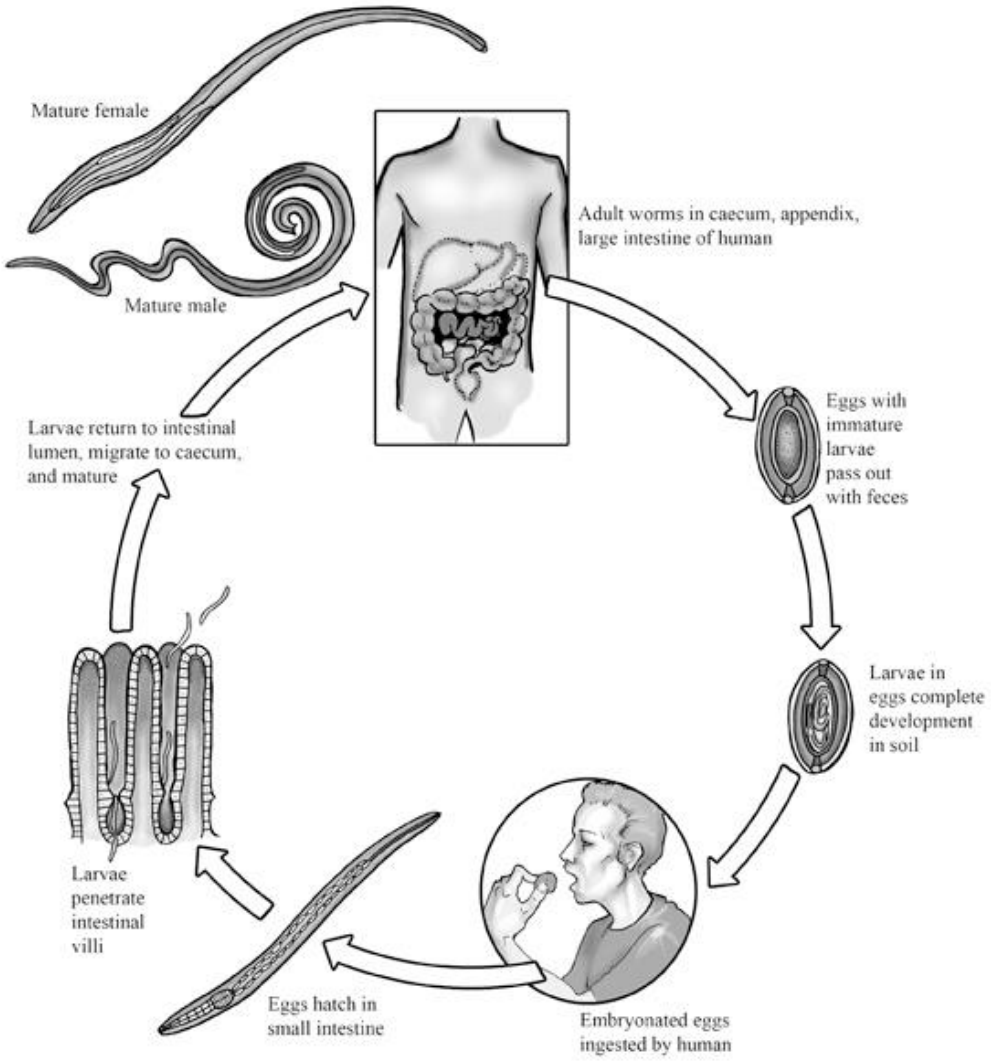


Fig. Life cycle of Trichocephalus trichiurus.

Enterobius vermicularis

Enterobius vermicularis, or the pinworm, causes enterobiosis or pinworm disease, which is an anthroponosic *contact helminthosis.*

Geographical distribution. Worldwide. Children are more often infected than adults. Spreading of the pinworm infection is facilitated by crowded indoor living.

Habitat. Cecum and appendix.

Morphology. The female is about 1 cm with thin, sharply pointed tail (hence the name pinworm), and the male is about 0.5 cm with curled up posterior end.

Life cycle. The whole cycle is completed in a single host. Infection occurs by ingestion of eggs. The first infection is either contagious from close association (contact) with patients or due to contaminated food and drink.

The males die just after copulation, and the females usually at night oviposit on the perianal (near the anus) skin, where the eggs get matured without passing onto soil (body

temperature is enough for maturation) in about 3-4 hours. This causes an intense itching and induces the patient to scratch, thereby carrying the mature eggs on their fingers (under nails) and results in autoinfection. This is especially common in children.

Pathogenicity. Clinical symptoms. The significant pathology is the irritation caused by the gravid females around the anus, which causes intense itching around the anus. Some cases of disease may develop appendicitis caused by the female worms.

Diagnosis. It is made by the use of the cellophane tape or a swab to adhere the eggs and worms (females) to the sticky surface of it when applied to the perianal region. The eggs almost are not found in feces. The worms may be discovered by the patient himself or by parents of the child during itching attack.

Prevention. Infections are more common in

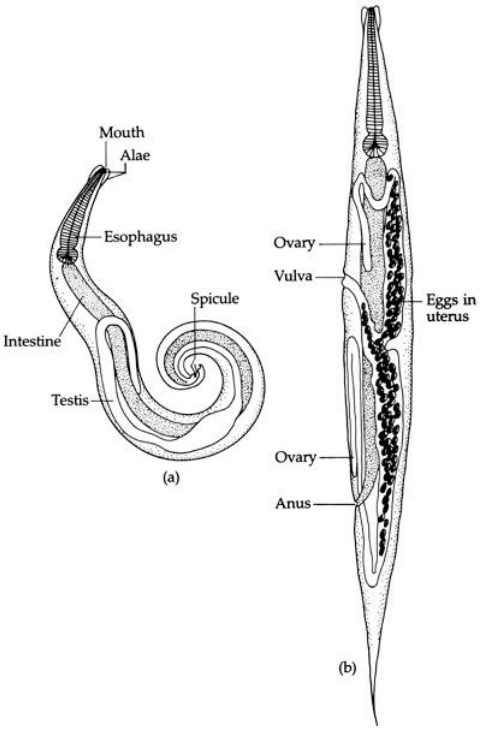


Fig. Morphology of Enterobius vermicularis

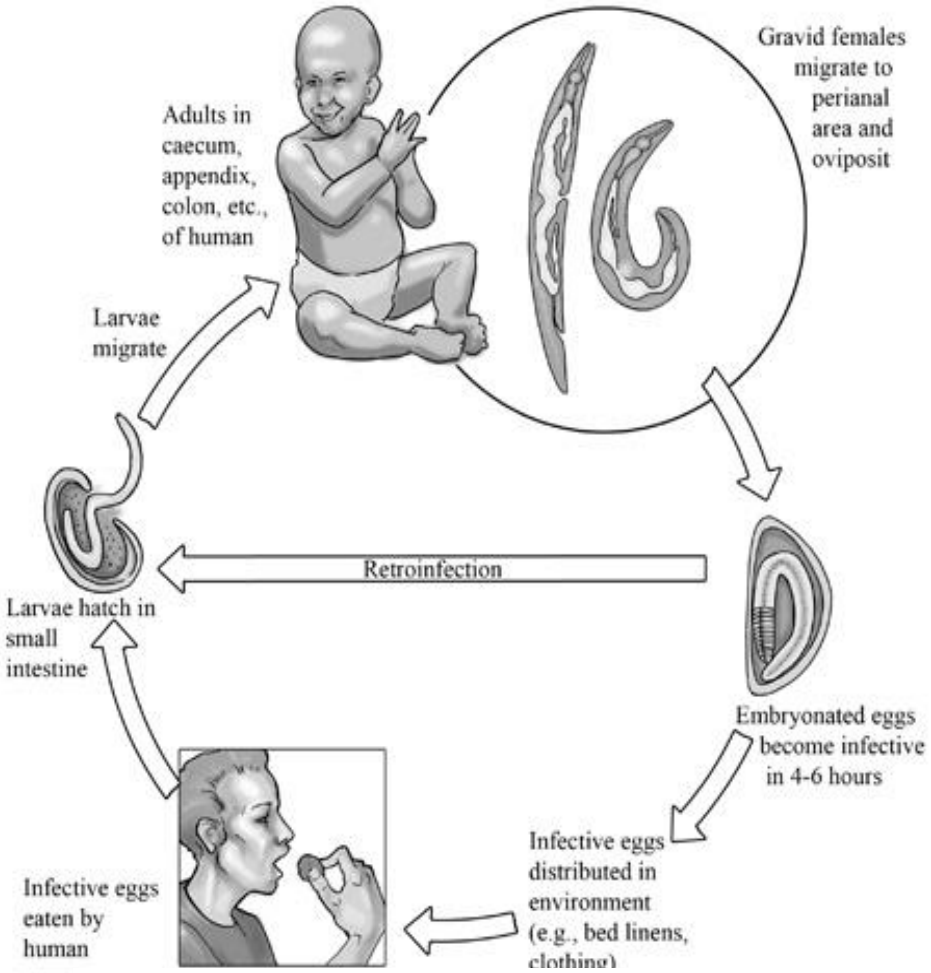


Fig. Life cycle of Enterobius vermicularis

members of the same family or in crowded living groups. Good sanitation and personal cleanliness are important. Clothing, bedding should be thoroughly laundered, the toys should be disinfected. Keeping personal hygiene to prevent re-infection for about a month may lead to self-healing of enterobiosis, since the life span of this parasite is about 4 weeks.

Nematodes developing by migration in host

Ascaris lumbricoides

Ascaris lumbriocoides is the most common parasite found in humans. Ascaridosis is anthroponosic, non-endemic.

Geographical distribution. Worldwide. Infection is very prevalent particularly in children.

Habitat. The adult worm lives in the lumen of small intestine (duodenum).

Morphology. The adults are whitish, the females are 20-40 cm long, the males are 10-30 cm and have a curved tail with two spicules. The mouth has 3 minute lips, which are not sufficient to attach the parasites in the small intestine, therefore it should crawl up against the peristaltic motion to prevent own elimination through feces. Within the body cavity is a fluid containing an irritant toxin resulting in allergic manifestations. The eggs are brownish, can be either fertilized or not. The fertilized eggs are smaller than the non-fertilized ones, and are surrounded by a coat with mammilations.

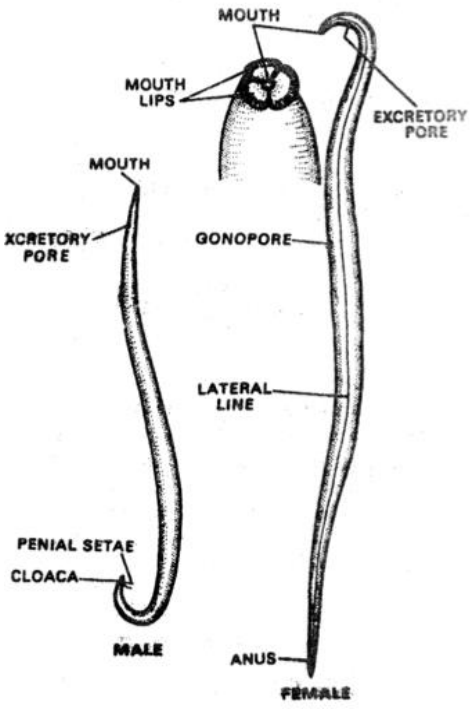


Fig. Morphology of Ascaris lumbricoides.

Life cycle. This parasite is a geohelminth, and the human is the only host. The females are highly prolific, laying about 200.000 eggs daily. They require a temperature less than 30°C, moisture and oxygen, before the development of the young larvae within eggs in soil. Infection occurs on ingestion of fruit or vegetables that are contaminated with these infective eggs. The eggs then hatch in the small intestine, to release the larvae. Larvae must then undergo a migration through the body of their host: penetrate the intestinal wall, enter the portal blood stream, and then migrate to the liver, then heart, then the lungs. Here in the alveolar capillaries they mature (measuring approximately 1.5 mm long) and enter bronchioles via rupturing capillary wall. From here they migrate up through the air passages of the lungs, to the trachea. They then enter the throat and are swallowed, finally ending up in the small intestine where they mature and mate, to complete their life cycle.

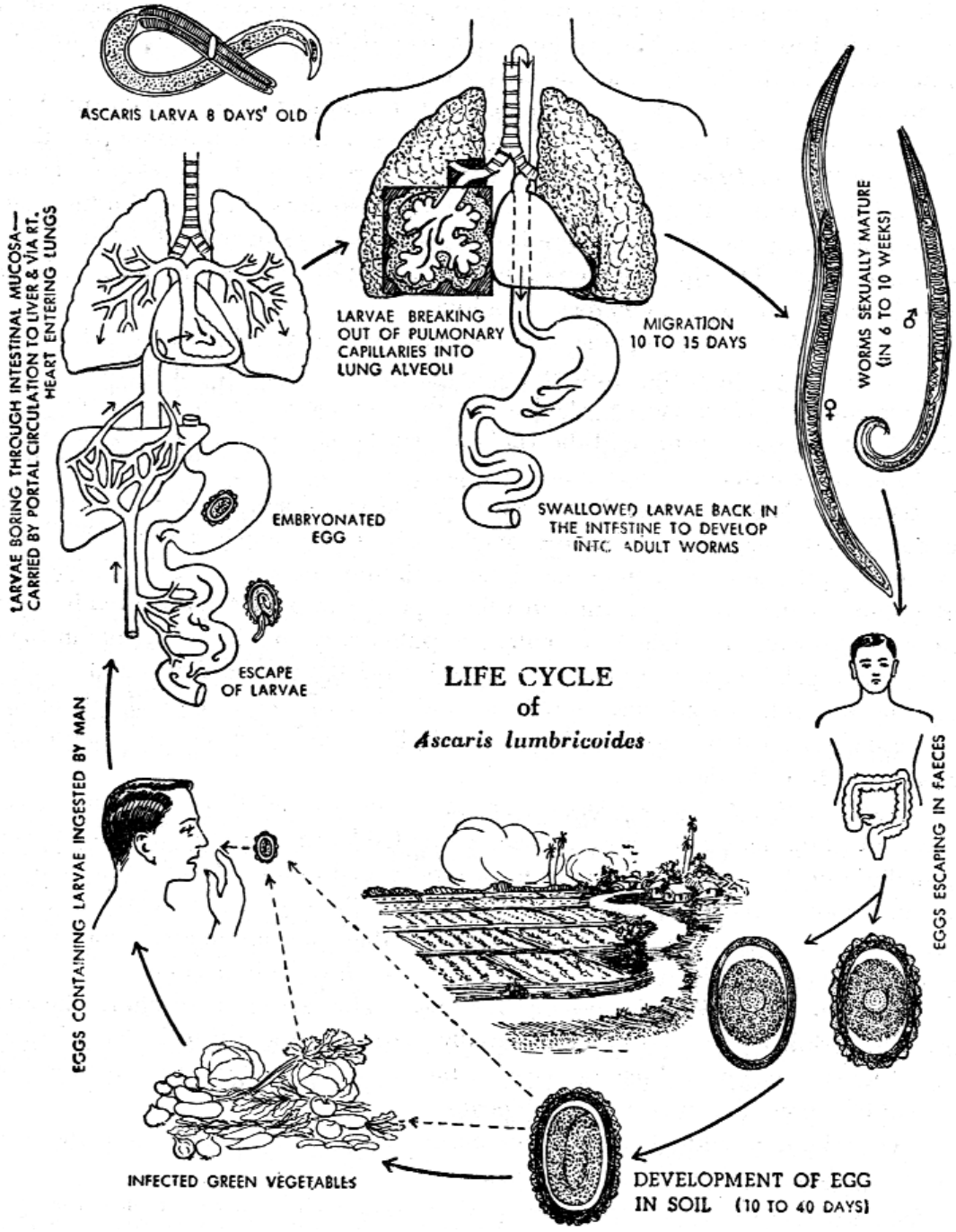


Fig. Life cycle of Ascaris lumbricoides.

Pathogenicity. Clinical features. The symptoms depend on the developmental stage of Ascaris (adult, larva) cycle in human.

Larva-induced symptoms. Migration of larvae in the lungs leads to hemorrhages, pneumonia and allergic reactions and even asthma attacks.

Pathology associated with adult parasites:

1. Toxic and *allergic action.* Fever, *hypersalivation*, neural disorders, skin rash, *immunosuppression.*

2. *Digestive disorders*. Abdominal discomfort, nausea, colic, *vitamin A deficiency* (night blindness), *malnutrition* (when many parasites are present).

3. *Mechanical effect.* In heavy infections the mass of worms may block the intestine (***ileus***). Adults often spread to other organs, e. g., the bile duct (obstructions causes *jaundice*), appendix, mouth, nose, trachea (cause ***suffocation*** – choking).

Diagnosis. Finding of adult worms and eggs. The adult worms may be found in stool (if passed out spontaneously or after treatment). The presence of adult worms in intestines can be detected by contrast X-ray with barium emulsion. Microscopic examination of stool may show both fertilized and unfertilized eggs.

Prevention and Control. a) improvement of proper disposal of human feces, b) treatment of infected patients, c) personal hygiene, d) fighting against mechanical vectors.

Hookworms: *Ancylostoma duodenale. Necator americanus*

In man there are two species causing hook worm diseases, *Ancylostoma duodenale* and *Necator americanus*, which cause ancylostomosis and necatorosis, respectively. Hook worm diseases are anthroponosic and endemic in tropics and subtropics.

Ancylostoma duodenale

Geographical distribution. Tropics and subtropics bordering the Mediterranean, India, China as well as South America, especially where conditions may be favorable: in mines, tea gardens, rice fields.

Morphology. Adults are grayish white or pinkish. The size is about 10-12 mm. The head has a slight bend in relation to the rest of the body. Hence comes the name *hookworm*. The buccal capsule is provided by 4 hook-like teeth and 2 knob-like teeth. The special glands secrete anticoagulant substance which allows permanent feeding with blood in small intestine capillaries.

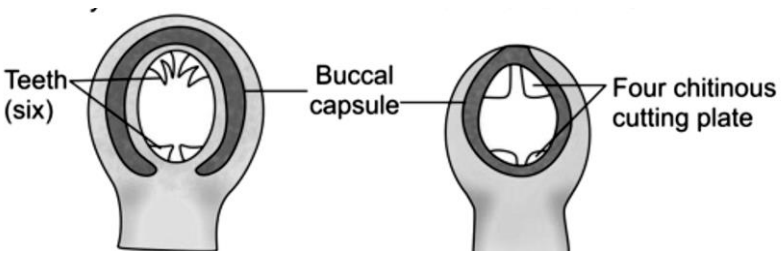


Fig. Buccal capsule of Hookworms.

Life cycle. Hookworms are geohelminthes. Man is the only host. The eggs hatched from adult worm in human intestine eliminate through feces into soil. The eggs require oxygen for hatching and develop in light loamy soils. The released *rhabditiform larvae* transform into invasive *filariform larva*. Humans become infected, usually by walking barefoot across contaminated soil when the filariform larvae penetrate through skin, usually that of the foot. The larvae then invade the blood vessels, reach the lung capillaries and alveoli, and migrate on to the bronchi, trachea, larynx, pharynx, and are swallowed back to small intestines. Here they mature and start a new reproductive cycle.

The filariform larvae of *Ancylostoma* may penetrate also *per os* through ingestion of raw unwashed vegetables or contaminated water. In this case most larvae that are ingested can also pass down to the intestine where they remain.

Pathogenicity. Clinical Features. The clinical effects can be divided into the ones caused by migration of larvae and those caused by the adult worms.

When larvae initially penetrate the skin, they can cause irritation and itching (usually called "*ground itch*"). When the larvae burst out of lung capillaries into the alveolar spaces, local hemorrhages and pneumonia develop; this may cause a cough. In heavy infections they can occupy the whole length of the small intestine and cause gastrointestinal problems such as epigastric pain, discomfort. Since the hookworms are hematophagous, they develop anemia (mainly due to iron deficiency). Anemia in turn may mediate edema, dry and brittle hair and skin, nail dystrophy, immunosuppression, abnormal appetite or *pica* (perverted taste for earth or mud), growth retardation in children.

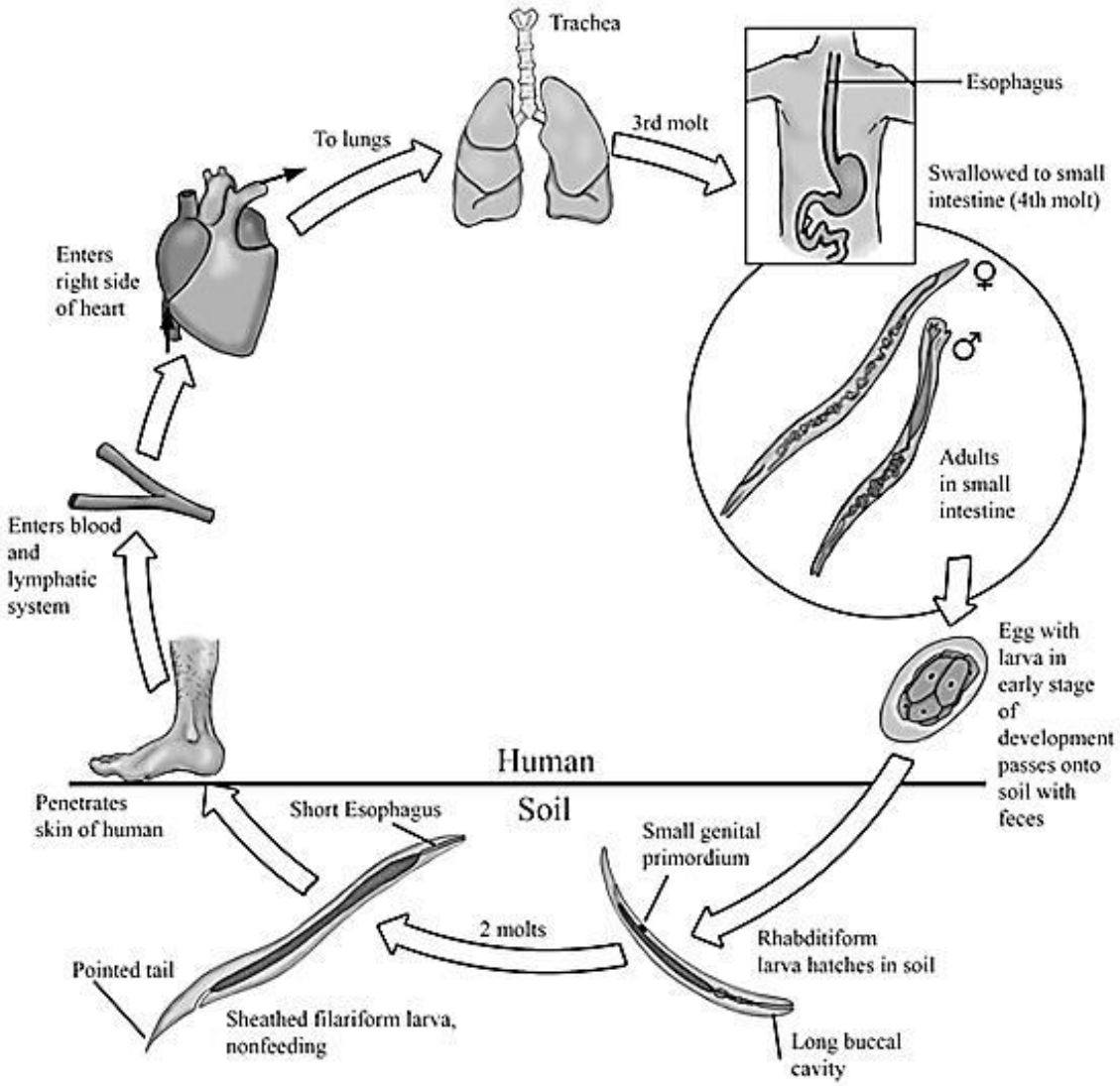


Fig. Life cycle of Hookworms.

Diagnosis. Finding of segmented eggs in stool, or revealing the adult worms through duodenal intubation.

Prevention and Control. a) safe and proper disposal of feces to prevent soil contamination; b) people should put on protective footwear avoiding walking barefoot; c) vegetables should be properly washed and cooked; d) treatment of infected persons.

Necator americanus

Necatorosis is endemic in North America and large areas of South America, Africa, India.

Morphology. Adults resemble those of *A. duodenale* except that American hookworm is shorter (about 8-10 mm), it has 4 chitinous plates – per 2 on ventral and dorsal surfaces.

Life cycle is similar to that of *A. duodenale*, though oral route of infection is uncommon.

Pathogenicity is also common with *Ancylostoma* but is milder in expression due to less blood ingestion in the wall of the small intestine and smaller sizes.

Diagnosis and prevention are same as in ancylostomosis.

Strongyloides stercoralis

Strongyloidosis is anthroponosic disease.

Geographic distribution. It is endemic in tropics, subtropics and warm moist climates, widespread in Eastern Europe and in the Mediterranean region.

Habitat. Small intestine (duodenum).

Morphology. The females are about 2-3 mm long. They are thought to produce larvae by parthenogenesis. The males are about 0.5-0.7 mm. The eggs liberate the rhabdit larvae into the intestinal lumen, from where they are passed to the feces. The rhabdits transform into filariform larvae enter the human through the skin.

Life cycle. *S. stercoralis* is a geohelminth and is considered as a ***facultative parasite***, since it has both free-living and parasitic life cycles. The general life cycle can be shown by direct development, indirect development and hyperinfection.

Direct development: Females produce rhabditiform larvae, which pass through feces. In the soil some of the rhabdits directly develop into infective filariform larvae.

Indirect cycle: Some rhabdits larvae that were eliminated from intestines, mature into free-living males and females, which mate and produce second batch rhabditiform larvae, which only under unfavourable conditions will develop into parasitic filariform larvae and infect the host.

Hyperinfection: In hypoimmune people the rhabdits may transform to filariforms still in the lumen and penetrate intestinal epithelium, thus providing ***internal reinfection***. Some rhabditiform larvae may leave the intestine but not the host, and transform into filariform larvae on the perianal skin, from where they penetrate the same host and through circulation reach intestines again (***external reinfection***). Here they mature into adults and start a new cycle.

After each type of cycle the filariform larvae penetrate the skin and migrate to the lungs. Here the larvae break out of the capillaries into alveolar spaces, migrate up the respiratory tract into the pharynx; they are then swallowed, reaching the small intestine, where the adults develop.

Pathogenicity. Clinical symptoms. Skin rash at the site of entry of the filariform larvae. Pneumonia develops during migration of the larvae in lung. Intestinal symptoms express only in massive infections and present with abdominal pain, diarrhea, vomiting frequently with malabsorption, gastrointestinal bleeding, perforation, or paralytic *ileus*.

In immunocompromized patients there are heavy burdens of worms, and filariform larvae may reenter intestinal mucosa and spread through circulation to many organs including the CNS.

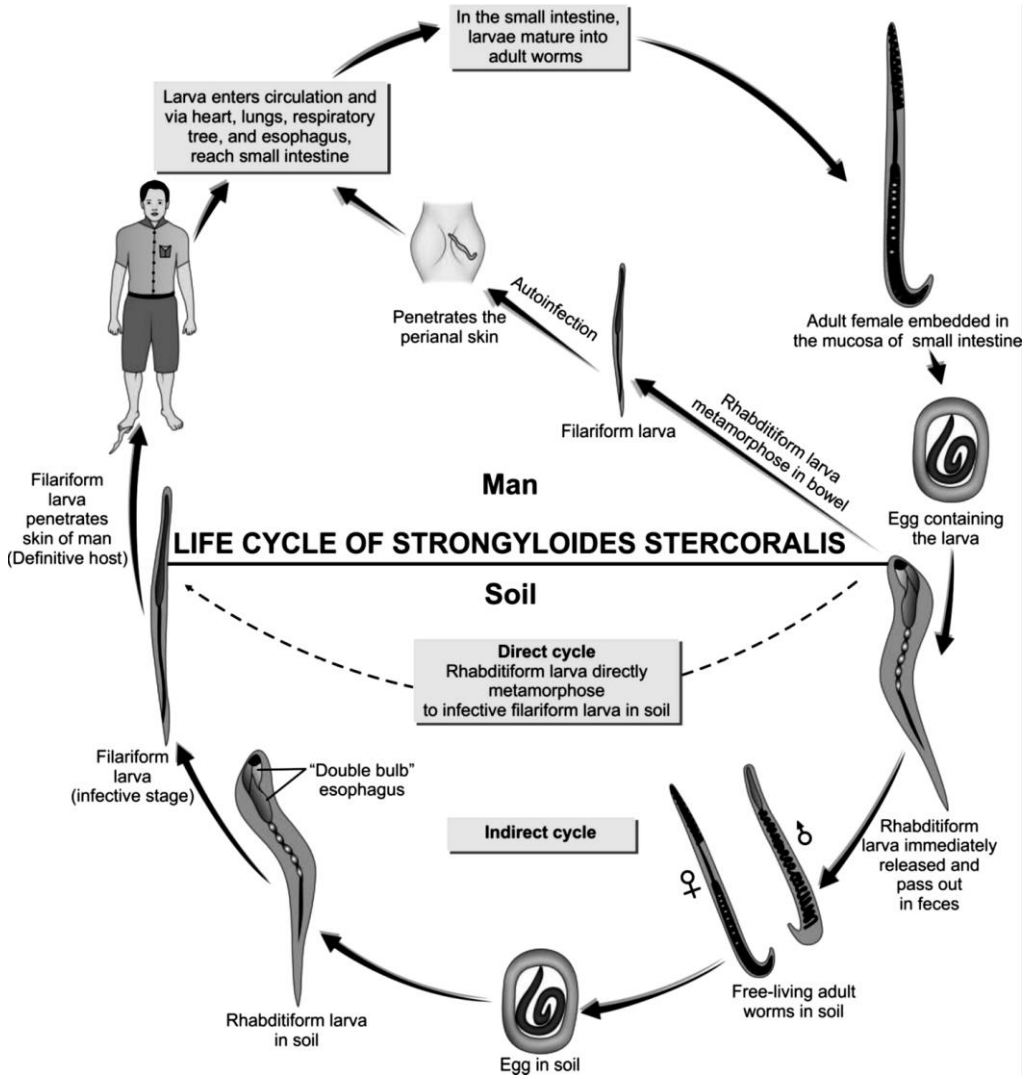


Fig. Life cycle of Strongyloides stercoralis.

Diagnosis is based on finding rhabditiform larvae in freshly passed stools, by a direct smear in cases of heavy infection.

Prevention and control. This is similar to prevention of hookworm infections (sanitation and proper disposal of human wastes, avoidance of walking barefoot, treatment of patients).

1. What is common for T. trichiura?
   A. whip-like appearance
   B. size about 3-5 mm
   C. habitat in small intestine
   D. migration
2. What is common symptom in enterobiosis?
   A. dysentery
   B. anaemia
   C. itching close to joints
   D. perianal itching
3. Which helminth develops by migration?
   A. Fasciola hepatica
   B. Hymenolepis nana
   C. Ascaris lumbricoides
   D. Trichocephalus trichurus
4. What is common for hookworm disease?
   A. vitamin A deficiency
   B. jaundice
   C. peritonitis
   D. iron deficiency
5. Diagnosis of strongyloidosis is based on finding of:
   A. rhabditiform larva in stool
   B. filariform larva in soil
   C. eggs in stool
   D. filariform larva in stool

B

1. What is not common for trichuriasis?
   A. affection of small intestine
   B. dysentery
   C. infection per os
   D. diagnosis by stool study
2. What is not common for Ascaris lumbricoides?
   A. maturation in soil
   B. eggs with larva as invasive stage
   C. non-fertilized eggs as invasive stage
   D. migration in human
3. What symptom is not common in Necatorosis?
   A. anaemia
   B. nail dystrophy
   C. dysentery
   D. immunosuppression
4. Strongyloidosis is not diagnosed by:
   A. immunological tests
   B. stool examination
   C. finding eggs
   D. finding rhabdit larva
5. What is not common for pinworm infection?
   A. prevalence in children
   B. being a contact helminthosis
   C. prevention by keeping hygiene
   D. finding eggs in stool

II

1. Ascaris:
   1. hatches 200.000 eggs per day
   2. is geohelminth
   3. is biohelminth
   4. has primary body cavity
   5. causes contact helminthosis

   A. 1,2,4 B. 2,4,5 C. 3,5 D. 1,4,5

2. The pathogenicity of Enterobius vermicularis is manifested in:
   1. appendicitis
   2. damages of intestinal wall by sharp tail
   3. allergic reaction
   4. obstruction of intestine
   5. suppression of immunity of organism

   A. 3,4,5 B. 1,2,3 C. 2,4,5 D. 1,4,5

3. Trichuriasis is characterised by:
   1. abdominal pain
   2. diarrhea
   3. dysentery
   4. jaundice
   5. pneumonia

A. 1,2,3 B. 2,3,4 C. 1,4,5 D. 1,2,4

4. What is common for necatorosis?
   1. fever
   2. anaemia
   3. local allergic dermatitis
   4. pulmonary hemorrhage
   5. jaundice

A. 2,3 B. 1,4,5 C. 1,3,4 D. 3,4,5

5. Strongyloidosis is prevented by avoiding to:
   1. walk barefoot
   2. eat unwashed vegetables
   3. drink not boiled water
   4. contaminate the soil with feces
   5. eat uncooked meat

A. 1,4 B. 1,2 C. 3,4 D. 2,5

Chapter 24
Biohelminth Nematodes (Trichinella spiralis, Dracunculus medinensis, Filaria). Larva migrans

Biohelminthes pass the life cycle only in host organisms, and two or more hosts are required for completion of whole cycle. The nematodal biohelminthes are *Trichinella spiralis*, *Dracunculus medinensis* and the species of *Filaria*.

Trichinella spiralis

Trichinella spiralis is an agent of trichinosis (or trichinellosis), which is an anthropozoonosic, non-endemic disease.

Geographical distribution. Worldwide but occurs much more frequently in Europe and the United States, where raw garbage containing pork scraps is fed to hogs. The disease is rare in Muslim countries for low consumption of pork.

Habitat. The adult worms are found attached to or buried in the mucosa of the duodenum. The larvae reside in striated muscles.

Morphology. The females measure about 3.5 mm, they are viviparous. The males measure only about 1.5. The larvae coil up spirally (hence the name *T. spiralis*) and encapsulated in the striated muscles of the host.

Life cycle. There is a wide range of carnivorous animals: mainly pigs, rats, dogs, cats, bear and man. *Trichinella* requires only one host in its life cycle, however, the alternation of hosts is required for preservation of the species.

Infection results from consumption of pork meat (such as sausages, salami, wurst) which contain viable, heat-resistant larva. The larvae are released in the stomach, and then locate to the small intestine, where mature worms develop (now human is a definitive host). The females hatch larvae, which penetrate the intestinal wall and migrate through the blood to the striated muscles of usually upper half of the body, e.g. the diaphragm, chest, face (tongue, ocular, chewing muscles). The larvae coil spirally, finally being encapsulated in a cyst, which eventually becomes calcified (now human becomes also intermediate host). The enclosed larva may remain viable for years (even in a cadaver). When muscle containing the larva is ingested by a carnivorous mammal, the larva excyst and reinitiates the life cycle. Humans are *dead end* in the life cycle of trichinella.

Pathogenicity. Clinical symptoms. Depend on the stage of infection. Adult worms cause almost no clinical symptoms, rarely presenting with diarrhea and abdominal pain. The larvae encysted in the muscles cause toxic and allergic manifestations: fever, allergic rash, edema of eyelids, muscle pain, difficulty in breathing (diaphragm or intercostal muscle affection), heart damage, neurological disorders including hallucinations. Death may occur from heart failure, respiratory complications, peritonitis or cerebral involvement.

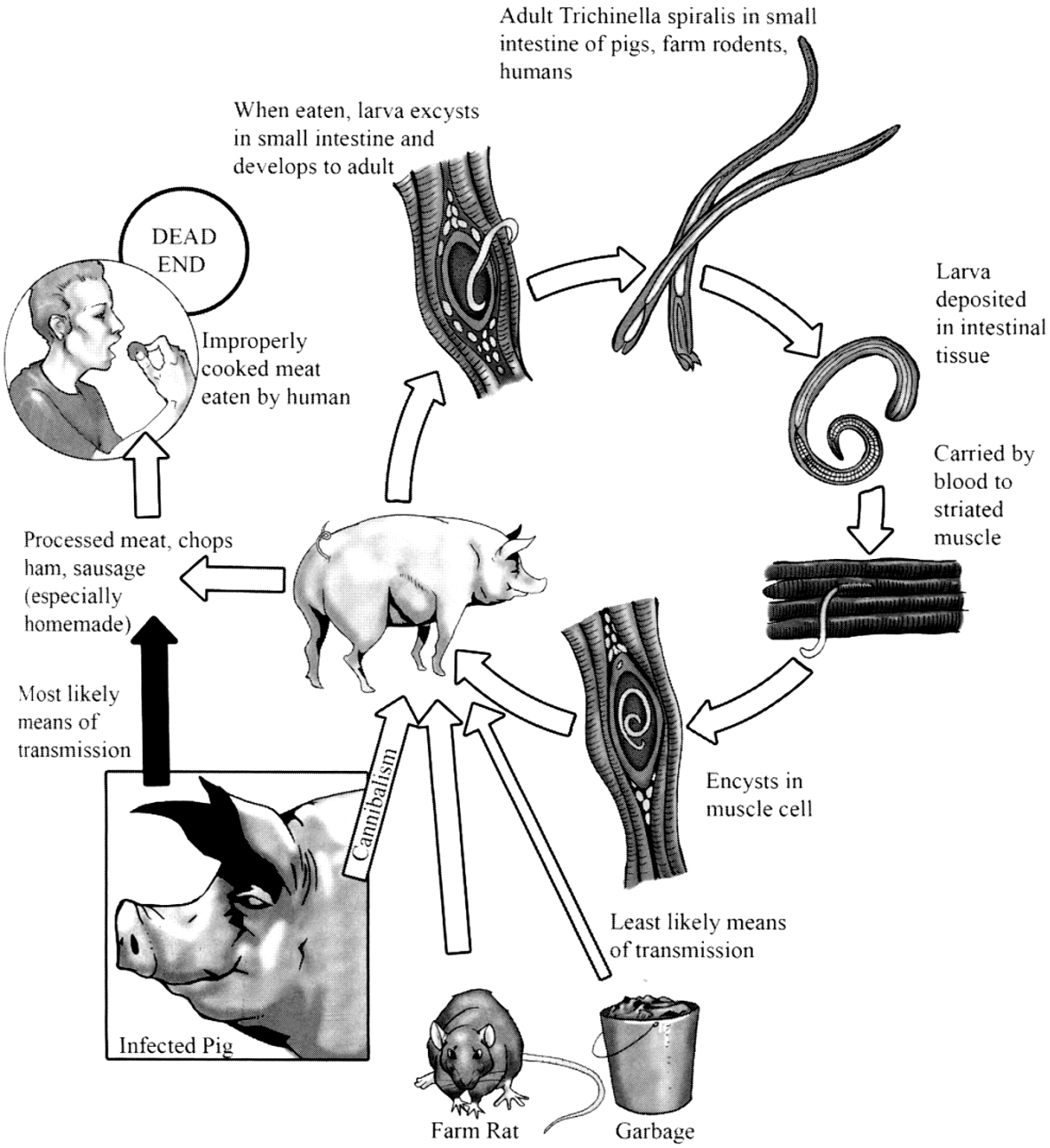


Fig. Life cycle of Trichinella spiralis.

Diagnosis. Demonstration of encapsulated larvae in muscle biopsy; immunological tests. Muscle X-ray shows calcified cysts. Blood examination reveals high eosinophilia.

Prevention. Proper meat handling as well as ordinary cooking, salting, smoking and microwaving the pork meat products will not kill encysted larvae. Sanitary control of pork meat at the markets and avoiding feeding garbage to pigs can prevent infection.

Dracunculus medinensis

Common name is Guinea worm or medina worm. Dracunculosis is an endemic disease. Once being anthropozoonosic, due to effective prevention measures the source of disease now is limitied only to humans (anthroponosic).

Geographical distribution. At present this parasite is found only in Africa.

Habitat. The adult females are usually found in the subcutaneous tissues, especially of the legs.

Morphology. Adult female worms can measure up to 1 m, males are only about 2 cm long. The females are viviparous and discharge the larvae into the water through an ulcerated area of the skin.

Life cycle. The definitive at present is only the man. Before some reservoir animals (dog, horse, cow, wolf, monkeys) could also harbor the parasite. Intermediate host is Cyclops. The larvae of *D. medinensis* are ingested by the Cyclops in the water and become invasive for

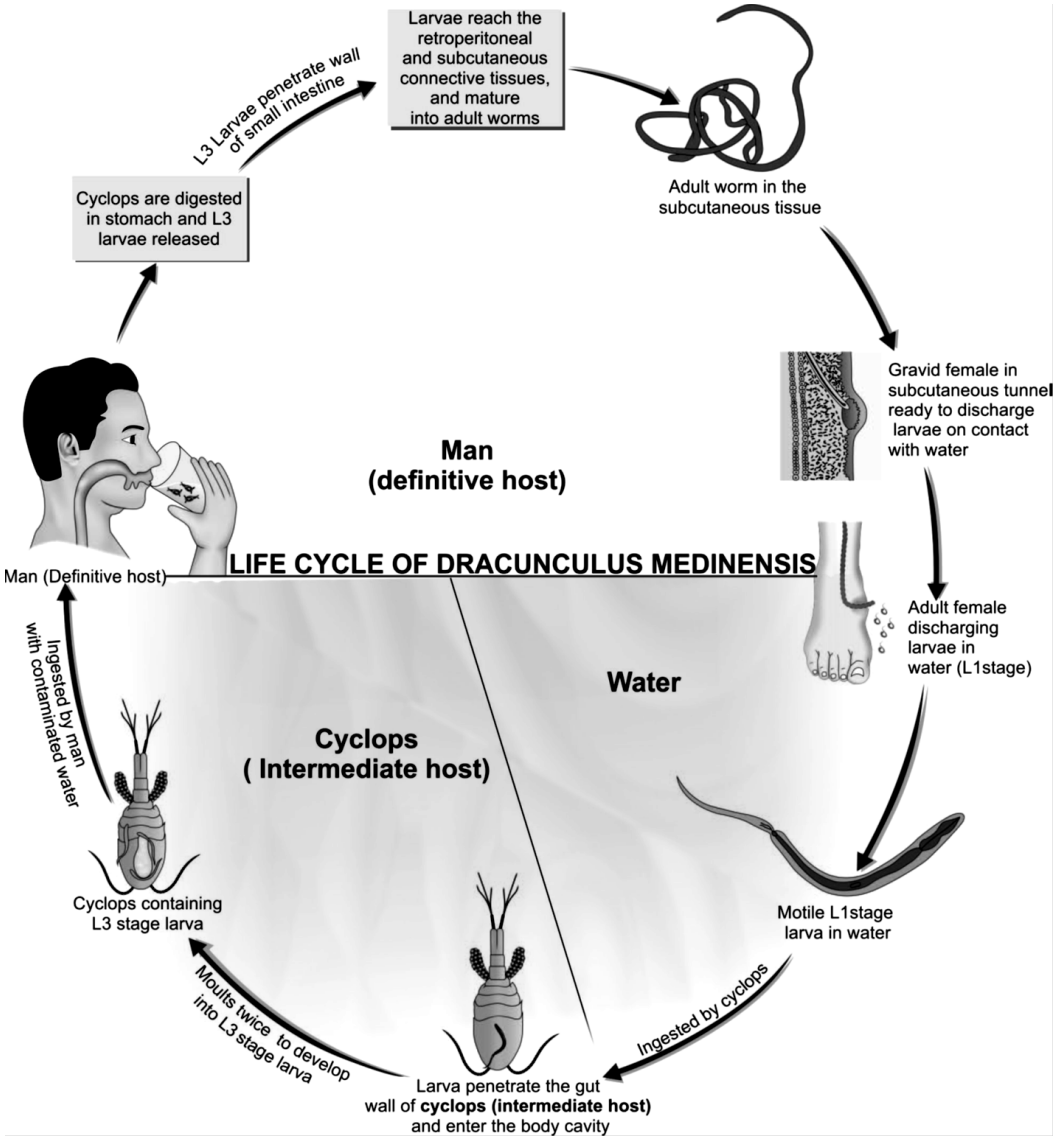


Fig. Life cycle of Dracunculus medinensis.

human. The Cyclops is swallowed by man with contaminated drinking water. Larvae develop into adult in the superficial subcutaneous tissues of mainly the legs, usually close to joints. Under the skin the worm secretes a toxin, which results in blister formation. It produces itching and burning sensation, which makes the human to expose that area to water. The blister later

ruptures and forms an ulcer discharging numerous larvae into the water and repeating the cycle.

Pathogenicity. Clinical symptoms. Mature worm develops a blister usually on the legs or feet. By the time of its eruption, the person may feel itching, swelling and burning sensations. Infected people try to relieve the pain by immersing the infected part in water and assist in discharge of the larvae into water. Then the worm may withdraw into the tissues and become absorbed or calcified, or it may be expelled. If the worm is removed surgically by twisting it around a stick, the wound heals promptly. Serious complications can result from dracunculosis, when the sores produced by the female worms are secondarily infected.

Diagnosis. Detection of adult worm is possible when it appears at the skin surface; the calcified remains of the worm that has died in the subcutaneous tissues may be found on X-ray examination.

Prevention. Control. The infection can be prevented by water sanitation measures to eliminate cyclops (water filtration or treatment with chlorine will kill the intermediate host); avoidance of drinking water containing Cyclops (using boiled or filtered water); preventing persons with an open worm ulcer from entering ponds and wells used for drinking water.

Filarial Nematodes

General characteristics

Morphology. Life cycle. The filariae are thread-like biohelminth nematodes. The filarial infections are called *filariatosis* (or *filariasis*), which are transmissive, endemic diseases. Filaria of humans are: *Wuchereria bancrofti, Brugia malayi, Onchocerca volvulus* and *Loa loa.*

The filariae have two hosts in the life cycle. The definitive host is a human or vertebrate animal (in *B. malayi*). The intermediate host is the arthropod vector. The adult worms inhabit specific tissues. The females are viviparous and after mating they produce microfilariae – thread-like larvae measuring 150-350 mkm, which are released to bloodstream or tissue space. They complete their development in the insect vector and mature to invasive larvae. The infection is transmitted to human through a bite of the insect.

Habitat. Various species of adult filaria inhabit lymphatic system, and others the subcutaneous and deep cutaneous tissues. The elongate form of microfilaria adapts them for the life within vascular system or for migration through tissues.

Microfilarial periodicity. The microfilaria may retain in the peripheral blood or subcutaneous tissue permanently or periodically. When the microfilarial worms leave the peripheral circulatory system, they accumulate in the small vessels of the lungs and liver. According to the day period when the microfilariae appear in the peripheral circulation or tissues the microfilaria are specified to *non-periodic* and *periodic* types. The non-periodic microfilariae are permanently present in peripheral blood or tissues. The periodic microfilariae are in turn of two types – microfilaria with *nocturnal* and *diurnal periodicity*, respectively present during night-time and day-time. The periodicity of microfilariae is a life cycle

adaptation of this parasite and enhances opportunity for filarial larvae to be ingested by the insect vectors that have diurnal or nocturnal periods of active feeding (synchronization with vector activity).

Wuchereria bancrofti

Wuchereria bancrofti is the causative agent of wuchereriosis which is a lymphatic filariasis. It is an anthroponosis.

Geographical distribution. Throughout the tropics and subtropics in Africa, Asia and Americas.

Habitat. Adults are found in the lymphatic vessels and lymph nodes of the human only. The microfilaria have *nocturnal periodicity* and are found in peripheral blood between 10 p.m. to 2-4 a.m.

Morphology. Adult females measure 5-10 cm, males 2.5-4 cm.

Life cycle. Human is the definitive host, and mosquito (genera *Anopheles, Culex and Aedes)* is the intermediate host or a vector. The microfilariae are ingested by mosquito during

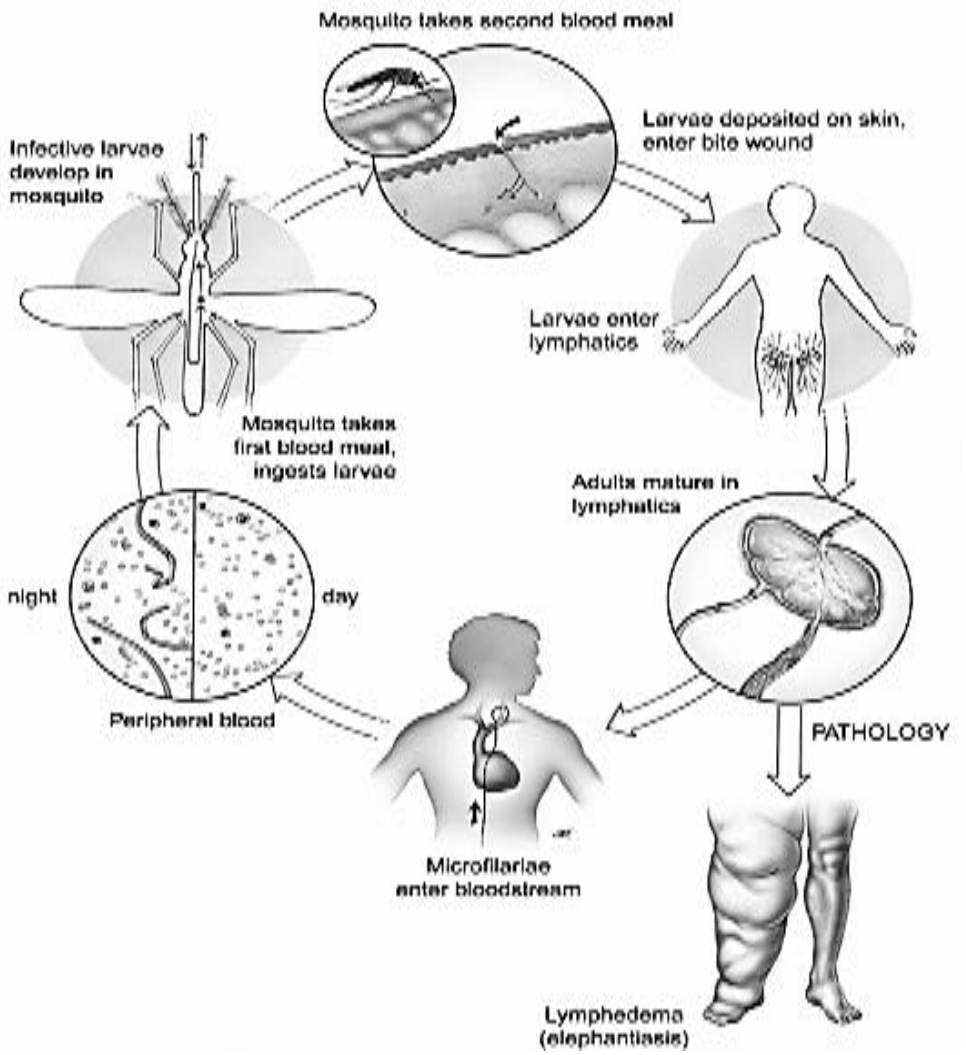


Fig. Life cycle of Wuchereria bancrofti.

its blood meal. When the mosquito bites a human, through blood the larvae spread to lymphatic

system and begin to grow into adults. After mating the microfilariae are hatched and enter peripheral circulation.

Pathogenicity. Clinical symptoms. Early manifestations of wuchereriosis are intermittent fever, allergic reactions. There is inflammation of lymph vessels (*lymphangitis*) and inflammation of lymph nodes (*lymphadenitis*), which are due to lymphatic dysfunction resulting from the presence of living and dead worms in these tissues. Obstruction of lymphatic system may result from mechanical blocking of the lymph flow, which leads to lymphedema – swelling of the organ and its enlargement (usually upper and lower limbs, testes, breast). In some cases chronic wuchereriosis may lead to chronic lymphedema, which results in *elephantiasis*. It is the hyperplasia of skin and subcutaneous tissue over the affected part (usually legs, testes), which may complicate in ulceration and secondary infections. The enlarged size and weight of the affected parts lead to disability.

Diagnosis. Demonstration of microfilariae in thick blood smears usually between 10 p.m. to 2-4 a.m. when microfilarial levels are higher; fining adults by X-ray (revealing dead and calcified adults in lymphatic system) or lymph node biopsy.

Control. Vector control, detection and treatment of infected cases.

Brugia malayi

This filarial is very similar with Wuchereria bancrofti having only minor differences. B. malayi occurs in South China, India, Malaysia, Thailand, Vietnam, Philippines. The microfilaria are smaller in size (230 mkm), and are often subperiodic (besides night, sometimes appear in peripheral blood also during daytime). brugiosis is anthropozoonotic disease, and it affects some monkeys. The intermediate host is the mosquito vector of genus *Mansonia* and *Anopheles* (not *Culex*). Clinical symptoms are similar with wuchereriosis but less expressed. Diagnosis and prevention are as for *W. bancrofti.*

Onchocerca volvulus

Onchocercosis (common name – river blindness) is endemic and anthroponosic disease.

Geographical distribution. Onchocercosis is spread in various parts of Central Africa and Central America. Its distribution is restricted by breeding habits of the vector (blackfly), whose larvae and pupae develop in fast-running rivers or streams.

Habitat. Adults reside in nodules formed in the subcutaneous connective tissues. Microfilariae are found in dermis permanently (*non-periodic*).

Morphology. Female adults may reach up to 50 cm in length and the male measures 3 cm.

Life Cycle. Man is the only definitive host and the intermediate host is a day-biting blackfly (or buffalo gnat). During a blood meal, an infected blackfly introduces filarial larvae onto the skin of the human. The females release microfilariae into subcutaneous tissue and eyes. In subcutaneous tissues the adult filariae reside in nodules. The microfilariae are released from

nodules and migrate to dermis and in the lymphatics of connective tissues, from where they are captured by the vector during a blood meal.

Pathogenicity. Clinical manifestations. The pathogenic effects are provided by both adult worms and microfilariae.

Adult worms form subcutaneous nodules (*onchocercomas*) found on bony prominences. They are painless and non-suppurating. The dead worms in nodules become calcified. In Africa the nodules are located on limbs, trunk, while in America the nodules are frequently seen on scalp. *Microfilariae*: cause lesions found in skin and eyes (cornea, deeper tissues of eye). In the connective tissues of the skin microfilariae produce itching and scratching, and dermatitis. Affected areas of the skin become thickened, depigmented, wrinkled and cracked, producing a "*leopard skin*". Ocular affection leads to impaired vision or total blindness (*river blindness).*

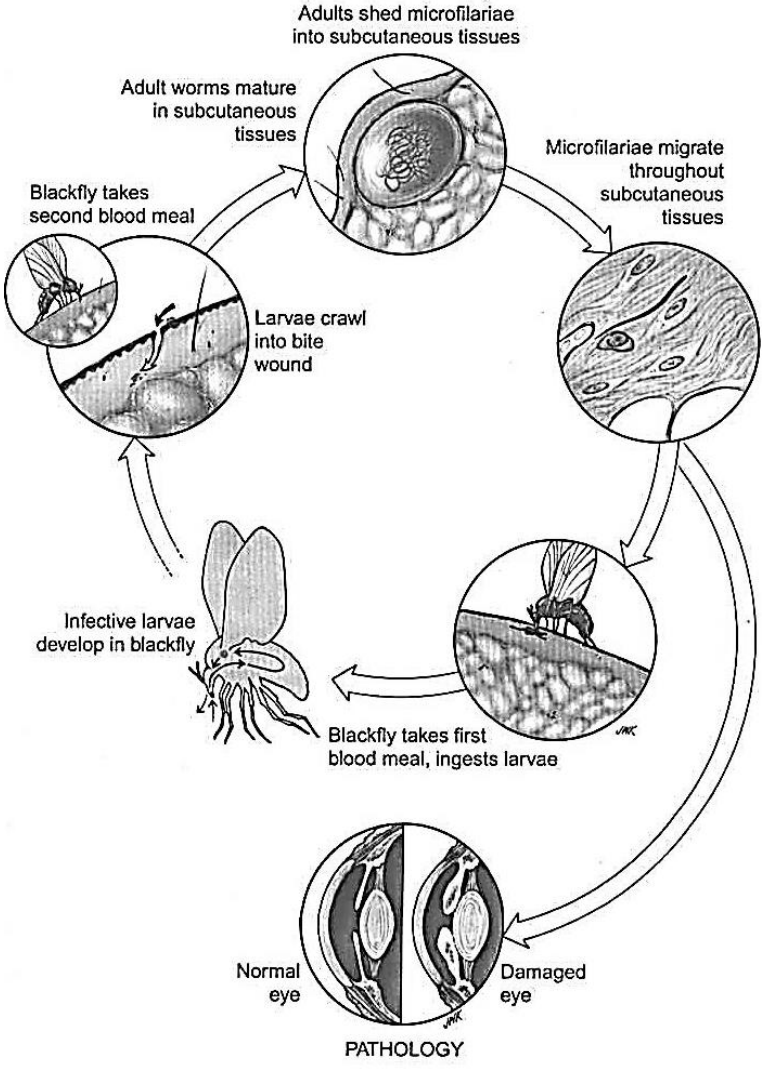


Fig. Life cycle of Onchocerca volvulus.

Diagnosis. Demonstration of microfilariae in the shaved pieces of skin snips and the adult worms in biopsy of nodules.

Prevention. Prophylactic measures should include vector control and treatment of infected population.

Loa loa

Loiasis, is an anthroponosic and endemic disease.

Geographical distribution. that is found in rain forest areas of Central and West Africa.

Habitat. Adult worms are found in the subcutaneous connective tissues as well as in subconjunctival tissue of the eye. Microfilariae circulate in blood and have *diurnal periodicity*.

Morphology. Adult females are about 5-7 cm long, males 2-3 cm.

Life cycle. The life cycle passes in two hosts: man and chrysops (deer fly). The microfilariae enter the definitive host through a day-biting female chrysops. The worm migrates rapidly through subcutaneous tissues and often reaches the eye tissues (conjunctiva). Microfilariae are released to peripheral blood during day time.

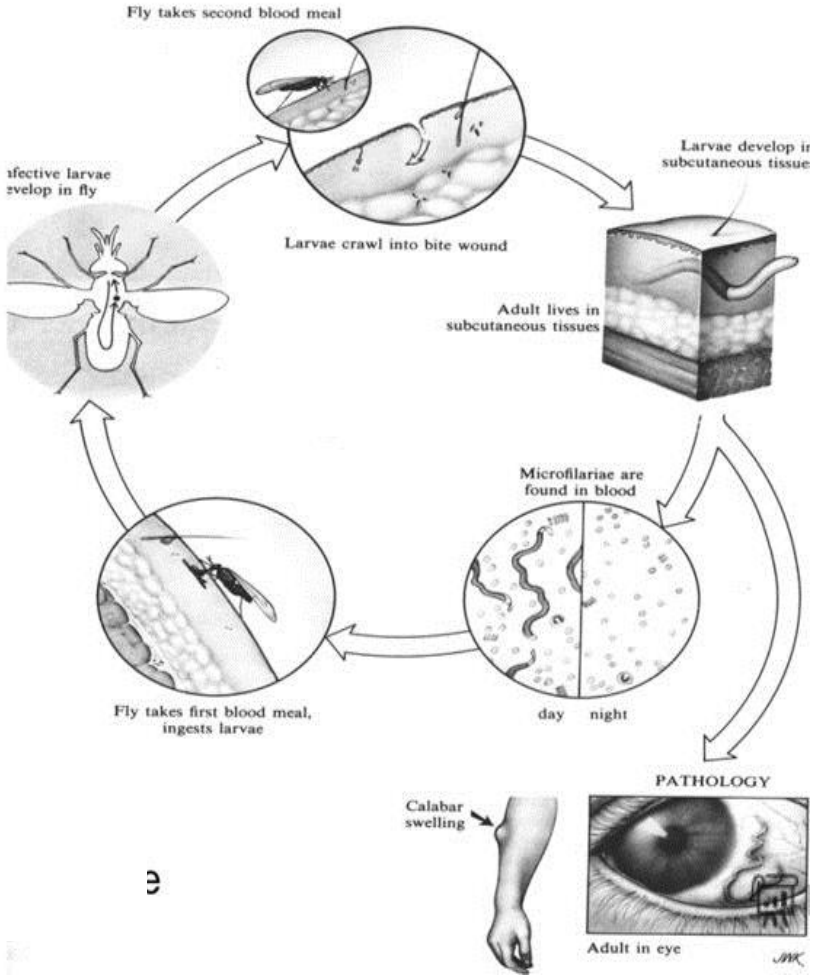


Fig. Life cycle of Loa loa.

Pathogenicity. Clinical symptoms. Migration of adult worms (1 cm per minute) following 3-4 years after infection causes edema of subcutaneous tissues, producing allergic swellings in various parts of the body, known as "*Calabar swellings*" or "*fugitive swellings*". Migration may be completely painless until otherwise it occurs on face and conjunctiva. Conjunctivitis is common manifestation in loaisis.

Diagnosis. The microfilariae are found in peripheral blood at day-time. The diagnosis is usually based on the history of Calabar swellings or the appearance of the worm in conjunctiva.

Prophylaxis. Protection from and fight against vector chrysops, as well as treatment of infected individuals.

Larva migrans

Some non-human species of mainly nematode larvae can be accidental parasites for humans. On entering into an unnatural host – man, they are not able to complete their complete development in the host's tissues for the final destination. They stop maturation during their migration either in skin or in viscera, here causing certain pathogenic effects. This phenomenon is known as ***larva migrans***, or migrating larva.

According to the mode of entrance there are two types of *larva migrans*:

1. Entering by skin penetration, which develops ***cutaneous larva migrans*** or ***creeping eruption.***
2. Entering *per os*, which results in ***visceral larva migrans.***

Cutaneous *larva migrans*. Animal hookworm larvae and the schistosome larvae of aquatic birds are responsible for this dermatologic disease. Infective larvae penetrate skin but are unable to pass through to the circulation and the lungs. They cause allergic dermatitis usually on extremities, accompanied by itching and inflammatory skin reaction.

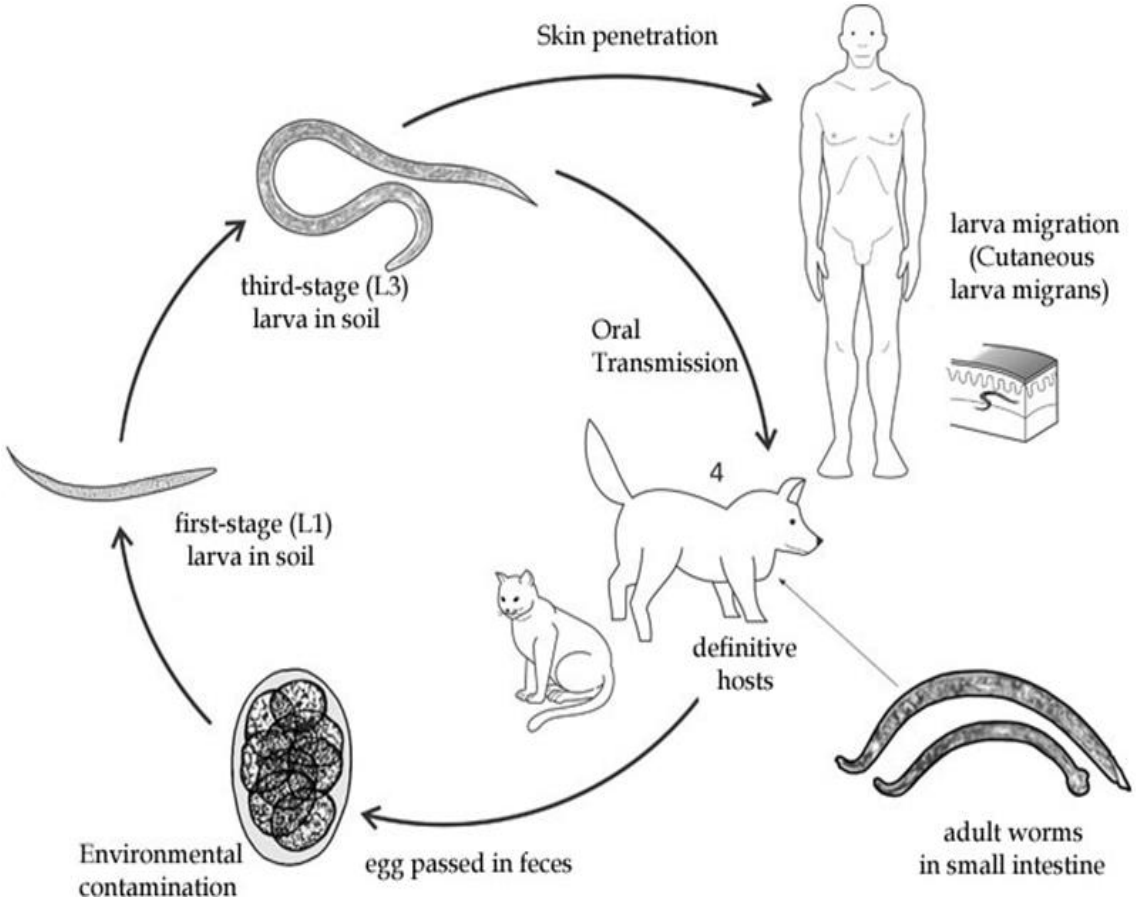


Fig. Cutaneous larva migrans.

Visceral *larva migrans*. The common causative agents are *Toxocara canis* (dog ascaris) or *Toxocara cati* (cat ascaris). The condition is known as *toxocariasis*. Infections are found worldwide. Dogs and cats are common hosts of adult worms. The nematodes complete life cycles in the intestines of their specific hosts and liberate the eggs to external environment. Infection in humans occurs usually in children, when they ingest eggs shed by household pets or found outside the home (sandboxes). After ingestion of eggs, larvae penetrate the bowel wall accessing through portal circulation to the liver and lungs. They form granulomas within these viscera. Larvae may pass to peripheral circulation and reach other tissues (lungs, retina, brain).

Diagnosis of *larva migrans* is usually made by specific serologic tests. Blood analysis finds hypereosinophilia and high leukocytosis.

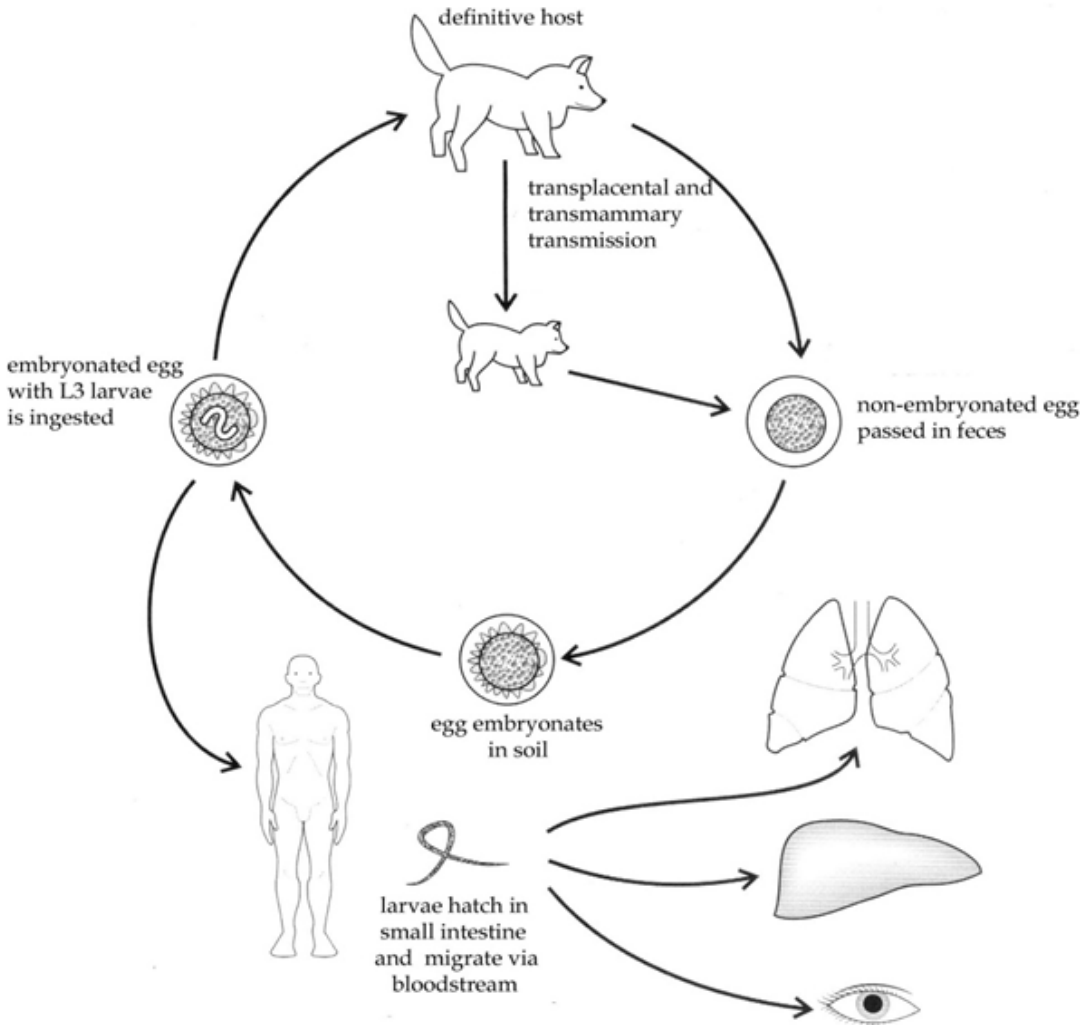


Fig. Visceral larva migrans.

1. What is common for Trichinella spiralis?
   A. development in single host
   B. anthroponosic pattern of infection
   C. infection through skin
   D. spiral-shape adults

2. Which biohelminth is transmitted by drinking contaminated water?
   A. Trichinella spiralis
   B. Loa loa
   C. Dracunculus medinensis
   D. Wuchereria bancrofti

3. What system is affected in wuchereriosis?
   A. lymphatics
   B. nervous
   C. excretory
   D. gastrointestinal

4. Which helminthosis is diagnosed by finding larva in blood?
   A. echinococcosis
   B. sparganosis
   C. strongyloidosis
   D. loaisis

5. Visceral larva migrans is common for:
   A. Ascaris lumbricoides in human
   B. Toxocara cati in cat
   C. Toxocara canis in dog
   D. Toxocara cati in human

B

1. What is not common in trichinellosis?
   A. allergy
   B. myalgia
   C. anthropozoonosic pattern
   D. dysentery

2. What is not common for D. medinensis?
   A. biohelminth life cycle
   B. transmissive spreading
   C. infection per os
   D. habitat under skin

3. What is not a reason of lymphatic obstruction in wuchereriosis?
   A. location of adults in lymph nodes
   B. location of microfilaria in lymph nodes
   C. lymphangitis
   D. location of adults in lymph vessels

4. What is not common for loaisis?
   A. elephantiasis
   B. fugitive allergic dermatitis
   C. Calabar swellings
   D. conjunctivitis

5. Which nematode does not cause visceral larva migrans?
   A. Ascaris lumbricoides
   B. Toxocara cati
   C. Toxocara canis
   D. Zoonosic ascaris species

II

1. Infection with trichinellosis occurs via:
   1. ingestion of raw pork
   2. ingestion of raw beef
   3. ingestion of raw bear meat
   4. drinking contaminated water
   5. walking barefoot

A. 1,2 B. 1,3 C. 3,4 D. 1,5

2. What is common for cycle of D. medinensis?
   1. developing as biohelminth
   2. developing as geohelminth
   3. cyclops as intermediate host
   4. fish as intermediate host
   5. migration through lungs

A. 1,3,5 B. 1,4 C. 1,3 D. 2,3,4

3. Periodicity of microfilaria depends on:
   1. time of their revelation in blood or skin
   2. vital activity of vectors
   3. vital activity of definitive hosts
   4. period of their development in host
   5. periodicity of fever attacks

A. 1,2 B. 2,3 C. 1,4 D. 2,5

4. Loaisis is prevented by:
   1. control of chrysops
   2. control of blackflies
   3. mosquito nets
   4. washing vegetables
   5. keeping hygiene

A. 1,3,5 B. 1,3 C. 2,3,4 D. 2,5

5. Visceral *larva migrans* is caused by parasites of:
   1. humans
   2. animals
   3. genus Schistosome
   4. genus Ascaris
   5. genus Strongyloides

A. 1,2 B. 2,4 C. 3,4 D. 2,5

Chapter 25

Medical Arachnoentomology. Phylum Arthropoda

Arthropoda (Arthropod – "joint-footed") are an enormous phylum. This is the most successful life-form on the Earth in terms of variety. It includes over 1 million known species and there are probably 10 times as many unidentified species.

The common general morphological characteristics of all arthropods include:

1. Segmented bodies.
2. An external skeleton is made of chitin, which makes them highly protective and mobile; and prevents desiccation (dehydration).
3. Jointed appendages – such as legs and antennae. This gives them their name (from the Greek *arthros* - jointed, *poda* - foot).
4. A ventrally located nerve cord and a dorsal blood vessel.
5. A hemocoel, an open body cavity in which blood flows and bathes the tissues and organs (open circulatory system).
6. Highly developed sensory organs.
7. Sexual dimorphism. Reproduction is sexual. They develop by metamorphosis through several moulting periods since the chitin shield hinders growth of the body. Metamorphosis can be complete or ***holometabolic*** (egg - larva - nymph - adult (*imago*)) or incomplete, that is ***hemimetabolic*** (egg – larva – adult).

Parasitic Arthropods

Three major arthropod groups include parasitic classes:

1. **Crustacea**, parasitism has evolved in many different classes (e.g. copepods and decapods).
2. **Arachnida –** parasitic species belong to order **Acarina** (e.g. mites and ticks).
3. **Insecta** (insects, e.g. mosquitoes, flies, bugs, lice and fleas).

Parasitic arthropods can express their pathogenic effects by:

1. Being a ***nuisance***.
2. Cause injury directly, usually through their bites and blood meal, which may result in ***inflammation or toxic effects***.
3. Constituents of their bodies (including excreta) behave as antigens, leading to ***allergic reactions***.
4. Causing diseases.
5. Transmitting disease agents (mechanical or specific ***vectors*** of viral, bacterial, protozoal and helminthic diseases).

Parasitic Arthropods as Ectoparasites

Blood-sucking organisms take small amounts of blood from many hosts. They do not stay on one host for their entire life, thus they are simultaneously temporary parasites. Examples include: bed bugs, fleas, mosquitoes, tsetse flies and black flies etc.

Micropredators have some general characteristics in common.

General characteristics of ectoparasites:

1. They have become specialized to find a capillary.
2. Their specialized mouthparts allow them to obtain blood.
3. They secrete anti-coagulants to prevent host blood from clotting.
4. Many ectoparasites also secrete an anesthetic to reduce pain during blood meal.

Class Crustacea

Cyclops is the intermediate host for *Dracunculus medinensis* and the fish cestodes *Diphyllobothrium latum.* Large crustaceans such as freshwater crayfish and crab serve as intermediate hosts for the lung fluke *Paragonimus westermani*.

Class Arachnida. Ticks and Mites

The class Arachnida includes the spiders, ticks, mites, scorpions and related organisms.

1. Members of the class Arachnida are generally characterised by having two body parts: the *cephalothorax*, which is formed by fusion of head and thorax, and *abdomen*.
2. There are four pairs of segmented legs attached to cephalothorax.
3. The head part (capitulum) contains three structures: a *hypostome*, a pair of *chelicerae* (jaws), a pair of *pedipalps* (sensory appendages). With these appendages the host skin is pierced and either whole capitulum or toothed hypostome is inserted into the opening.
4. Metamorphosis is holometabolic. Larvae have 3 pairs of legs, and beginning from nymph four pairs of legs develop.
5. Most arachnids are terrestrial.

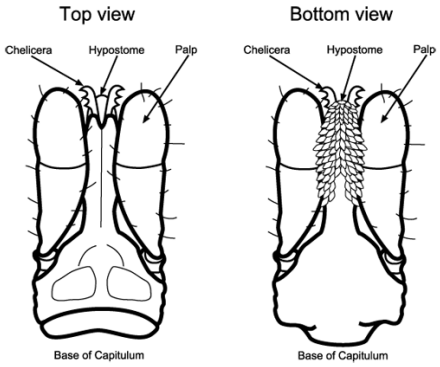


Fig. Head part of ticks.

The representatives of the order Acarina (ticks and mites) have medical significance. The mites are structurally alike to ticks but much smaller in sizes. Ticks are differentiated into two types: soft ticks and hard ticks. The order Acarina includes soft ticks (*Argasidae*), hard ticks (*Ixodidae*) and mites.

Hard ticks (*Ixodidae*)

Hard ticks possess a hard shield called *scutum*, which lies over the front part of the body of the female (scutum should not interfere with feeding), but covers the whole body of the

male. The blood-fed female may reach about 1 cm length (before blood meal it is only 3-4 mm). The capitulum with chelicerae and hypostome is easily observable from dorsal surface. They anchor the hypostome firmly into the skin by means of barbs on the chelicerae, and because of this they can be difficult to remove.

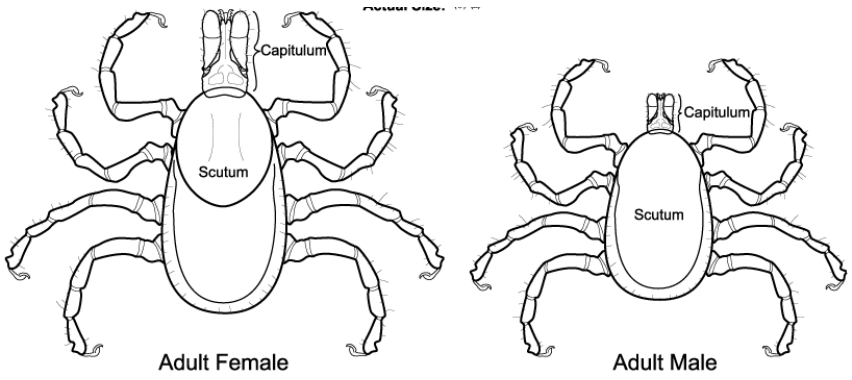


Fig. Morphology of hard ticks.

Ixodid ticks are brownish in colour, their feeding can take many days (because of little chance to find the next host). The bite may be painless (anesthetic secreted). The females are highly fertile and may lay thousands of eggs. Most species can survive for more than one year without feeding.

Hard ticks are of medical importance, since they can:

a) transmit variety of diseases;

b) cause tick paralysis, when the toxins in hard ticks can develop motor paralysis particularly if bitten at the base of the skull. Prompt removal of the engorging tick prevents progression of ascending paralysis.

Human infecting Ixodid ticks include the genera *Ixodes, Dermacentor* and *Amblyomma.*

Ixodes ricinus (dog tick) is the principal vector of *Lyme disease* spread in Northern America, Europe, Eurasia. It is also the vector of *Central European Encephalitis* virus in Eastern Europe and Russia. *Ixodes persulcatus* (taiga tick) transmits *Russian Spring-Summer encephalitis* virus. The reservoirs for these two viruses are ground squirrels.

Dermacentors transmit rickettsial disease *Rocky Mountain Spotted Fever* and tularaemia.

Transovarial transmission of the pathogens is possible in Ixodid ticks.

Soft ticks (*Argasidae*)

Argasid ticks are soft ticks, since they lack the chitinous *scutum* present in hard ticks. They are more primitive than hard ticks and are characterized by a tough leathery integument, flattened oval shape, grayish colour. Argasids need to be examined ventrally to observe their capitulum or mouthparts. The average size

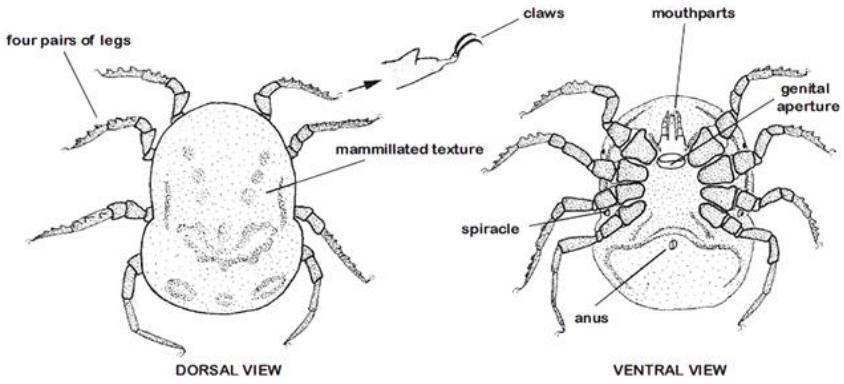


Fig. Morphology of soft ticks.

of soft ticks before blood meal is about 5-8 mm. These are ectoparasites of birds and mammals, including man. Soft ticks more readily may find their hosts, usually feed on blood for hours and the females produce less progeny than Ixodids. Argasids often infest the habitat of the host.

Soft ticks generally have a world-wide distribution (Europe, Africa, Asia and the Americas).

The most important disease vectors are in genus *Ornithodorus*. *Ornithodorus papillipes* is a vector for the prokaryotic agents of tick-borne relapsing fever, tularaemia, and some arboviruses (arthropod-borne viruses). Tick-borne relapsing fever is spread in Middle Asia, Iran, India. *Ornithodorus* can be kept alive in captivity for more than ten years.

Mites

Most mites are minute (mainly microscopic) free-living or parasitic arthropods in terrestrial or aquatic environments. They resemble ticks in morphology with a capitulum and four pairs of legs. Mites are most frequently ectoparasites of the skin, mucous membranes and feathers. Most important genera that may affect humans include: *Sarcoptes, Demodex, Dermatophagoides.*

Sarcoptes scabiei (itch mite)

It lives exclusively on human skin and causes ***scabies***. The female is about 0.3-0.4 mm, colourless and oval with 4 pairs of short legs.

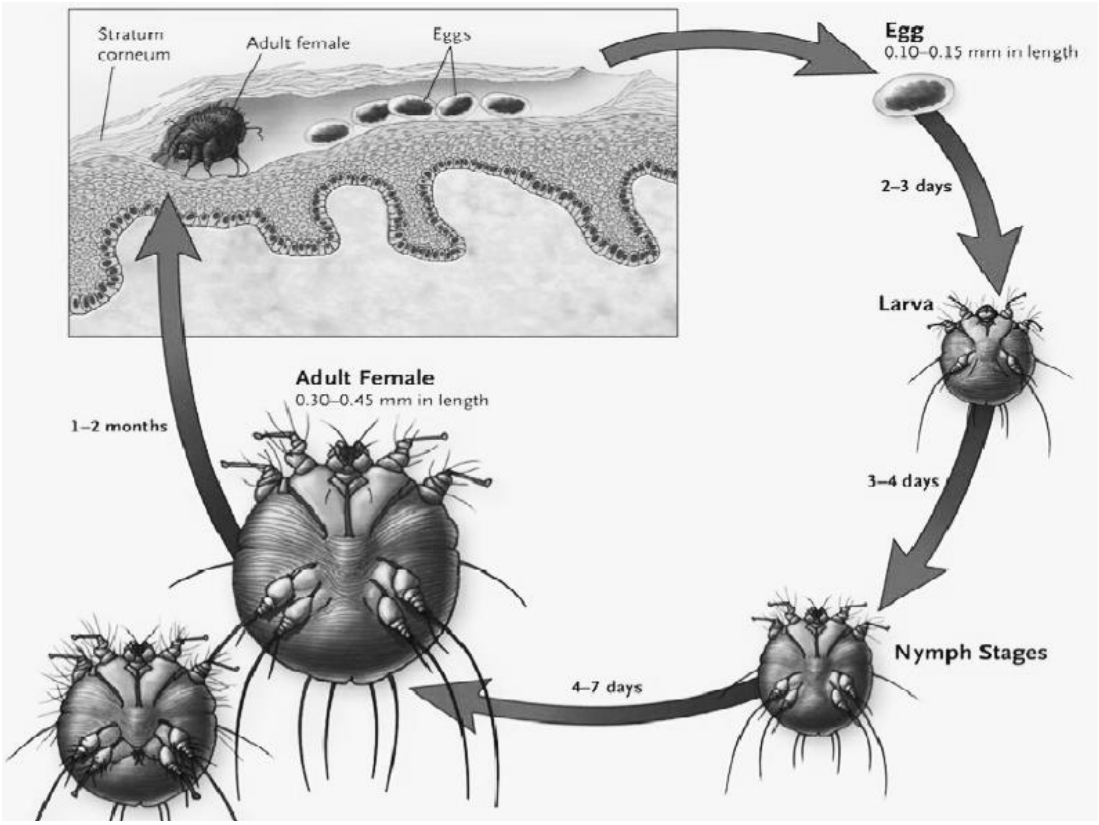


Fig. Morphology and life cycle of scabies mite.

Transmission of scab mites occurs through direct contact with infected persons, or with their clothing and bedding. The adult mites enter the skin and dig burrows in the epidermis. Eggs are hatched in the burrows and transform to larvae, which excavate new burrows and get matured. Preferred sites of infestation are the skin folds between fingers (interdigital spaces), knee fold, groins. The infestation causes intense itching. Scratching may result in bleeding and ***scab*** (hard coating, or crust, on the skin formed during the wound healing) formation, frequently followed by secondary infection.

Diagnosis demands discovery of the mites or their eggs by epidermal shave biopsy or superficial scraping. Scrapings can be observed either by hand lens or low magnification of microscope.

Prevention includes personal hygiene and sanitation. *Lindane* lotion is the treatment of choice.

Demodex folliculorum mites are 0.3 mm in length, live in the sebaceous follicle for 5-6 days and migrate onto contiguous skin at night. Demodicosis is common in immunocompromized and allergic people. Classically, *Demodex* appear as 1 mm "sleeves" around the base of the eyelashes, or obstruct follicles causing acne on face. Diagnosis is confirmed by microscopic examination of any developmental stage of *Demodex* in the follicle extract or eyelash. Washing with soap and water is the most effective method of prevention.

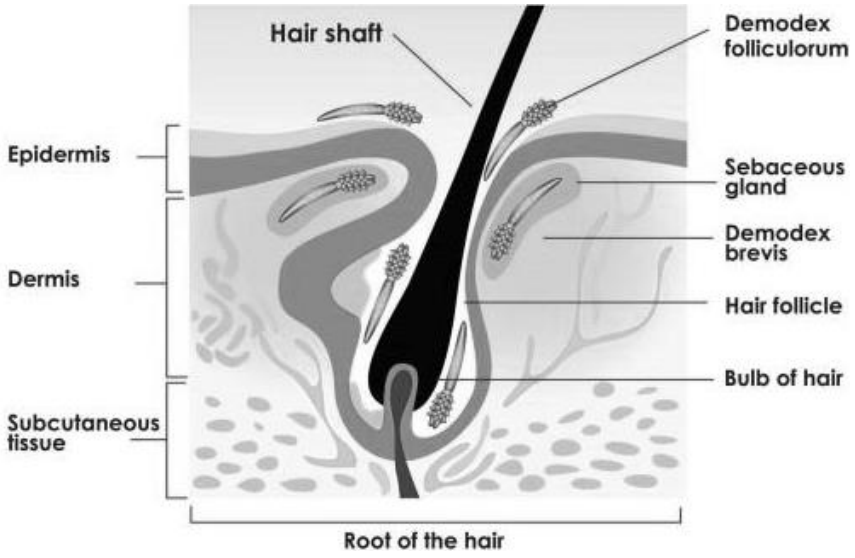


Fig. Dislocation of Demodex mites in hair follicle.

Dermatophagoides, the common dust mite, commonly inhabit beds, mattresses, carpets and house dust. They are motile and feed on residual organic debris. Size is about 0.3 mm. Dust mites are highly allergenic, even when dead and are associated with complex allergies such as asthma, allergic rhinitis, conjunctivitis and atopic dermatitis. Treatment involves removal of accumulated antigens from mattresses and pillows.

Chapter 26
Class Insecta

General Characteristics of Insects

Around one million species of insects account for a great majority of the species of animals on the earth. Insects can be found in almost all terrestrial and freshwater habitats. Common characteristics of insects may include:

1. A body composed of three segments: a head, thorax, and abdomen.
2. Two pairs of wings attached to the thoracic region. There are some orders of insects without wings and some orders with only one pair.
3. Three pairs of legs attach to thoracic segments.
4. A pair of relatively large compound eyes and a pair of antennae.
5. Their mouthparts are related to their feeding habits.
6. They breathe through a tracheal system, branched tubules that carry gases right to the metabolizing tissues.
7. Nervous system of insects is complex, includes ventral nerve cord and number of ganglia.
8. Sense organs are complex and acute. In addition to antennae and compound eyes, some insects are quite sensitive to sounds, and their chemoreceptive abilities are astounding.
9. Reproduction is sexual. Development can be both holometabolous and hemimetabolous. In *holometabolous metamorphosis* the hatched larva feeds and grows, moulting its skin periodically. When larval growth is completed, it stops feeding and builds a case or cocoon around itself. In this non-feeding condition it is called a *pupa*. It is the stage when all the larval tissues change into the adult tissues. Adult emerges from pupa after final metamorphosis.

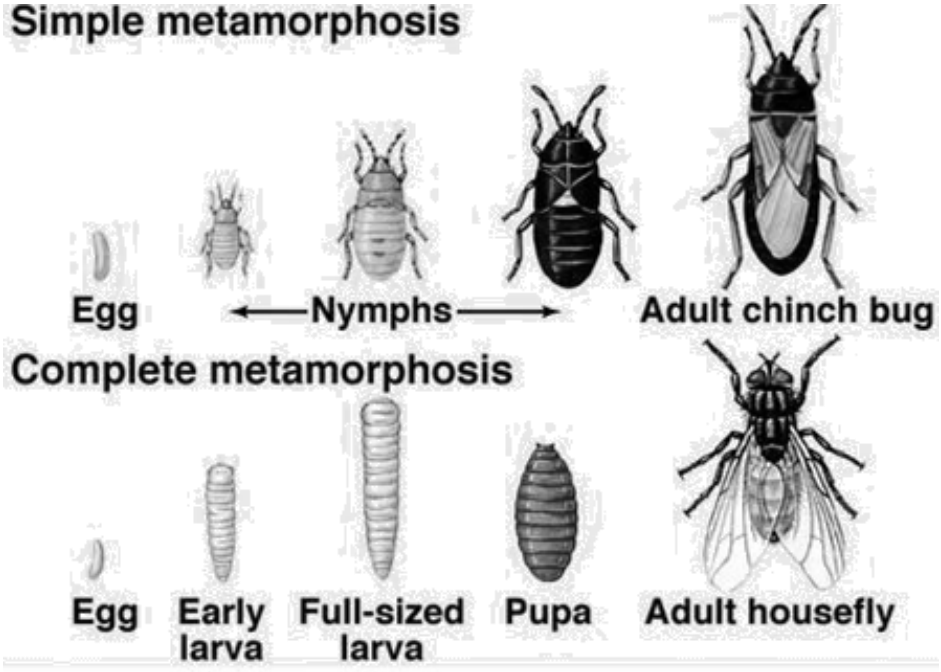


Fig. Complete and incomplete metamorphosis of insects.

In regard to **medical significance** of insects they are divided into following groups:

1. *Synanthropic insects.*
2. *Blood sucking temporary ectoparasites.*
3. *Blood sucking permanent ectoparasites.*
4. *Larval endoparasites.*
5. *Vectors of diseases.*

1. Synanthropic Insects

These are non-parasitizing insects that live with humans (*syn* – together, *anthropos* – human) in their dwellings. They contaminate human habitats and the food by their excretions. For example, cockroaches, house flies, ants and some beetles (e.g., flour beetle). During feeding these insects can mechanically transmit (on palps, body or intestinal tract) different disease agents such as viruses, bacteria, protozoal cysts, helminthic eggs.

Fight against the synanthropic insects is realized through keeping clean the dwelling and keeping the food far from the reach of insects.

2. Insects as Temporary Blood-sucking Parasites

These insects are very mobile arthropods approaching the host only during feeding and living the rest of their life-time free out of the host. They may transmit different pathogenic agents to animals and humans. Like other blood-sucking arthropods, the insect ectoparasites have also become specialized to find a capillary through their specialized mouthparts, which allow them to obtain fluids – blood or lymph. They secrete anti-coagulants to prevent host blood from clotting, and many insects also secrete an anesthetic to reduce pain during blood meal. Sometimes their bite causes severe allergic reaction.

Fleas (*Siphonaptera*)

The human flea, *Pulex irritans*, is found all over the world. It has a little host specificity and can be found on dogs, rats, mice, etc. The species on rats, *Xenopsylla cheopis*, also bites man.

Fleas are laterally compressed and wingless, 1-4 mm in size. The body is generally covered with bristles. They have stout, spiny legs, adapted for jumping. The metamorphosis is holometabolous.

Flea bites induce allergic rash commonly on the unprotected lower leg and all over the body of children who have contact with animals. Mainly the rat fleas spread the plague agents (*Yersinia pestis*). *Pulex irritans* is not a major vector of plague. Cat and dog fleas serve as intermediate hosts for another common tapeworm (*Dipylidium caninum)*, which can be spread to humans, especially children with exposure to pet animals.

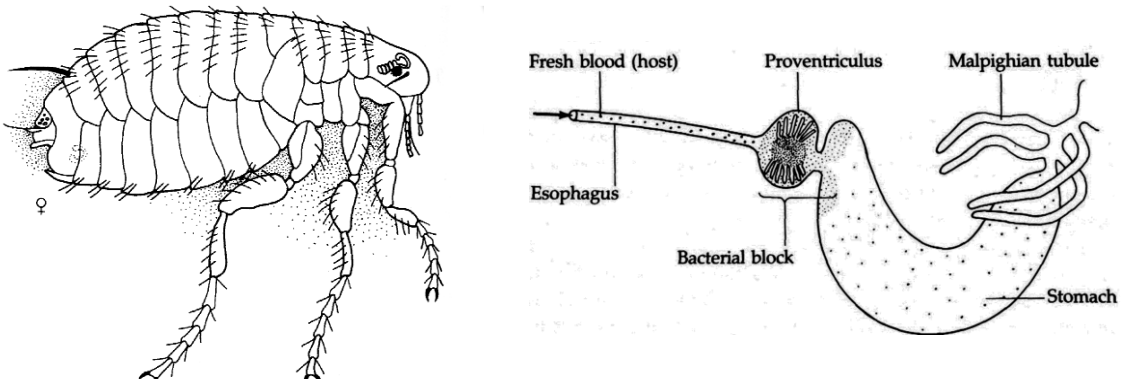


Fig. Adult rat flea and the proventriculus of flea blocked with plague agents.

Plague is a facultative transmissive disease in sense that it can be transmitted also through direct contact with rodents or non-transmissive routes (respiratory; drinking contaminated water). Once ingested by the flea, *Y. pestis* may reproduce so rapidly that it blocks the flea's *proventriculus* (organ between the esophagus and stomach). When the flea then again has a blood-meal, the blood intake is blocked by this plug, and the blood and bacilli are forced back into the wound (regurgitation), infecting the host.

Bugs (*Hemiptera*)

The basal half of the front wings is leathery and the apical half as membranous textures. At rest, these wings cross over one another to lie flat along the insect's back. Hemiptera undergo incomplete metamorphosis.

***Cimicidae* (Bedbugs)**

The Cimicidae species have greatly reduced wings and do not fly.

Cimex lectularius, otherwise called bedbug, is brownish in colour and dorsoventrally flattened. Bedbugs are photophobic, and during the day will remain hidden in any small cracks or crevices. Allergic skin reactions (large wheals, exceeding 1 cm, which are accompanied by itching and inflammation) commonly on the arms and shoulders are caused by saliva of bedbugs.

There is a suggestion that bedbugs might play a role in the spread of hepatitis B.

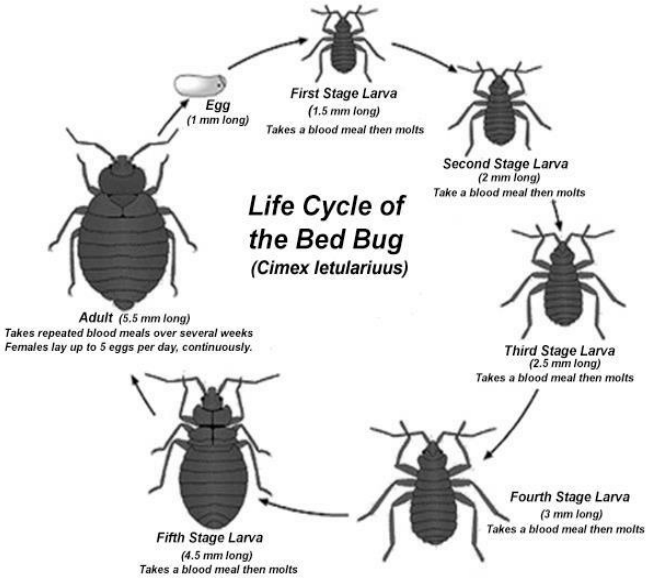


Fig. Life cycle of bed bug: incomplete metamorphosis.

Reduviidae

The *Reduviidae* are commonly called Triatomine bugs or kissing bugs that are spread in Central and South America. The kissing bug is dorso-ventrally flattened and is armed with a

long, piercing proboscis. *Triatoma* are predominantly nocturnal and feed on a sleeping person's exposed body parts, usually face (lips, eyelids). They will not feed through clothing, since the mouthpart is not that penetrating. The bite of *Triatoma* is painless but may swell and cause a substantial wound that itches for several days. The *Triatomine* bugs are vectors of *Trypanosoma cruzi,* the agent of Chagas' disease. If the feces of the bugs is scratched into the bite or onto mucous membranes, it can enter the human body; therefore, always disinfection is needed at the bite site with iodine to prevent infection, and then wash it to remove fecal material.

Fig. Reduviid bug.

***Diptera* (True flies)**

Diptera or true flies are one of the largest insect orders in the world and include many familiar insects such as mosquitoes, midges, sand flies, house flies and blowflies.

Diptera can be distinguished by the following features:

1. One pair of membranous wings.
2. Hind wings are reduced to small club like structures calledhalters. The halters are used for balance during flight.
3. A large and moveable head.
4. Sucking, piercing-sucking or sponge-like mouthparts (all adapted for a liquid diet)
5. Large compound eyes.
6. Short simple antennae, frilled or bushy in mosquitoes.
7. Complete metamorphosis.

Mosquitoes (Culicidae): *Anopheles, Aedes, Culex*

Around 3.500 species of mosquitoes are spread worldwide. Adult females in most species are temporary blood-feeding ectoparasites of vertebrates, since they require blood meal to mature eggs. Mosquitoes are small with very long slender legs. The head contains a pair of compound eyes, a pair of antennae, and a proboscis. They have two wings with scales. The thorax and abdomen are often also covered with scales. Mosquitoes have holometabolous development (egg, larva, pupa, adult). The eggs are laid in water or on a moist surface. Eggs, larvae and pupae are aquatic. The larva is an active feeding stage. It feeds on particulate organic material in the water. The larvae of most species have a breathing tube (except *Anopheles*) and must occasionally come to the surface of the water to get oxygen. The pupa is lighter than water and floats on surface. It has a comma-shaped body bearing a pair of respiratory trumpets.

Mosquitoes may be classified as Anopheline (genus *Anopheles*) or Culicine (genera *Aedes*, *Culex*).

Subfamily Anophelinae. Genus *Anopheles* is recognized by maxillary palps as long as proboscis in both sexes. Eggs are laid singly on water surface; larvae are without respiratory

siphon, and they must lie parallel to the water surface in order to get a supply of oxygen through a breathing opening. At rest (during feeding), *Anophelines* usually position abdomen at an angle to the surface.

Anopheles is vector of malaria, Bancroftian and Brugian filariasis and of multiple arboviruses (dengue fever, yellow fever and haemorrhagic fever).

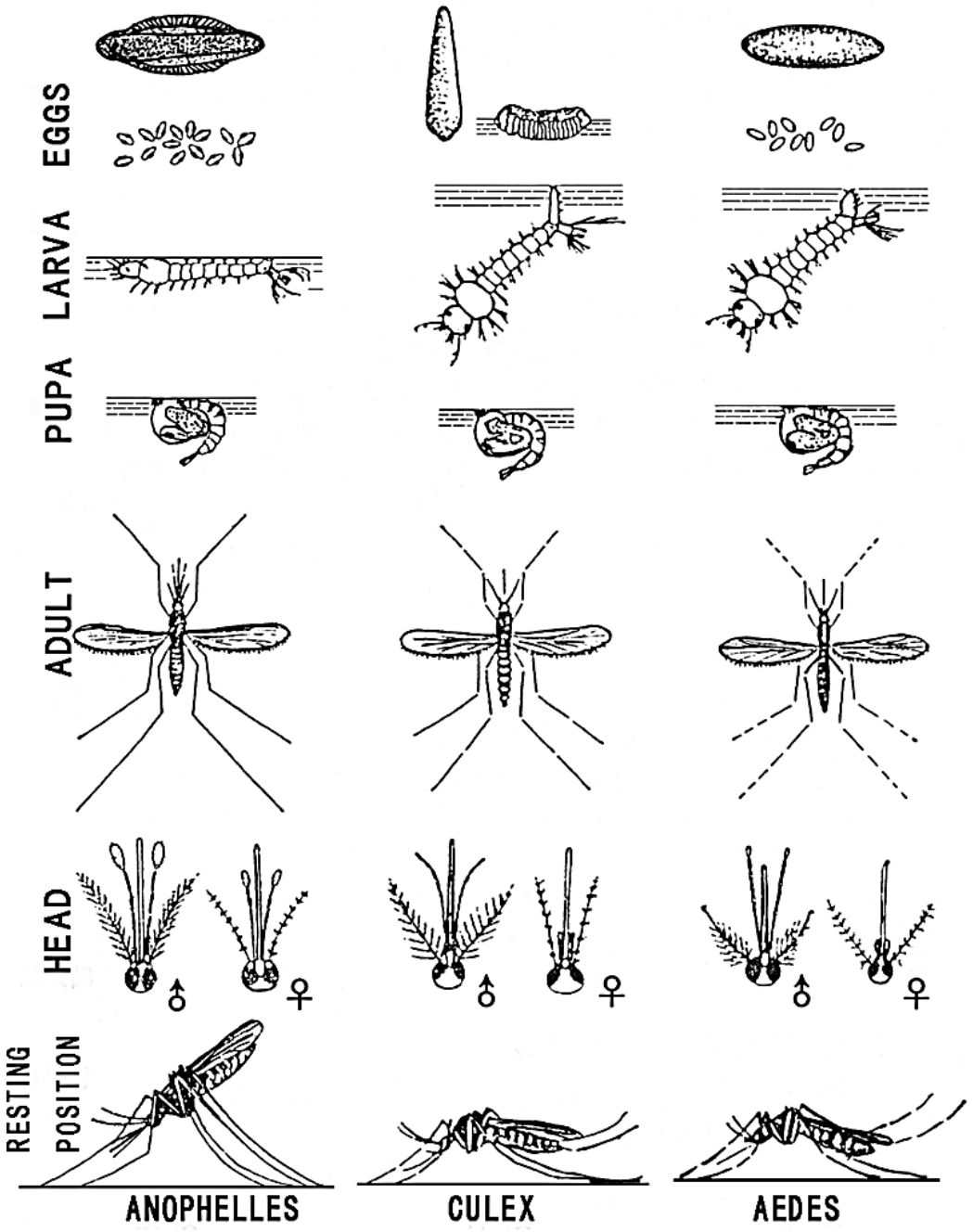


Fig. Morphological stages of Anopheline and non-Anopheline mosquitoes.

Subfamily Culicinae. Includes genera *Aedes* and *Culex*. They are recognized by short maxillary palps in female (still long in male). If a mosquito is incorrectly sexed, a female Anopheline may be confused with a male Culicine. Eggs are laid singly (*Aedes*) or in rafts (*Culex*) on water surface; larvae have respiratory siphon and position under angle to the water surface. Culicine adults maintain their abdomen in a parallel position.

Aedes lays eggs singly, usually in temporary aquatic habitats (tree holes, human-created cavities). *Aedes* and *Culex* mosquitoes are vectors of Bancroftian filariasis and arboviruses (arthropod-born viruses) such as yellow fever and dengue.Prevention includes measures against adult and larval stages of mosquitoes (see in Malaria).

Flies (*Muscidae*)

Blackflies

Adult blackflies are small insects that measure 1-5 mm in length, and possess a shiny thorax that ranges in colour from black to various shades of gray or yellow. Females of *Simulium* species deposit eggs on the plants or stones in fast-flowing rivers. The blackflies of genus *Simulium* are vectors of *Onchocerca volvulus* causing onchocercosis in Central and South America and Central Africa. In addition, the bite of blackflies can themselves be troublesome and frequently produce severe reactions.

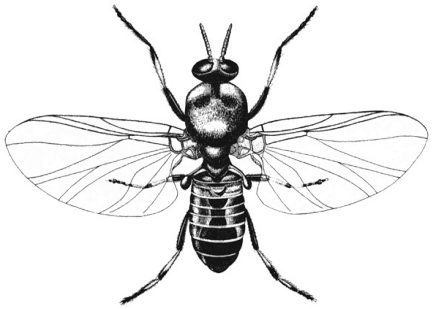


Fig. Blackfly.

Sandflies

Phlebotomine sandflies transmit leishmaniosis agents (visceral, cutaneous, mucocutaneous). *Phlebotomus* prevail in the Eastern Hemisphere, and genus *Lutzomia* in Western Hemisphere. Sandflies are 1.5-2.5 mm long, with long and slender legs, and short setae (hair) that cover most of its body and wings. Sandflies are not strong fliers, usually remaining close to their breeding sites in damp areas rich in organic debris (e.g., under logs and dead leaves, inside hollow trees, and in animal burrows) and fly usually at twilight.

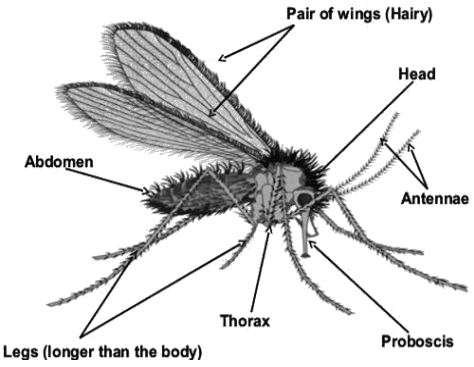


Fig. Sand fly.

Tsetse flies

Members of the genus *Glossina* are dangerous not only because they are vectors of African trypanosomosis (*T. brucei gambiense, T. b. rhodesiense*) but also because both male and female flies feed on blood, and their bites inflict large, painful welts on the humans. *Glossina palpalis* transmits the Gambian sleeping sickness, and *Glossina morsitans* is the vector of Rhodesian sleeping sickness. Tsetse flies measure 6-14 mm, with long proboscis. They usually attack moving subjects (humans, animals) and objects (cars). The female harbours fertilized eggs that hatch at intervals into larvae. The developing larvae burrow into the soil and pupate.

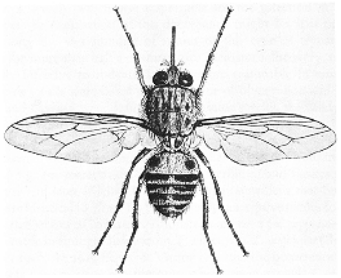


Fig. Tse-tse fly (Gl. morsitans).

Tabanid flies

Tabanid flies are large (about 3 cm), stoutly built and often brightly coloured. They are strong fliers and may violently attack variety of mammals, including humans. Only adult females are blood feeders. Members of two genera are transmitters of human diseases: *Chrysops*, or commonly known as deerfly, and *Tabanus*, called horsefly. They are prominent vectors of tularaemia, anthrax. Tularaemia is prevalent in the US, Canada, Europe, the former USSR, Turkey and Japan. *Chrysops* transmits also loaosis (*Loa loa*).

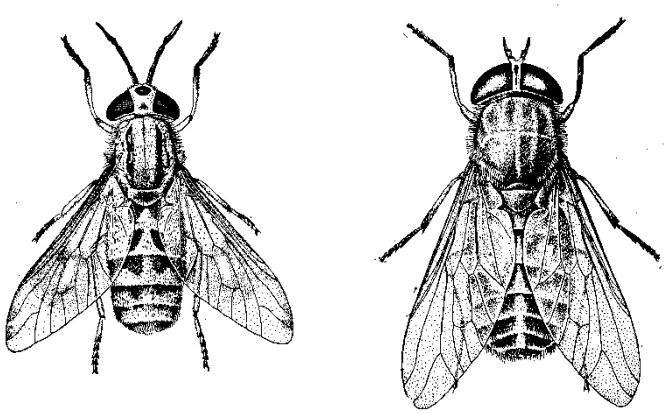


Fig. Chrysops and Tabanus.

3. Insects as Permanent Ectoparasites

Lice *(Anoplura)*

Louse is an insect which is the only permanent ectoparasite of humans on whom it spends its entire life cycle.

Human lice all belong to order *Anoplura*. Three types affect man: the head louse (*Pediculus humanus capitis*), the body louse *(Pediculus humanus humanus*) and the pubic or crab louse (*Phthirus pubis*). Infestation with lice generally is known as *pediculosis*. Crab louse causes *phthiriosis*.

Lice are small wingless insects about 2-4 mm, the body flattened dorso-ventrally. Their legs are inwardly curved and have well developed "claws" for grasping hair or cloth fibres. The claws in the pubic louse are very pronounced giving rise to its alternative name of crab louse. Lice development is hemimetabolous (egg-nymph-adult). The lice eggs are glued to hair or cloth fibres and are called *nits*.

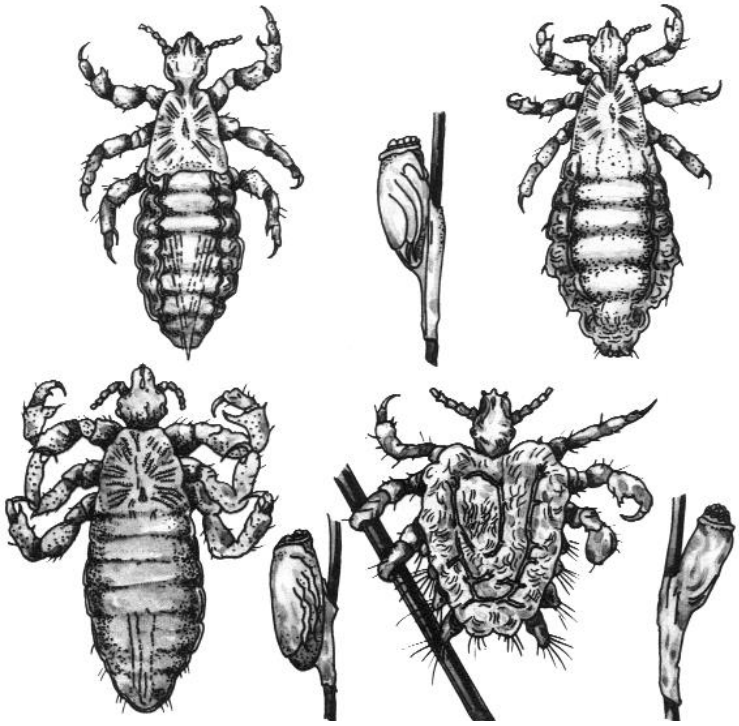


Fig. Head lice: male and female (top), body louse (bottom left), pubic louse (bottom right) and nits attached to hair.

Head Lice (*Pediculus humanus capitis*)

Head lice have grayish coloration and live on the skin among the hair on head. The lice saliva injected during feeding results in itching which is annoying (*pediculosis*), and besides can result in infection if scratched too vigorously. Anyone can become infested – the presence of head lice is not the result of unclean conditions. But mainly children, particularly those of elementary school age, are most likely to get head lice because of their close contact and social

interactions with each other (e.g., sharing hats, combs and brushes) which creates opportunities for the lice to be spread among them.

The eggs (nits) glue to the base of the hair shaft, frequently behind the ears or on the nape of the neck. Head lice can infest clothing and other items that come in contact with the head (e.g., hats, shirt collars, brushes, combs, etc.). Physical removal of adults and nits is an important tactic in head lice control. All bedding and clothing of infested people should be washed and dried at a high temperature. There are several insecticidal products available to control head lice.

Body Lice (*Pediculus humanus humanus*)

Body lice are whitish in colour and look almost identical to head lice, but they locate either on the body or clothing attaching the nits to the fibres of undergarments, particularly along seams and other areas of close body contact. Body lice spend most of their life on clothing and crawl onto the host to feed for short periods. Body louse pediculosis is more likely to occur in situations where the same clothing is worn constantly for several days or weeks.

The head and body lice are also transmitters of pathogens causing louse-borne relapsing fever, louse-borne typhus.

Pubic Lice (Phthirus pubis)

Pubic or crab lice are usually found on the hairs in the pubic areas; however, they can be found among the coarser hairs of the chest, armpits, eyebrows, eyelashes, moustaches and beards. Crab lice are dark gray-to-brown in colour. The name "crab lice" comes from their flattened, oval crab-like shape.

Crab louse causes phthiriasis – its bite produces round gray to bluish coloured swellings on the pubic skin, allergic reaction and intense itching, which may predispose to secondary bacterial infections. Lice infesting the eyelids can cause severe inflammation and swelling around the eyes. Crab lice are spread primarily during sexual contact through pubic skin (rather than genital tract), or less commonly via clothing. Successful treatment and control is based on a combination of sanitation and pediculicides. Crab lice are not known to transmit disease organisms.

4. Insect Larvae as Endoparasites.

Myiasis

The larvae of some *Diptera* have adapted to the parasitic life mode and reside in luminary or parenchimatous organs of the host. These larvae of Dipterans realize anaerobic respiration and are able to move inside the host body. Pupation usually occurs in the environment. The adults have a free living life cycle.

The disease caused by insect larvae is commonly known as ***myiasis***. Myiasis is the infestation with insect larvae, which is common in domestic and wild mammals all over the world. According to the life cycle development and sites of predilection in the host the larval endoparasites are divided into three groups:

1. There are fly species that obligatorily require a host to complete larval development (*obligatory myiasis*). *Wohlfahrtia magnifica* can lay larvae on open skin sores and intact mucosa of ear, nose, eyes, from where they penetrate to deeper tissues and feed on them. The parasitizing larvae may rupture blood vessels and destruct even bone tissue. Infection with this species is dangerous, since because of the vigorous activity of the larvae they may penetrate the middle ear, nasal sinuses or the brain.

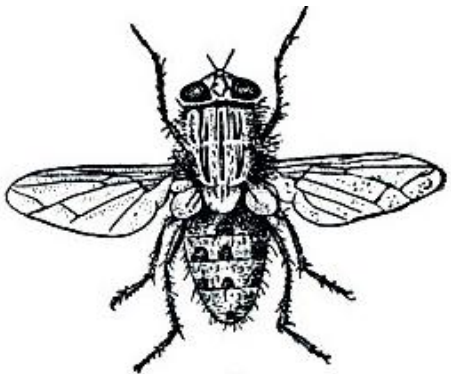


Fig. Wohlfahrtia magnifica.

2. Some flies develop in a host if entry is facilitated by the presence of malodorous wounds or sores but that can complete development also without a host (*facultative myiasis*). These are species that normally lay their eggs in decaying animal or vegetable matter: green-bottle flies, blue-bottle flies, black bottles, blow fly. They occasionally lay their eggs on open sores of animals or humans, especially if the sores are necrotic or malodorous.
3. Accidental endoparasites (*accidental myiasis*) usually have no requirement or even preference for development in a host. However, eggs may be accidentally deposited on oral or urogenital openings, and larvae gain entrance to intestinal or urogenital tracts. The housefly *Musca domestica*, latrine flies, green- or blue-bottle flies may develop accidental myiasis.

Prevention of myiasis includes measures against flies, including proper sanitation measures.

1. What characteristic feature is common for ticks?

a. segmented body
b. pseudocoelom
c. four pairs of walking legs
d. three pairs of walking legs

2. The vector of Russian Spring-Summer Encephalitis virus is:

a. Ixodes ricinus
b. Ornithodorus papillipes
c. Sarcoptes scabiei
d. Ixodes persulcatus

3. Which one is the pathogen of the disease?

a. Dermacentor ticks
b. Sarcoptes scabiei
c. Ornithodorus papillipes
d. Ixodes persulcatus

4. Ornithodorus papillipes transmits agent of:

a. brugiousis
b. tularaemia
c. tick-borne relapsing fever
d. endemic typhus

B

1. Which of the following is not common for Arthropoda?

a. reproduction is sexual
b. segmented legs
c. the outer covering is cuticle
d. chitin made external skeleton

2. What is not common for Sarcoptes scabiei?

a. microscopic sizes
b. lives exclusively on human skin
c. metamorphosis is holometabolic
d. vector of tularaemia pathogen

3. Demodex folliculorum is not found in sebaceous follicles of:

a. lower extremities
b. face
c. neck
d. skin of shoulders

4. Which one is not a member of Ixodid family?

a. Dermacentor
b. Ixodes ricinus
c. Ornithodorus papillipes
d. Ixodes persulcatus

II

1. Arthropods possess:

1. chitin made external skeleton
2. pseudocoelom
3. hypostome
4. a pair of chelicerae and pedipalps
5. integument

a. 1,2 b. 4,5 c. 1,3,4 d. 2,3

2. Tick's larva:

1. has three pairs of walking legs
2. has four pairs of walking legs
3. moults to nymph
4. moults to imago
5. has unsegmented legs

a. 1,3,4 b. 3,5 c. 1,4,5 d. 1,3

3. The members of Ixodes are:

1. Sarcoptes scabiei
2. Ixodes persulcatus
3. Ornithodorus papillipes
4. Ixodes ricinus
5. Demodex folliculorum

a. 1,2,3 b. 2,4 c. 1,3,5 d. 2,4,5

Chapter 27
Laboratory Diagnosis of Helminthoses: Ovohelminthoscopy

Very often parasitic diseases do not manifest expressed clinical symptoms which may assist in diagnosis. The direct diagnosis is usually based on laboratory examinations of various samples depending on the parasite species and its habitat. These can involve blood, stool, urine, mucus, tissue biopsy and puncture samples. Most applicable and useful method for diagnosis of gastrointestinal protozoal infections and helminthoses is stool examination, which may find trophozoites, cysts of protists, and eggs, larvae, segments of helminthes.

Ovohelminthoscopy

Direct diagnosis of helminthic diseases often relies on microscopic identification of the helminth eggs in the infected material (stool, urine, mucus). This method of diagnosis is known as ***ovohelminthoscopy***. The morphology and location of helminth eggs is a valuable tool to the diagnosis of specific helminth diseases.

For the identification of helminth species the following features of eggs should be looked for:

1. Shape, size, colour and markings on the egg shell surface.
2. Presence of operculum.
3. Ovum or differentiated embryo inside.
4. Three pairs of hooklets in ova of cestodes.

Trematode Eggs

Hermaphrodite Flukes: Their eggs are rounded, yellowish-brown, with thin shells, an operculum, which opens as the larvae (a miracidium) hatches.

Schistosomes: The eggs are thin-walled, transparent and contain a miracidium larvae, but in this case do not have an operculum (the egg splitting open laterally), and are usually equipped with a spine.

Cestode Eggs

Diphyllobothrium latum: The eggs are similar in appearance to the eggs of hermaphrodite flukes such as Fasciola, with thin egg shells and an operculum. However, they do not contain a miracidium, but in this case a coracidium larvae.

Other Cestoda: Their eggs have characteristically thick egg shell walls, non-operculated and contain oncosphere larvae, equipped with three pairs of hooks.

Nematode Eggs

Nematode eggs generally conform to the same pattern, with thin egg shells containing either an unembryonated mass of cells, or the first-stage L1 larvae. There are however a few exceptions to this.

Table 1. Main features of Trematode eggs.

Trematode Species	Shape, colour	Size, *mkm*	Operculum; Other features
Fasciola hepatica	Oval, yellow (bile stained)	130-150 x 60-90	Operculated, knob on opposite pole
Paragonimus westermani	Oval, brownish, with thin shells	70-80 x 40-50	Operculated
Dicrocoelium lanceatum	Oval, asymmetric, dark brown	38-45 x 22-30	Operculated
Opisthorchis felineus	Oval, asymmetric, bile-stained	30 x 15	Operculum not prominent, with terminal knob
Clonorchis sinensis	Flask-shaped, bile-stained	27-35 x 11-20	Operculum at the narrow end
Schistosoma haematobium	Elongated, transparent	120-170 x 50-60	No operculum, with terminal spine
Schistosoma mansoni	Elongated, transparent	110-160 x 60-65	No operculum, with lateral spine
Schistosoma japonicum	Oval or subspherical, transparent	85 x 65	No operculum, with minute terminal spine

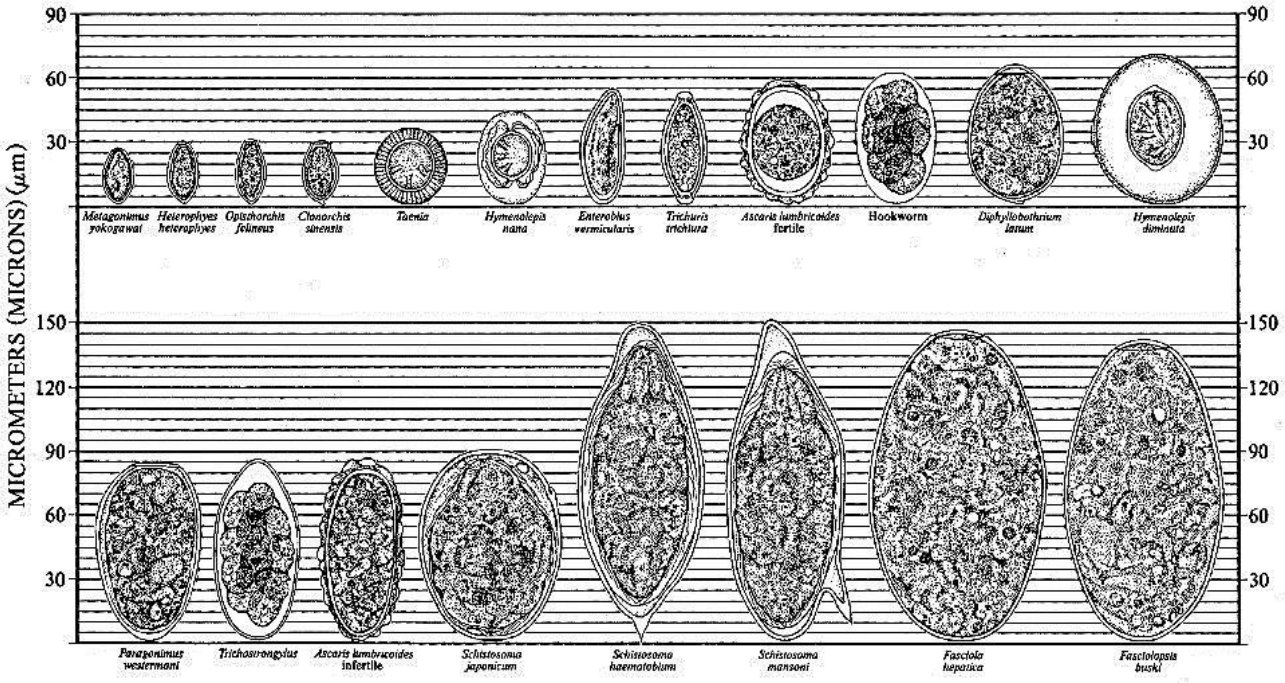


Fig. Relative sizes and comparative morphologies of helminth eggs.

Table 2. Main features of Cestode eggs.

Cestode Species	Shape, colour	Size, *mkm*	6-hooked embryo (oncosphere); other features
Diphyllobothrium latum	Oval, asymmetric, brownish,	60-75 x 40-50	Operculated, germ cells within (no oncoshpere)
Taenia solium, Taenia saginata	Spherical or oval, yellowish	30 x 35	No operculum, thick, radiated shell
Hymenolepis nana	Spherical, transparent	35 x 50	No operculum, double-membraneous shell, polar filaments

Table 3. Main features of Nematode eggs.

Nematode Species	Shape, colour	Size, *mkm*	No operculum, Other features	Shell wall
Enterobius vermicularis	Elliptic, asymmetric, transparent	55 x 25	Contains larva	Thin
Trichocephalus trichiurus	Elongate, barrel shaped, yellow-brownish	54 x 22	with polar hyaline plugs	Thick
Ascaris lumbricoides, Fertilized	Round or oval, brown	60 x 50		Thin
Ascaris lumbricoides, Non-fertilized	Oval, yellowish	90 x 45	embryonal cells in various stages of cleavage	thick shell, albuminous coat
Hookworms	Oval-elliptic, transparent	60 x 40	Segmented: 4-8 blastomeres	Thin shell
Strongyloides stercoralis	Oval-elliptic, transparent	70-100 x 40-60	Segmented: 8-16 blastomeres	Thin

INTRODUCTION

This book emphasizes the fundamental aspects of cell structure and processes focusing on eukaryotic cell biology as it relates to human disease, thus making the subject more accessible to medical students. Principles of classical genetics are introduced in context of medical genetics, and concepts of general parasitology and human parasite diseases provide basic understanding and demonstrate the cross-disciplinary nature of biology in biomedical sciences. The text and figures are easy-to-follow. Pedagogically enriched, the book provides engaging chapter-end assessment exercises to enhance and strengthen the learning of the readers.

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